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English for Students of Optics

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Учебник состоит из 12 модулей, объединённых единой тематикой и включающих задания по развитию навыков различных видов чтения и коммуникативные упражнения, которые направлены на развитие умения обсуждать профессионально-ориентированные темы. Каждый модуль снабжён лексико-грамматическими упражнениями по теме модуля. В учебнике приведены только оригинальные тексты из зарубежных источников, ссылки на которые даны в конце учебника. Тексты A предназначены для изучающего чтения с целью активизации лексико-грамматического материала модуля; тексты B, C, (D) предусматривают ознакомительное и просмотровое чтение, стимулирующее развитие речевых навыков. Учебник содержит терминологический словарь и раздел с ключами.

Для студентов 3-го курса и магистрантов первого года обучения по специальности «Лазерные и оптико-электронные системы», продолжающих изучение английского языка. Может быть использован как для аудиторных занятий, так и для самостоятельной работы студентов.

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ПРЕДИСЛОВИЕ

Целью предлагаемого учебника является обучение студентов старших курсов специальности «Лазерные и оптико-электронные системы» пониманию и переводу оригинального научного текста.

Учебник состоит из 12 модулей, объединенных единой тематикой и включающих такие разделы, как *Reading and discussion* («Чтение и обсуждение»), *Word study* («Лексика»), *Grammar revision* («Грамматические конструкции»), *Increase your vocabulary* («Обогащаем словарный запас»). Разделы *Reading and discussion* включают задания по развитию навыков различных видов чтения и коммуникативные упражнения, направленные на развитие умения обсуждать профессионально-ориентированные проблемы. Тексты A, (B) предназначены для изучающего чтения и подлежат детальной проработке с целью активизации лексико-грамматического материала модуля. Тексты B, C, (D) предусматривают ознакомительное и просмотровое чтение, стимулирующее развитие речевых навыков. Каждый модуль снабжен лексико-грамматическими упражнениями по теме модуля.

Работе над каждым текстом урока предшествует изучение терминологического словаря (*Terminology*), а также лексические упражнения, способствующие закреплению лексики урока (*Word study*).

Раздел «Чтение и обсуждение» (*Reading and discussion*) включает упражнения следующих типов:

- упражнения на контроль понимания текста;
- лексические упражнения, способствующие обогащению словарного запаса (*Increase your vocabulary*);
- грамматические упражнения (*Grammar revision*), направленные на распознавание оборотов с неличными формами глагола;
- упражнения на развитие навыков аннотирования;
- обсуждение текста и составление презентаций по теме модуля.

Каждый модуль заканчивается дополнительными заданиями (*Supplementary reading tasks*), которые включают упражнения по расшифровке текста (*Arrange the paragraphs in a logical way* или *Unscramble the text*). Такие задания студенты могут выполнять в парах по принципу *jigsaw reading*.

Словарь, приведенный в конце учебника, поможет студенту в понимании как основных, так и дополнительных текстов и заданий модуля.

Авторы выражают благодарность кафедре «Лазерные и оптико-электронные системы» МГТУ им. Н.Э. Баумана в лице профессора, д-ра техн. наук В.Е. Карасика и канд. техн. наук В.А. Лазарева.

The Map of the Book

Modules	*Subject*	*Reading*	*Grammar revision/ Vocabulary*
1	**Interference**	A. Interference B. Optical interferometers C. Elements of the theory of interference	❑ Functions of 'that' ❑ The Gerund ❑ Terminology ❑ Suffixes ❑ Irregular plurals
2	**Diffraction**	A. Diffraction B. Fresnel and Fraunhofer diffraction C. The concave grating	❑ The Participle, Absolute Participle Construction ❑ Modal verbs ❑ Terminology
3	**Polarization**	A. Polarization of light waves B. A polarizing microscope C. Wiener's method	❑ The Infinitive ❑ Complex Object ❑ Complex Subject ❑ Prefixes ❑ Terminology
4	**Lasers**	A. Types and comparison of laser sources: introduction B. Nd:YAG laser vs. ruby laser C. Free electron laser	❑ Subject and predicate groups ❑ Attributes ❑ Meanings of *result*, *list* and *order* ❑ Terminology
5	**Classes of Laser Sources**	A. Classes of laser sources B. Semiconductor lasers C. Glass lasers D. X-Ray lasers	❑ Synonyms ❑ Negative prefixes ❑ Revision of Verbals ❑ Terminology ❑ International words ❑ Meanings of *increase* and *provide*
6	**Properties of Lasers**	A. Properties of some important lasers B. Soldiers in lockstep C. Average power scaling	❑ Antonyms ❑ Terminology ❑ Meanings *of term* and *state*

Writing	*Speaking*	*Supplementary reading tasks*
Writing an abstract Written translation	Interference Interferometers The nature of light	The cause and effect relationship in vision
Writing an abstract Written translation	Fresnel and Fraunhofer diffraction Huygens' principle	The correspondence principle Huygens' principle
Writing an abstract Written translation PowerPoint presentation	Polarization The principle behind a polarizing microscope operation	A fundamental property of anisotropic media Rainbows
Writing an abstract Written translation PowerPoint presentation	Fundamentals of lasers Types of lasers	469nm fiber laser source Good fundamentals
Writing an abstract Written translation PowerPoint presentation	Laser sources Semiconductor lasers	Irnee D'Haenens dies; assisted Maiman in building the first laser New camera on Subaru Telescope may directly observe exoplanets
Writing an abstract Written translation PowerPoint presentation	Properties of lasers Lasers in space research	New laser equipment stops snoring and blindness Laser-propelled spacecraft

Modules	*Subject*	*Reading*	*Grammar revision/ Vocabulary*
7	**Laser Operation**	A. Laser operation B. Stoichiometric lasers C. Laser safety	❑ Synonyms and antonyms ❑ International words ❑ Terminology ❑ Meanings of *vary* and *as*
8	**Optical Fibres**	A. Communication with lasers: introduction B. Optical fibre data transmission systems C. Optical fiber video transmission systems D. Optical fibre public telecommunication systems	❑ Terminology ❑ Word-building ❑ Noun attributes
9	**Holography**	A. Fundamentals of holography B. Recording and reconstruction processes C. Denisyuk's discovery D. Holographic information storage	❑ Terminology ❑ Negative prefixes
10	**Laser Rangefinding**	A. Pulsed laser rangefinding systems B, C. Cooperative and non-cooperative targets D. Atmospheric aerosol pollution monitoring	❑ Terminology ❑ Articles
11	**Q-Switching**	A. Q-Switching. Choosing the best alternative B. Acousto-optic Q-switches C. FO strain sensor to watch for quakes	❑ Terminology
12	**Nonlinear Optics**	A. Intense laser beams bring nonlinearity to light B. The cutting edge of NLO C. Unwanted effects D. Raman to the rescue	❑ Terminology ❑ Phrasal verbs

Writing	*Speaking*	*Supplementary reading tasks*
Writing an abstract Written translation PowerPoint presentation	Laser operation Stoichiometric lasers Laser safety	Light is a thing and it travels from one point to another. High-beam switcher recognizes cars
Written translation PowerPoint presentation	Optical fibre communication systems	Production of fiber lasers in Russia New sources and fibers combine to deliver flexible fiber-optic lighting
Written translation PowerPoint presentation	Holography	Applications of holography Space holography used for real-world science From the history of holography
Written translation PowerPoint presentation	Pulsed laser rangefinding systems	Spaceborne laser radar Apollo 11 experiment still going strong after 35 years
Written translation PowerPoint presentation	Q-switching	Q-switching: the electro-optic alternative Q-switching: the dye-cell alternative Random-number generator gets its input from quantum vacuum fluctuations
Written translation PowerPoint presentation	Nonlinear optics	Choosing a nonlinear crystal Features of the BBO crystal

Module 1
INTERFERENCE

Texts:

A. Interference
B. Optical interferometers
C. Elements of the theory of interference

Grammar revision:

- ❑ Functions of ‘that’
- ❑ The Gerund

Terminology

interference [ˌɪntəˈfɪər(ə)ns] – интерференция, взаимодействие;
an interfering beam – интерферирующий пучок
common [ˈkɔmən] – общий, обычный;
a common source – общий источник
disturbance [dɪˈstɜːb(ə)ns] – распределение поля возмущения;
violent [ˈvaɪəl(ə)nt] disturbance – сильное возмущение;
instantaneous [ˌɪnstənˈteɪnɪəs] disturbance – мгновенное возмущение;
optical disturbance – распределение оптического поля
crest [krest] – гребень волны
trough [trɔf] – подошва волны
film [fɪlm] – плёнка
propagation [ˌprɔpəˈgeɪʃ(ə)n] – распространение
superimpose [ˌs(j)uːp(ə)rɪmˈpəuz] – накладывать (одну волну на другую);
superposition – наложение, суперпозиция
succession [səkˈseʃ(ə)n] – последовательность
validity [vəˈlɪdətɪ] – действительность, обоснованность, точность;
rigorous validity – абсолютная точность (правильность, обоснованность)

Word study

1. Read the following international words and translate them without a dictionary:

manifestation [ˌmænɪfesˈteɪʃ(ə)n], region [ˈriːʤ(ə)n], corpuscular [kɔːˈpʌskjələ], model [ˈmɔd(ə)l], analogous [əˈnæləgəs], associate (v.) [əˈsəusɪeɪt], [-ʃɪeɪt], individual [ˌɪndɪˈvɪʤuəl], coherent [kə(u)ˈhɪər(ə)nt], monochromatic [ˌmɔnəkrəˈmætɪk], intensity [ɪnˈten(t)sətɪ], situation [ˌsɪʧuˈeɪʃ(ə)n], combine [kəmˈbaɪn], adequate [ˈædɪkwət], geometry [ʤ(ɪ)ˈɔmɪtrɪ], form [fɔːm], analysis [əˈnæləsɪs], analyses (pl.) [əˈnælɪsiːz], electromagnetic [ɪˌlektrə(u)mægˈnetɪk], theory [ˈθɪərɪ], character [ˈkærəktə], linear [ˈlɪnɪə].

2. Read the following words and say which part of speech they belong to:

a) observation, reflection, propagation, assumption, interpretation, superposition, succession; disturbance, interference; statement; validity, linearity, intensity; observer;
b) soapy, linear, careful, analogous, instantaneous, optical, natural, geometrical;
c) simultaneously, particularly, precisely, experimentally, practically, similarly, adequately.

3. Compare the singular and plural forms of the nouns:

phenomenon – phenomena, medium – media, analysis – analyses, datum – data, maximum – maxima, minimum – minima, axis – axes.

4. Translate the following word-combinations:

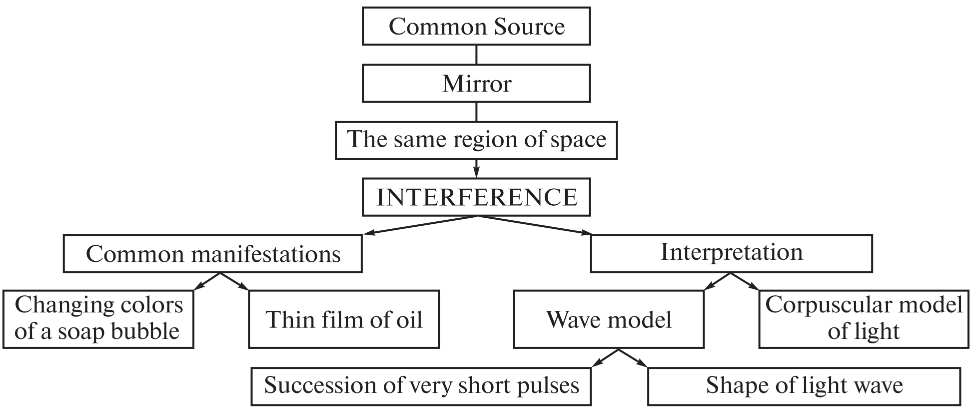
soap bubble, soapy water; wave motion, wave superposition, wave model; light effects, color effects; light intensity, light propagation, light wave; superposition principle; interference phenomena; common manifestations.

Reading and discussion 1

5. Read Text 1A and answer the following questions.

1. What conditions are necessary for interference to occur?
2. What theory of light propagation provides the interpretation of this phenomenon?
3. Could you bring the examples of light interference from the text given below?

Text 1A
INTERFERENCE



For many years optics has been divided into three branches: physical, physiological and geometrical. The expansion of knowledge has led to modernization of these classical subdivisions, which are now generally referred to as Optical Physics, Vision and Optical Engineering. Optical Physics is a very active subject, indeed pursued in most universities and other research centers.

It has enjoyed rebirth since the invention of the laser in I960, which is undoubtedly the most important optical discovery of recent times. Optical physics includes the study of quantum electronics, partial coherence, holography, interference, polarization, diffraction, image enhancement, non-linear optics and similar subjects.

General Considerations

Everyone has noticed the changing colors of a soap bubble, or a thin film of oil floating on water. These are perhaps the most common manifestations of interference, a phenomenon that is observed when two or more beams of light from a common source arrive, along different paths, at the same region of space. In each of these two cases, the interfering beams are those reflected at the two surfaces of a thin film – a film of soapy water in air, or a film of oil between air and water.

The corpuscular model of light does not afford any simple interpretation of interference phenomena. The wave model, however, suggests a most natural interpretation. Indeed, the phenomena observed when two light beams are superimposed are closely analogous to those associated with the superposition of two surface waves, such as those produced by two pebbles falling into a pool of water.

A careful observer will notice that in certain regions, where the crest of one wave arrives simultaneously with the trough of the other, the effects of the two waves almost cancel, while in other regions, where a crest meets a crest or a trough meets a trough, the superposition of the two waves produces a more violent disturbance than do the individual waves. Similarly, in the region where two coherent monochromatic light beams overlap, there are places where the light intensity is practically zero and others where it is particularly strong. The situation is more complicated if white light is used. As we have already mentioned, white light is a superposition of light of different colors, each color gives a separate set of maxima and minima, and these combine to give the color effects mentioned above.

In order to interpret interference phenomena it is necessary to specify the wave model of light more precisely than we have done so far. We found that we could account for the phenomena of geometrical optics by assuming that light waves consist of a succession of very short pulses, without making any assumptions as to the exact shape of these pulses. However, knowledge of the shape of light waves, which geometrical optics ignores, is essential for the interpretation of interference phenomena.

Our analysis of interference phenomena is based upon the superposition principle, which can be stated as follows: the instantaneous optical disturbance at a point where two or more light waves cross is the sum of the optical disturbances that would be produced by each of the waves separately. This statement implies that the propagation of a light wave is not affected by the presence of other light waves in the same medium, the observation that two light beams whose paths cross in a region of space continue unperturbed beyond this region is an experimental test of the superposition principle. In the electromagnetic theory of light the rigorous validity of the superposition principle for light waves is guaranteed by the linear character of Maxwell's equations.

Increase your vocabulary

6. Look through the text above and find equivalents of the following Russian phrases:

тонкая пленка нефти, наиболее часто встречающиеся проявления, изменяющиеся цвета, внимательный наблюдатель, наложение света, последовательность импульсов, делать предположение, точная форма, создавать более сильное возмущение, пучки монохроматического света частично совпадают, чтобы объяснить явление интерференции, определить более точно, последовательность коротких импульсов, это утверждение означает, уравнение Максвелла.

7. Complete the sentences below with the appropriate word or word-combination.

1. The natural interpretation of interference phenomena can be given by
   a) a corpuscular theory of light
   b) wave model
2. In regions where a crest meets a crest or a trough meets a trough, the superposition of the two waves produces a violent
   a) interference
   b) disturbance
3. White light is a superposition of light of
   a) different colors
   b) similar colors
4. According to the superposition principle the instantaneous optical disturbance is a sum of optical disturbances produced by
   a) all the waves together
   b) each of the waves separately

8. Translate and memorize the definitions below.

Interference is a phenomenon when two or more beams of light from a common source arrive, along different paths, at the same region of space.
White light is a superposition of light of different colors.
Coherent waves are waves whose phase difference remains constant in time.

Grammar revision

9. Translate the sentences into Russian focusing on the functions of 'that'.

that	conjunction	object clause	что
		subject clause	то, что
		relative clause	который
	indicative pronoun		тот, та, то, те
	used to substitute for a singular or plural (those) noun		

1. That light has many different effects is known to everybody. 2. If sources have a phase difference that varies rapidly and irregularly with time, they are said to be incoherent. 3. We found that light waves consist of a succession of very short pulses. 4. The fact is that optical disturbance is directly related to the light intensity. 5. The interfering beams are those reflected at the two surfaces of a thin film. 6. Interference phenomena are similar to those produced by Fresnel[1] mirrors. 7. This phenomenon is similar to that mentioned above. 8. The effects of light are closely analogous to those associated with waves.

10. Translate the sentences focusing on the use of the Gerund.

by, in	*measuring*	измеряя, путем измерения, при измерении
on (upon), after		измерив, после измерения
without		не измеряя, без измерения
before		до измерения, прежде чем измерить

1. The image formed by the returning light can then be observed directly without being weakened by reflection. 2. The ray in passing from air to water is refracted towards the normal. 3. Before discussing the results of experiments, we must state that it is impossible to observe interference between light waves emitted by independent sources. 4. By measuring the angle between two mirrors we can determine the distance between two sources. 5. A phenomenon that is observed in superimposing two or more beams of light is known as interference. 6. It is impossible to speak about optical disturbance without mentioning the light intensity. 7. On passing a narrow beam of sunlight

[1] *Augustin-Jean Fresnel* ([freɪˈnel], 1788–1827), was a French engineer who contributed significantly to the establishment of the theory of wave optics. Fresnel studied the behaviour of light both theoretically and experimentally.

through a glass prism Lomonosov found that the patch of light on a screen was broadened out into a band of colours: red, orange, yellow, green, blue, indigo and violet.

11. Answer the questions about Text 1A.

1. What is interference? 2. What are the most common manifestations of interference? 3. What happens when the crest of one wave arrives simultaneously with the trough of the other? 4. In what case can a violent disturbance be produced? 5. What does the superposition principle state? 6. Does the presence of other light waves affect the propagation of a light wave? 7. What confirms the validity of superposition principle experimentally?

12. Translate the following text into English.

Чтобы наблюдать явления интерференции, необходимо использовать когерентные источники света, т.е. источники, разность фаз которых постоянна во времени. Такие источники можно создать путем использования одного источника и его изображения или используя два различных изображения одного и того же источника.

13. Write an abstract of Text 1A:

- point out the most important information from each paragraph
- summarize the information obtained;
- use the cliché: (is/are reported, given, stated)
- avoid complex sentences

14. Use the structural scheme on page 9 to speak about interference.

Reading and discussion 2

15. Skim Text 1B and answer the following questions.

1. What standard unit is taken for interferometric measurement?
2. What invention widened the possibilities of interferometric measurements?
3. What are the advantages of hologram interferometry?

Text 1B

OPTICAL INTERFEROMETERS

Optical interferometers are very important scientific tools. The standard unit of length is based on interferometric measurement using the wavelength of krypton 86 and our view of the whole world of physics is greatly dependent on the unit of length. Einstein's relativity theories were constructed to explain the results of some very important interferometric experiments made by

Michelson[1] and Morley[2]. The invention of holographic interferometry has in the last years to a great extent widened the possibilities of interferometric measurements.

Hologram interferometry can be used for measurement of dimension deformation, vibration and changes in refractive index. It is a general agreement that hologram interferometry has the following advantages over ordinary interferometry: 1) Displacement of non-optical rough surfaces that scatter light in a diffuse way can be measured with interferometric accuracy because each small surface defect is compared with its own image. 2) An object can be compared with itself as it was during earlier exposure. Thus the dimensions of the object during two or more conditions can be compared. 3) When the measuring object is to be compared with a master[3] the latter can be substituted by its holographic image which might make possible a saving of time and space.

16. Translate Text 1C in writing using a dictionary.

Text 1C

ELEMENTS OF THE THEORY OF INTERFERENCE

There are two general methods of obtaining beams from a single beam of light, and these provide a basis for classifying the arrangements used to produce interference. In one the beam is divided by passing light through apertures placed side by side. This method, which is called division of wave front, is useful only with sufficiently small sources. Alternatively the beam is divided at one or more partially reflecting surfaces at each of which part of the light is reflected and part transmitted. This method called division of amplitude can be used with extended sources and so effects may be of greater intensity than with division of wave front. In either case, it is convenient to consider separately the effects which result from the superposition of two beams (two-beam interference), and those resulting from the superposition of more than two beams (multiple-beam-interference). Historically, interference phenomena have been the means of establishing the wave nature of light and today they have important practical uses, for example in spectroscopy and metrology.

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[1] *Albert Abraham Michelson* (1852 – 1931) was an American physicist known for his work on the measurement of the speed of light and especially for the Michelson-Morley experiment. In 1907 he received the Nobel Prize in Physics. He became the first American to receive the Nobel Prize in sciences.

[2] *Edward Williams Morley* (1838 – 1923) was an American scientist famous for the Michelson-Morley experiment.

[3] a master [ʻmɑːstə] – эталон.

Supplementary reading tasks

The cause and effect relationship in vision

Task 1. Rearrange the paragraphs below in a logical way.

1. How do we see luminous objects? The Greek philosophers Pythagoras (b.[1] ca.[2] 560 BC[3]) and Empedocles of Acragas (b. ca. 492 BC), who unfortunately were very influential, claimed that when you looked at a candle flame, the flame and your eye were both sending out some kind of mysterious stuff, and when your eye's stuff collided with the candle's stuff, the candle would become evident to your sense of sight.	2. Despite its title, this chapter is far from your first look at light. That familiarity might seem like an advantage, but most people have never thought carefully about light and vision. Even smart people who have thought hard about vision have come up with incorrect ideas. The ancient Greeks, Arabs and Chinese had theories of light and vision, all of which were mostly wrong, and all of which were accepted for thousands of years.
3. Modern people might feel uneasy about this theory, since it suggests that greenness exists only for our seeing convenience, implying precedence over natural phenomena. Nowadays, people would expect the cause and effect relationship in vision to be the other way around, with the leaf doing something to our eye rather than our eye doing something to the leaf. But how can you tell? The most common way of distinguishing cause from effect is to determine which happened first, but the process of seeing seems to occur too quickly to determine the order in which things happened.	4. One thing the ancients did get right is that there is a distinction between objects that emit light and objects that don't. When you see a leaf in the forest, it's because three different objects are doing their jobs: the leaf, the eye, and the sun. But luminous objects like the sun, a flame, or the filament of a light bulb can be seen by the eye without the presence of a third object. Emission of light is often, but not always, associated with heat. In modern times, we are familiar with a variety of objects that glow without being heated, including fluorescent light and glow-in-the-dark toys.
5. Today, photography provides the simplest experimental evidence that nothing has to be emitted from your eye and hit the leaf in order to make it "greenify." A camera can take a picture of a leaf even if there are no eyes anywhere nearby. Since the leaf appears green regardless of whether it is being sensed by a camera, your eye, or an insect's eye, it seems to make more sense to say that the leaf's greenness is the cause, and something happening in the camera or eye is the effect.	6. Bizarre as the Greek "collision of stuff theory" might seem, it had a couple of good features. It explained why both the candle and your eye had to be present for your sense of sight to function. The theory could also easily be expanded to explain how we see nonluminous objects. If a leaf, for instance, happened to be present at the site of the collision between your eye's stuff and the candle's stuff, then the leaf would be stimulated to express its green nature, allowing you to perceive it as green.

[1] b. – the written abbreviation of *born*
[2] ca. – the written abbreviation of *circa* [ˈsɜːkə] (=about)
[3] BC – до нашей эры

Task 2. Choose correct definitions for these words and expressions (underlined in the text).

Para 2:

to come up with means (a) to reach a particular standard, (b) to think of an idea, (c) to have to deal with problems or difficulties;

Para 4:

to get right means (a) to put exactly in a particular position or place, (b) to begin doing something immediately, (c) to understand correctly;

to be familiar with means (a) to be able to recognize, (b) to speak in an informal or friendly way, (c) to have a good knowledge or understanding of something;

a variety of means (a) a lot of things of the same type that are different from each other in some way; (b) a particular type of person or thing; (c) consisting of or including many different kinds of things or people;

Para 1:

luminous means (a) large, heavy, and lumpy, (b) very famous or highly respected, (c) shining in the dark;

stuff means (a) things (such as substances, materials, or groups of objects) when you do not know what they are called, or it is not important to say exactly what they are; (b) the people who work for an organization, (c) the qualities of someone's character;

Para 6:

bizarre means (a) too full of small details, (b) an occasion when a lot of people sell different things to collect money for a good purpose, (c) very unusual or strange;

Para 3:

feel uneasy means (a) not to feel worried or anxious, (b) to be worried or slightly afraid (c) to feel comfortable or relaxed;

to imply means (a) to suggest that something is true or that you feel or think something, without saying so directly, (b) to fix an idea, attitude, etc. firmly in somebody's mind, (c) to ask somebody to do something in an anxious way because you want or need it very much;

precedence over means (a) an official action or decision that has happened in the past and that is seen as an example or a rule to be followed, (b) the job of being president of a country or an organization, (c) the condition of being more important than somebody or something else;

rather than means (a) instead of something, (b) fairly or to some degree, (c) more than a little, but not very;

Para 5:

regardless of means (a) paying no attention to somebody or something; treating somebody or something as not being important, (b) concerning somebody or something, (c) without being affected or influenced by something;

to make sense means (a) to behave in a sensible way and do what is best in some situation, (b) to understand something, especially something difficult or complicated, (c) to have a clear meaning and be easy to understand.

Module 2
DIFFRACTION

Texts:

A. Diffraction
B. Fresnel and Fraunhofer diffraction
C. The concave grating

Grammar revision:

- ❑ The Participle, the Absolute Participle Construction
- ❑ Modal Verbs

Terminology

rectilinear [ˌrektɪˈlɪnɪə] propagation [ˌprɔpəˈgeɪʃ(ə)n] of light – прямолинейное распространение света;
the law of rectilinear propagation of light – закон прямолинейного распространения света
to depart [dɪˈpɑːt] – отступать;
departures [dɪˈpɑːʧəz] from the law – отступления от закона
an obstacle [ˈɔbstəkl] – препятствие, предмет;
opaque [əˈpeɪk] obstacles – непрозрачные предметы
to encounter [ɪnˈkauntə] obstacles – наталкиваться на (встречать) препятствия
to bend (bent – bent) around obstacles – огибать препятствия
blurred [blɜːd] boundaries [ˈbaund(ə)rɪz] – расплывчатые границы, неясные очертания
luminous [ˈluːmɪnəs] – светящийся
a light bulb [ˈlaɪtbʌlb] – электрическая лампа;
a distant light bulb – удалённая электрическая лампа
to perceive [pəˈsiːv] – воспринимать, различать

Word study

1. Read the following words and translate them without a dictionary:

diffract [dɪˈfrækt], diffraction [dɪˈfrækʃ(ə)n], diffracted [dɪˈfræktɪd]; concentrate [ˈkɔns(ə)ntreɪt], concentration [ˌkɔns(ə)nˈtreɪʃ(ə)n], concentrated [ˈkɔn(t)s(ə)ntreɪtɪd]; identify [aɪˈdentɪfaɪ], identification [aɪˌdentɪfɪˈkeɪʃ(ə)n], identical [aɪˈdentɪk(ə)l]; compute [kəmˈpjuːt], computation [ˌkɔmpjuˈteɪʃ(ə)n], computed [kəmˈpjuːtɪd]; correct [kəˈrekt], correctly [kəˈrektlɪ]; ideal [aɪˈdɪəl], ideally [aɪˈdɪəlɪ]; spectrum [ˈspektrəm], spectra [ˈspektrə]; material [məˈtɪərɪəl] (n., adj.); resultant [rɪˈzʌlt(ə)nt]; phase [feɪz]; discrete [dɪˈskriːt]; sinus [ˈsaɪnəs], sinusoidal [ˌsaɪnəˈsɔɪd(ə)l].

2. Read and translate the following word-combinations:

light – light streaks, a light source, an electric light bulb, monochromatic light, non-monochromatic light;
wave – primary waves, secondary waves, interfering waves, sinusoidal waves;
source – an ideal point source, a monochromatic light source;
surface – an arbitrary surface, an auxiliary surface, a wave surface.

3. Translate the word-combinations below avoiding the preposition 'of':

явления дифракции, очертания горы, сильный источник света, электрическая лампа, интерференция вторичных волн, синусоидальные волны, источник синусоидальных волн, интерференция синусоидальных волн, теория дифракции, источник монохроматического света, волновая поверхность.

4. Find equivalent phrases either in Text 2A or in the right-hand column:

1) по сравнению с длиной волны	a) to treat monochromatic light as
2) явлениями дифракции объясняется	b) to take optical disturbance into account
3) полузакрытыми (прищуренными) глазами	c) beyond the surface
4) общие положения теории Гюйгенса	d) infinitesimal intensity
5) учитывать волновое возмущение	e) to compute the resultant disturbance
6) рассматривать немонохроматический свет как	f) compared with the wave length
7) за пределами поверхности	g) an infinite number of interfering waves
8) чтобы вычислить полученное волновое возмущение	h) general concepts embodied in Huygens' principle
9) бесконечное число интерферирующих волн	i) with half-shut eyes
10) бесконечно малая интенсивность	j) diffraction phenomena are responsible for

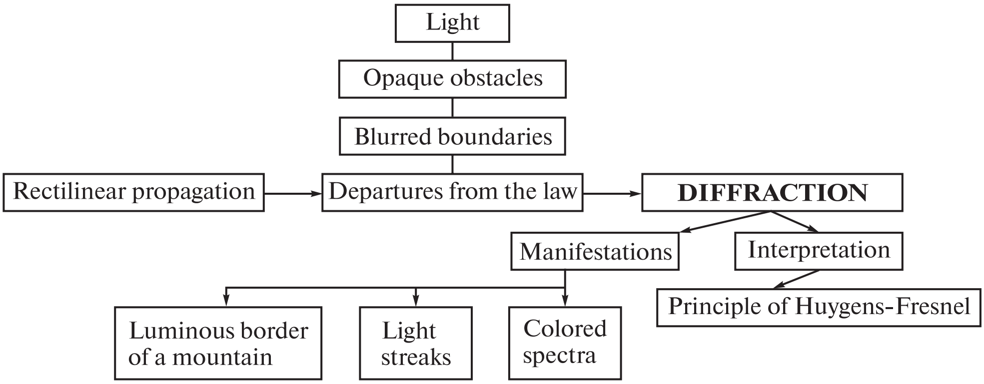
Reading and discussion 1

5. Read Text 2A and answer the questions below.

1. What examples of diffraction phenomena are listed in the text?
2. In what way can diffraction phenomena be explained?
3. What methods can be used for computing optical disturbance?

Text 2A

DIFFRACTION



The law of rectilinear propagation of light is not rigorously correct. To some extent, light bends around opaque obstacles, so that shadows always have slightly blurred boundaries, even in the limiting case of an ideal point source. These departures from the law of rectilinear propagation of light are known as diffraction phenomena. They are not very conspicuous because the dimensions of the obstacles that light encounters along its path are usually large compared with the wavelength. However, they are part of our common experience. Diffraction phenomena are responsible for the intensely luminous border that outlines the profile of a mountain a few seconds before the sun rises behind it. The light streaks that we perceive when we look at a strong and concentrated light source with half-shut eyes are due to diffraction. The colored spectra, arranged in the pattern of a cross, that we see when we look at a distant electric light bulb through a piece of thin, closely woven material are again diffraction phenomena.

We can explain diffraction phenomena by making use of the general concepts embodied in Huygens[1]' Principle. However, it will no longer suffice to work out the consequences of Huygens' Principle for the limiting case of infinitely short pulses. It will be necessary, instead, to take the actual form of the optical disturbance into account, and consider in detail how the secondary waves interfere with one another at various points of space. The results are simplest in the case of sinusoidal waves. We shall therefore begin by developing the theory of diffraction for monochromatic light and then treat non-monochromatic light as a superposition of sinusoidal waves of different wavelengths.

For the special case of sinusoidal waves, Huygens' Principle may be stated as follows. Consider an arbitrary surface surrounding a source of monochromatic

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[1] *Christian Huygens* [hɔɪgənz], FRS (1629 – 1695) was a prominent Dutch mathematician, astronomer, physicist and horologist. His work included early telescopic studies elucidating the nature of the rings of Saturn and the discovery of its moon Titan, the invention of the pendulum clock and other investigations in timekeeping, and studies of both optics and the centrifugal force.

light. The various points of the surface behave as virtual secondary sources of sinusoidal waves, and the optical disturbance beyond the surface results from the interference of these waves.

This formulation of Huygens' Principle was first given by Fresnel and is known as the principle of Huygens-Fresnel. The frequency of the secondary sources is, of course, identical with that of the primary wave and their phase relations are determined by the relative phases of the primary wave at the points where the secondary sources are located. If, in particular, the auxiliary surface is a wave surface, then the secondary sources are all in phase with one another.

To compute the resultant disturbance, we can use the methods for the addition of sinusoidal functions. In the present application, however, we shall be faced with the problem of dealing with an infinite number of interfering waves, each having an infinitesimal intensity, while in the study of interference phenomena we had to consider only a finite number of interfering waves of finite intensity or, at most, a discrete series of such waves.

Increase your vocabulary

6. Use the structural scheme and word-combinations in ex. 4 to translate the sentences.

1. Эти отступления от закона прямолинейного распространения света известны как явления дифракции.
2. Явления дифракции можно объяснить, используя принцип Гюйгенса.
3. Явлениями дифракции объясняются полоски света, которые мы видим, когда смотрим на сильный источник света прищуренными глазами.

7. Match the synonyms:

to encounter, to determine, to take into account, to be located, to perceive, to develop, to result from, to explain, to result in, to consider, to see, to deal with, to work out, to be due to, to compute, to be responsible for, to take into consideration, to be situated, to meet, to interpret.

Grammar revision

8. For each verb below make five forms of the Participle. What are the functions of the Participle?

to give, to compare, to explain, to consider, to develop, to determine, to compute, to perceive, to arrange, to encounter.

9. Translate the sentences concentrating on the forms and functions of the Participle.

1. Optics is a branch of science studying in particular the processes of light radiation and propagation in different media. 2. While studying optics at

BMSTU students of optics learn to design various optical instruments. 3. It was not until 1690 that Huygens published his major work on the wave theory of light worked out as early as 1678. 4. We have just considered an arbitrary surface surrounding a source of monochromatic light. 5. Having made use of Huygens' Principle and the principle of Huygens–Fresnel, Fresnel developed the light diffraction theory in 1818. 6. Basing on Maxwell's laws Fresnel developed the equations for reflection and refraction. 7. When used in an optical instrument, the doubling of the image is not perceptible to the eye. 8. When seen through a prism, a small white object appears as a spectrum with the violet end the most deviated. 9. Substances differ widely in their properties varying from almost perfect transparency to almost perfect opacity.

10. Translate the sentences that follow paying attention to the position of the Absolute Participle Construction.

1. The experiment being performed at night, each experimentator was provided with a lantern[1]. 2. When looking at a concentrated light source with half-shut eyes we perceive light streaks, the latter being due to diffraction. 3. We dealt with an infinite number of interfering waves, each having an infinitesimal intensity. 4. After due[2] consideration a different method was employed, the lens being placed between the slit and the revolving mirror. 5. An optical instrument making use of only a limited portion of a wave front, it is evident that a clear comprehension of the nature of diffraction is essential for a complete understanding of practically all optical phenomena. 6. Problems of diffraction are of great importance in engineering, diffraction imposing limitations[3] on system performance.

11. Read and translate the following sentences focusing on modal verbs denoting obligation.

1. While studying interference phenomena we had to consider only a finite number of interfering waves of finite intensity. 2. It should be noted that the law of rectilinear propagation of light is not rigorously correct. 3. Light waves are so small, however, that this bending or diffraction takes place to an extent so minute that special precaution have to be taken to observe it. 4. The object whose hologram is to be obtained is illuminated with a laser beam. 5. The wave and particle properties of light are to be regarded as complementary[4] rather than antagonistic, each being correct when dealing with the phenomena in its own domain. 6. Before obtaining the algebraic relations we must make certain conventions concerning the sign to be attributed to the quantities considered. 7. If the earth were at rest, the telescope would have to be aimed directly at the star, but since the earth is actually in motion the telescope must be inclined at an angle Q in order that the star may be seen. 8. In the experiment to measure the velocity of light two experimentators were to take

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[1] a lantern ['læntən] – фонарь
[2] due – соответствующий, надлежащий
[3] impose [ɪm'pəuz] limitations – накладывать ограничения
[4] complementary [ˌkɔmplɪ'ment(ə)rɪ] – взаимодополняющий

part. One man was first to uncover his lantern, and observing this light from this lantern, the second was to uncover his.

12. Answer the question about Text 2A.

1. What are the most common manifestations of diffraction? 2. What theory could be used to interpret diffraction phenomena? 3. What is non-monochromatic light according to the text? 4. State the Principle of Huygens-Fresnel. 5. What does the optical disturbance beyond the surface surrounding a source of monochromatic light result from? 6. What method can be used to compute the resultant disturbance?

13. Write an abstract of Text 2A 'Diffraction'.

14. Use the structural scheme on page 20 to speak about diffraction.

Reading and discussion 2

15. Skim Text 2B and answer the following questions.

1. Under what conditions do Fresnel and Fraunhofer diffraction takes place?
2. Why is it necessary to distinguish between them?

Text 2B

FRESNEL AND FRAUNHOFER[1] DIFFRACTION

Let us consider the light reaching points on a screen when a diaphragm having a small opening is placed between the screen and a distant point source. According to geometrical theory the edges of the opening cast a shadow on the screen and no light is found within the shadow.

It is customary to distinguish between two cases. When the screen is relatively close to the opening we consider those portions of the secondary waves that travel toward a specified point and speak of Fresnel diffraction. If the screen is relatively far from the opening, the lines from various surface elements in the opening on the screen are nearly parallel. We then consider those portions of the secondary waves that leave the opening in a specified direction, and speak of Fraunhofer diffraction. Fraunhofer diffraction occurs also if a lens is placed just beyond the opening, since a lens brings to a focus at a point in its focal plane all light traveling in a specified direction.

There is of course no difference whatever in the nature of the diffraction process in the two cases, and Fresnel diffraction merges gradually into Fraunhofer diffraction as the screen is moved away from the opening. But the character of the diffracted beam is considerably different in the two cases, so it is useful, although not necessary, to distinguish between them.

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[1] *Joseph Fraunhofer* (1787 – 1826) was a German optician known for the discovery of the dark absorption lines (Fraunhofer lines) in the Sun's spectrum, and for making excellent optical glass and achromatic telescope objectives.

16. Translate Text 2C in writing using a dictionary.

Text 2C

THE CONCAVE GRATING

The plane grating requires the use of two lenses, the first to render parallel the light incident on the grating, and the second to bring the diffracted rays to a focus. These lenses add to the complexity of a spectrograph, and furthermore, if investigations are to be made in the ultraviolet, the lenses may have to be made of some material other than glass since ordinary optical glass is not transparent much outside the visible spectrum. Both lenses may be dispensed with in the concave reflection grating. A concave grating is ruled on a polished concave spherical surface, the rulings being the intersections with the surface of equidistant planes parallel to the principal axis of the surface. The surface acts at the same time both as a grating and as a concave mirror.

Supplementary reading tasks

Task 1. Match the words and word-combinations in the left-hand column (underlined in the text below) with their definitions in the right-hand column:

1) deal with	a) whatever happens or happened
2) to contradict	b) a mistake or problem in an argument, plan, set of ideas etc.
3) (to cast) a shadow	c) based on what is reasonable or sensible
4) in any case	d) to disagree with something, especially by saying that the opposite is true
5) valid	e) close to the exact number, amount etc., but could be a little bit more or less than it [= rough; ≠ exact]
6) a flaw	f) not clear in shape or sound [=blurred]
7) approximate	g) to take the necessary action, especially in order to solve a problem [= handle]
8) (to be) specific	h) the dark shape that someone or something makes on a surface when they are between that surface and the light
9) fuzzy	i) detailed and exact

The correspondence principle

The only reason we don’t usually notice diffraction of light in everyday life is that we don’t normally <u>deal with</u> objects that are comparable in size to a wavelength of visible light, which is about a millionth of a meter. Does this mean that wave optics contradicts ray optics, or that wave optics sometimes gives wrong results? No. If you hold three fingers out in the sunlight and cast a shadow with them, either wave optics or ray optics can be used to predict the straightforward result: a shadow pattern with two bright lines where the light has gone through the gaps between your fingers. Wave optics is a more general theory than ray optics, so in any case where ray optics is valid, the two theories will agree. This is an example of a general idea enunciated by the physicist Niels Bohr[1], called the correspondence principle: when flaws in a physical theory lead to the creation of a new and more general theory, the new theory must still agree with the old theory within its more restricted area of applicability. After all, a theory is only created as a way of describing experimental observations. If the original theory had not worked in any cases at all, it would never have become accepted.

In the case of optics, the correspondence principle tells us that when λ / d is small, both the ray and the wave model of light must give approximately the same result. Suppose you spread your fingers and cast a shadow with them using a coherent light source. The quantity λ / d is about 10^{-4} [2], so the two models will agree very closely. (To be specific, the shadows of your fingers will be outlined by a series of light and dark fringes, but the angle subtended by a fringe will be in the order of 10^{-4} radians, so they will be invisible and washed out by the natural fuzziness of the edges of sun shadows caused by the finite size of the sun.)

Task 2. Rearrange the paragraphs below in a logical way.

Huygens' Principle

1. Thomas Young[3] (1773 – 1829) was the person who finally, a hundred years later, did a careful search for wave interference effects with light and analyzed the results correctly. He observed double-slit diffraction of light as well as a variety of other diffraction effects. The crowning achievement was the demonstration by the experimentalist Heinrich Hertz[4] and the theorist James Clerk Maxwell that light was an electromagnetic wave. Maxwell is said to have related his discovery to his wife one starry evening and told her that she	2. The history is interesting. Isaac Newton[5] loved the atomic theory of matter so much that he searched enthusiastically for evidence that light was also made of tiny particles. The paths of his light particles would correspond to rays in our description; the only significant difference between a ray model and a particle model of light would occur if one could isolate individual particles and show that light had "graininess" to it. Newton never did this, so although he thought of his model as a particle model, it is more

[1] *Niels Henrik David Bohr* (1885 – 1962) was a Danish physicist who made foundational contributions to understanding atomic structure and quantum mechanics, for which he received the Nobel Prize in Physics in 1922. Bohr mentored and collaborated with many of the top physicists of the century at his institute in Copenhagen. He was part of the British team of physicists working on the Manhattan Project.

[2] pronounced: ten to the minus fourth power

[3–5] См. с. 26

was the only person in the world who knew what starlight was	accurate to say he was one of the builders of the ray model.
3. Almost all that was known about reflection and refraction of light could be interpreted equally well in terms of a particle model or a wave model, but Newton had one reason for strongly opposing Huygens' wave theory. Newton knew that waves exhibited diffraction, but diffraction of light is difficult to observe, so Newton believed that light did not exhibit diffraction, and therefore must not be a wave. Although Newton's criticisms were fair enough, the debate also took on the overtones of a nationalistic dispute between England and continental Europe, fueled by English resentment over Leibniz's supposed plagiarism of Newton's calculus. Newton wrote a book on optics, and his prestige and political prominence tended to discourage questioning of his model.	4. Returning to the example of double-slit diffraction, f, note the strong visual impression of two overlapping sets of concentric semicircles. This is an example of Huygens' principle, named after a Dutch physicist and astronomer. (The first syllable rhymes with "boy.") Huygens' principle states that any wavefront can be broken down into many small side-by-side wave peaks, g, which then spread out as circular ripples, h, and by the principle of superposition, the result of adding up these sets of ripples must give the same result as allowing the wave to propagate forward, i. In the case of sound or light waves, which propagate in three dimensions, the "ripples" are actually spherical rather than circular, but we can often imagine things in two dimensions for simplicity.
5. Since Huygens' principle is equivalent to the principle of superposition, and superposition is a property of waves, what Huygens had created was essentially the first wave theory of light. However, he imagined light as a series of pulses, like hand claps, rather than as a sinusoidal wave.	6. In double-slit diffraction the application of Huygens' principle is visually convincing: it is as though all the sets of ripples have been blocked except for two. It is a rather surprising mathematical fact, however, that Huygens' principle gives the right result in the case of an unobstructed linear wave, h and i. A theoretically infinite number of circular wave patterns somehow conspire to add together and produce the simple linear wave motion with which we are familiar.

[3] *Thomas Young* (1773 – 1829) was an English polymath. Young made notable scientific contributions to the fields of vision, light, solid mechanics, energy, physiology, language, musical harmony, and Egyptology. He "made a number of original and insightful innovations" in the decipherment of Egyptian hieroglyphs (specifically the Rosetta Stone).

[4] *Heinrich Rudolf Hertz* (1857 – 1894) was a German physicist who clarified and expanded James Clerk Maxwell's electromagnetic theory of light, which was first demonstrated by David Edward Hughes using non-rigorous trial and error procedures. The scientific unit of frequency – cycles per second – was named the "hertz" in his honor.

[5] *Sir Isaac Newton* PRS MP (1642 – 1727) was an English physicist, mathematician, astronomer, natural philosopher, alchemist and theologian, who has been considered by many to be the greatest and most influential scientist who ever lived.

Task 3. Match the words and expressions (underlined in the text) with their definitions:

1) a theorist	a) the material that everything in the universe is made of, including solids, liquids, and gases
2) to relate to	b) a branch of advanced mathematics which deals with variable quantities
3) made of	c) a shape or pattern that looks like a wave
4) matter	d) to extend over so as to cover partly
5) tiny	e) produced, for example by putting the different parts together
6) in terms of	f) half a circle
7) to exhibit	g) to seem to be working together to bring about a particular result
8) calculus	h) to show how two different things are connected
9) to question	i) to separate something into smaller parts so that it is easier to do or understand
10) to overlap	j) used to say that lots of small amounts gradually make a large total
11) a semicircle	k) to have or express doubts about whether something is true, good, necessary etc.
12) to break down into	l) a quality or power that a substance, plant etc has
13) ripples	m) someone who develops ideas within a particular subject that explain why particular things happen or are true
14) superposition	n) from a particular point of view
15) to add up	o) to spread
16) to propagate	p) to clearly show a particular quality, emotion, or ability
17) a property	q) putting one picture, image, or photograph on top of another so that both can be partly seen
18) to conspire	r) extremely small

Task 4. Compare what you have learnt about diffraction and Huygens' Principle from the above text with what you found out from Text 2A.

Module 3
POLARIZATION

Texts:

A. Polarization of light waves
B. A polarizing microscope
C. Wiener's method

Grammar revision:

❑ the Infinitive, complexes with the Infinitive

Terminology

polarization [ˌpəul(ə)raɪ'zeɪʃ(ə)n] – поляризация;
linear ['lɪnɪə] polarization – линейная поляризация
polarizing ['pəul(ə)raɪzɪŋ] filter – поляризационный фильтр (поляризатор);
sheet polarizer ['pəuləˌraɪzə]– пленочный (листовой) поляризатор
analyzer [æn(ə)'laɪzə] – анализатор, дисперсионная призма
to oscillate ['ɔsɪleɪt] – колебаться, вибрировать;
oscillation [ˌɔsɪ'leɪʃ(ə)n] – колебание, качание;
oscillating ['ɔsɪleɪtɪŋ] function – функция колебаний, осциллирующая функция
transparency [træn'spær(ə)nsɪ] – прозрачность;
transparent [træn'spær(ə)nt] – прозрачный, просвечивающий
incandescent [ˌɪnkæn'des(ə)nt] lamp – лампа накаливания
transverse [trænz'vɜːs] – поперечный
to absorb [əb'zɔːb] – поглощать, впитывать;
absorption [əb'zɔːpʃ(ə)n] – поглощение
axis ['æksɪs] (pl. axes ['æksiːz]) – ось;
transmission [trænz'mɪʃ(ə)n] axis – ось пропускания
incident ['ɪnsɪdənt] light – падающий свет
optical vector – электрический вектор
to emerge [ɪ'mɜːʤ] from – появляться, выходить из

Word study

1. Read and translate the following words without a dictionary:

function ['fʌŋkʃ(ə)n], position [pə'zɪʃ(ə)n], vector ['vektə], component [kəm'pəunənt], plastic ['plæstɪk], detail ['diːteɪl], vibration [vaɪ'breɪʃ(ə)n]; scalar ['skeɪlə], parallel ['pærəlel], physical ['fɪzɪk(ə)l], equivalent [ɪ'kwɪv(ə)lənt], microscopic [ˌmaɪkrə'skɔpɪk], ordinary ['ɔːd(ə)n(ə)rɪ], isotropic [ˌaɪsəu'trɔpɪk], approximate [ə'prɔksɪmət].

2. Read and translate the adjectives below, pay attention to their affixes:

a) finite – infinite; regular – irregular;
b) coherent – incoherent; polarized – unpolarized;
c) distinguishable, appreciable, incandescent, resultant, angular, perpendicular.

3. Read and translate the word-combinations below:

direction – preferred direction, intermediate direction, direction of propagation;
quantity – vector quantity, scalar quantity;
plane – vibration plane, plane polarization, plane-polarized light, plane light wave.

4. Find equivalent phrases either in Text 3A or in the right-hand column:

1) в определённых случаях	a) in more detail
2) исследовать природу	b) to keep in a fixed position
3) с другой стороны	c) some distinctive property
4) отличительные особенности	d) from the above considerations
5) изготовление солнцезащитных очков	e) to inquire into the character of
6) держать неподвижно	f) closely obeys a law
7) строго подчиняется закону	g) the manufacture of sunglasses
8) направление которого не совпадает с	h) on the other hand
9) более подробно	i) in certain cases
10) из вышесказанного	j) whose direction does not coincide with

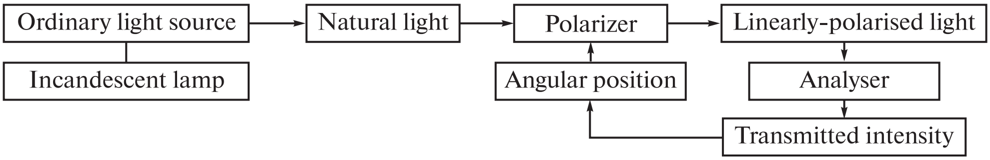
Reading and discussion 1

5. Read Text 3A and answer the following questions.

1. What example can be used to explain the phenomenon of polarization?
2. What is the main essence of Malus law?
3. What light wave is called linearly polarized?

Text 3A

POLARIZATION OF LIGHT WAVES



By the study of interference and diffraction we have learned that the optical disturbance is a rapidly oscillating function of time whose form, in certain cases, approximates that of a sinusoidal function. However, we have not yet inquired into the character of the optical disturbance.

It is clear that, if optical disturbance is a scalar quantity, or if it is a vector parallel to the direction of propagation, all planes through the same light ray are physically equivalent. If, on the other hand, the disturbance is a vector pointing in a direction different from the direction of propagation, the plane combining this vector might be expected to possess some distinctive property.

The question thus arises whether the infinite numbers of planes passing through the same light ray are physically distinguishable. This question can be answered by a simple experiment with a sheet polarizer, which is a sheet of transparent plastic widely used, e.g., in the manufacture of sunglasses. Let us hold a sheet polarizer before our eyes and look through it at a light source such as an incandescent lamp. If we rotate the sheet in its own plane, we notice no change in the light intensity. We now place a second sheet polarizer between the light source and the eye. If we rotate the second sheet in its own plane, keeping the first in a fixed position, we find the light intensity to change periodically. The intensity is practically zero at two angular positions of the second sheet 180° apart, and it is a maximum at angular positions halfway between. If we actually measure the intensity I of the light that emerges from the second sheet polarizer, we find that it closely obeys a law of the following type:

$$I = I_0 \cos^2 \Theta_i,$$

where I_0 is the initial intensity, and Θ_i is the angle between the light's initial polarization direction and the axis of the polarizer. This law expressed is called the Law of Malus[1].

The very fact that the transmitted intensity depends on the angular position of the second sheet proves that the optical disturbance is a vector quantity, whose direction does not coincide with the direction of propagation. We shall call this vector the optical vector. To explain in a natural way the details of the above experiment, as well as many other observations, it is

[1] *Étienne-Louis Malus* (1775 – 1812) was a French officer, engineer, physicist, and mathematician. He participated in Napoleon's expedition into Egypt (1798 to 1801) and was a member of the mathematics section of the Institut d'Égypte. His name is one of the 72 names inscribed on the Eiffel tower.

necessary to assume that the optical vector of a plane light wave propagating in an isotropic medium is perpendicular to the direction of propagation.

From the above considerations, there develops the following picture. Light waves are transverse waves. In the light coming from an ordinary light source, the optical vector changes direction rapidly and irregularly with time, while it always remains perpendicular to the direction of propagation. As we shall discuss later in more detail, this behavior is due to the incoherent superposition of the optical disturbances coming from the many microscopic sources that form any ordinary light source. The light under such conditions is called natural or unpolarized light.

Consider a light wave incident perpendicularly upon a sheet polarizer. The sheet transmits the light wave without appreciable absorption if the optical vector is parallel to a certain preferred direction (the "transmission axis"), while it absorbs completely if the optical vector is perpendicular to this preferred direction. If the optical vector has an intermediate direction, it may be regarded as the resultant of two vectors, one being parallel and the other perpendicular to the transmission axis of the sheet polarizer. The sheet transmits the first component and absorbs the second so that, in all cases, the optical vector of the light wave emerging from the filter is parallel to the transmission axis. We shall call this wave linearly polarized or plane polarized. We shall call the plane containing the direction of propagation and the optical vector the plane of vibration. Any optical device capable of transmitting only linearly polarized light will be called a polarization filter.

Increase your vocabulary

6. Match the terms and definitions:

1) polarizer	a) an oscillation vector whose direction does not coincide with the direction of propagation
2) analyzer	b) an instrumental means which detects light polarization and directions of vibrations
3) optical vector	c) an instrumental means to produce polarized light

7. Translate the following sentences.

1. То, что интенсивность света зависит от углового положения второго поляризатора, доказывает, что распределение поля есть векторная величина. 2. При двух угловых положениях поляризатора, повернутого на 90°, интенсивность практически равна нулю. 3. Из опыта с пленочным поляризатором следует, что световые волны являются поперечными волнами. 4. Свет, исходящий из естественного источника света, называется неполяризованным (естественным). 5. Любое оптическое устройство, посредством которого передается только линейно-поляризованный свет, называется поляризационным фильтром.

Grammar revision

8. Read and translate the following sentences focusing on the forms and functions of the Infinitive.

1. Screens made of transparent substances are frequently used to diffuse the light from a source. 2. To prevent aberrations the mirror must be of large aperture. 3. To obtain the algebraic relations we must make certain conventions concerning the sign to be attributed to the quantities considered. 4. The first attempts to measure the velocity of light were made in 1667. 5. To obtain a 100% monochromatic light is impossible. 6. Probably one of the first optical phenomena to be noted was that the shadow of an object illuminated by a source of small dimensions had the same shape as the object. 7. Yu. Denisyuk[1] was the first to propose three-dimensional media to be used for recording holograms. 8. One of the earliest optical instruments ever to be made was the humble pair of spectacles. 9. A pair of spectacles has served to extend our useful life by at least 20 years.

9. Read and translate the following sentences paying attention to complexes with the Infinitive.

1. Most optical media have the same properties and are considered to be isotropic. 2. The great progress in all branches of optics may be said to have resulted indirectly from the invention of the electric lamp. 3. While the experiment was entirely correct in principle, we know the velocity of light to be too great for the time interval to be measured in this way with any degree of accuracy. 4. A pocket microscope developed in 1702 is known to have produced magnifications up to 40. 5. The laser beam is a highly collimated bundle of rays and as such has proved to be of great help in many applications in industry, medicine, etc. 6. The matrix has turned out to be of great advantage in many scientific considerations. 7. Light is believed to be an electro-magnetic radiation at very high frequencies (10 cps). 8. We know a light beam to consist of thousands and millions of rays in a wide frequency range and at various states of polarization. 9. The incident wave was assumed to be monochromatic. 10. We believe the degree of polarization to be a maximum when the angle of incidence equals the polarization angle.

10. Answer the questions about Text 3A.

1. What instrument was used in the experiment to obtain polarized light? Describe the experiment. 2. What does the experiment with a sheet polarizer prove? 3. What does the transmitted intensity depend on? 4. What does the law of Malus state? 5. Is optical disturbance a scalar or vector quantity? 6. What light is considered to be linearly polarized? 7. What is a polarizing filter?

11. Write an abstract of Text 3A.

12. Use the diagram on page 30 to speak about polarization.

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[1] *Yuri Nikolaevich Denisyuk* (1927–2006) was a Soviet physicist known for his contribution to holography, in particular for the so-called *Denisyuk hologram*.

Reading and discussion 2

13. Skim Text 3B and discuss the principle behind a polarizing microscope.

Text 3B

A POLARIZING MICROSCOPE

When ordinary light is directed from the mirror to the polarizer, it emerges from the polarizer as polarized light. It passes on through the optical system to the analyzer. Since the vibration direction of the analyzer is set at 90 degrees to that of the polarizer, none of the light which reaches the analyzer is allowed to pass to the eye. The extraordinary ray coming from the polarizer has become the ordinary ray of the analyzer and it is therefore reflected out of the field of the microscope. The field appears black unless an object which rotates the plane of polarization interferes with the natural path of the light. This peculiarity of the polarizing microscope is what makes it so valuable for analysis of many materials.

14. Translate Text 3C in writing using a dictionary.

Text 3C

WIENER'S METHOD

To observe the interference between incident and reflected waves is not an easy matter, mainly because the distance between the planes of maximum and minimum intensity is less than one wavelength. The problem, however, can be solved with a technique devised by Wiener[1]. A very thin film of photographic emulsion is placed at a small angle to the reflecting surface, if the incident light is in the appropriate state of polarization, the film developed will show a series of light and dark bands, the maximum darkening occurring along the lines where the plane of the film intersected the planes of maximum intensity.

This technique was a very important one historically because it provided the first experimental determination of the plane of light waves. Most other polarization experiments, in fact, while proving the existence of linearly polarized light, do not furnish information about the actual direction of the vector representing the optical disturbance. For example, the experiment described shows a sheet polarizer to transmit only light waves whose optical vector is parallel to a certain preferred direction. It does not enable us to mark this preferred direction on the sheet. We can now do so by performing Wiener's experiment with light that has gone through the sheet polarizer. We

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[1] *Otto Heinrich Wiener* (1862 – 1927) was a German physicist. Wiener is known for the experimental proof of standing light waves. In 1890 he succeeded in determining the wavelength of light.

repeat the experiment a number of times, rotating the sheet in its own plane between exposures of the photographic films until the interference bands become sharpest or until they disappear completely. In the first instance the transmission axis of the polarizer will be the direction parallel to the reflecting surface. In the second instance, it will lie along the intersection of the plane of the sheet with the plane of incidence.

15. Make a PowerPoint presentation on one of the subjects covered in Module 3.

Supplementary reading tasks

Task 1. Match the adjectives in the left-hand column (underlined in the text) below with their definitions in the right-hand column:

1) isotropic	a) caused by or connected with something you have already mentioned
2) random	b) strange or unusual
3) crystalline	c) happening or chosen without any definite plan, aim, or pattern
4) perpendicular	d) having no definite shape or features
5) amorphous	e) having properties that are identical in all directions
6) curious	f) happening a number of times, usually at regular times
7) periodical	g) not leaning to one side or the other but exactly vertical
8) corresponding	h) very clear or transparent

Task 2. Supply the missing prepositions:

1) often referred _____ as double refraction; 2) is due _____ the particular arrangement; 3) monochromatic light passes _____ a polariscope; 4) is perpendicular _____ that of the polarizer; 5) obtained _____ cleavage; 6) change periodically _____ a maximum and a minimum; 7) the light emerging _____ the plate.

Task 3. Read the text that follows and describe the experiment to prove the main feature of anisotropic media.

A fundamental property of anisotropic media

Until now we have confined our attention to the propagation of light in isotropic media, i.e., substances whose optical properties are the same in all directions. Liquids, as well as amorphous solid substances such as glass and plastics, are usually isotropic because of the random distribution of the molecules. In many crystals, the optical as well as the other physical properties are different in different directions. This optical anisotropy, often referred to as double refraction, or birefringence, is due to the particular arrangement of the atoms in the crystalline lattice and is found to produce many curious and interesting phenomena, which we propose now to investigate.

We start with a simple experiment. A parallel beam of monochromatic light passes through a polariscope formed, for example, by two sheet polarizers, and then falls upon a screen. We rotate the analyzer until the light spot on the screen disappears. The transmission axis of the analyzer is then perpendicular to that of the polarizer, i.e. the polarizer and the analyzer are crossed. Between the analyzer and the polarizer we now insert a thin, plane-parallel plate cut from a birefringent crystal obtained by cleavage. The light on the screen will, in general, reappear. The analyzer being rotated, the light intensity will change periodically between a maximum and a minimum, but will not become zero for any position of the analyzer. We thus conclude that the light emerging from the plate is no longer linearly polarized.

After removing the plate, we again place the analyzer and the polarizer in the crossed position, reinsert the birefringent plate, and rotate it in its own plane. For each complete turn, we find four positions, at 90° to one another, for which the light spot on the screen disappears. We conclude that the light now emerging from the plate has the same linear polarization as the light incident upon the plate. We can check this conclusion by rotating the analyzer and noting that the corresponding variation of the transmitted light intensity follows the law of Malus. It is thus possible to trace on the plate two mutually perpendicular lines such that a linearly polarized light wave vibrating in a direction parallel to either line traverses the plate without changing its state of polarization. We call these lines the axes of the plate.

By generalizing this result, we can describe the fundamental property of optically anisotropic medium as follows: for every direction of propagation there are only two waves vibrating in one or the other of two mutually perpendicular planes that preserve their state of polarization while traveling through the medium.

Consider now a wave which, upon entering the plate, is linearly polarized, but does not vibrate in either of the two preferred directions. We may regard the incident wave as the superposition of two linearly polarized waves vibrating in the two preferred directions. If the velocities of propagation of these two waves were the same, the two component waves after traversing the plate would recombine into a linearly polarized wave with the same plane of vibration as the incident wave. Since we know from experiment that this is not the case, i.e. since we know the state of polarization of the wave to change on traversing the plate, we conclude that the velocities of propagation in an anisotropic medium of the waves vibrating in the two preferred directions are different. We can, of course, check this conclusion directly by measuring (e.g. with an interferometer) the velocities of propagation through a birefringent plate of the two waves whose planes of vibration contain one or the other of the two axes of the plate.

Task 4. Match the verbs from the text below with their synonyms or definitions:

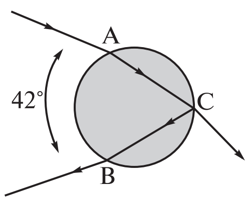
1) admire	a) send back the light
2) improve	b) bring about, produce
3) stretch	c) make better
4) reflect	d) vanish
5) appear	e) to look at something and think how beautiful or impressive it is
6) cause	f) increase, intensify, strengthen
7) contain	g) become visible
8) enhance	h) hold, comprise, include
9) disappear	i) extend

Rainbows

Rainbows are the most famous of many extraordinary displays that can be seen in the sky. Everybody seems to love them, from children to old men, and few wouldn't stop at least a few seconds to admire a fully developed rainbow. It has to do, undoubtedly, with its beautiful sequence of colors; but also with its perfect geometrical shape against the random background of clouds. If one could see the polarization of the rainbow, a new order would become apparent: the rainbow is strongly polarized. Indeed, with a polarizer its contrast significantly improves and you can find otherwise undetectable rainbows!

Rainbows form the arc of a perfect circle centered on the shadow of your head. Yes, that's right. Everybody sees a slightly different rainbow even if standing side by side: each one has his own personal rainbow! If you are not sure where a rainbow should appear during rainy weather do the following. Look for the shadow of your head on the ground; that's the center of the circle (antisolar point). Next, find the radius by stretching in a line your two hands (thumb to thumb) at arm length. Of course, if the tip of your finger doesn't reach above the horizon, then the sun is too high for a rainbow.

The drops of water refract and reflect the rays from the sun backwards, at 42 degrees to the incoming rays. Thus, the rainbow is seen in a direction opposite to the sun as a circle of that radius, an angular size of which is independent of your distance to the raindrops. This is also true for the rainbow produced by a watering hose: no matter how much you step back, you won't be able to include its full diameter in your photograph (you need a very-wide-angle lens for that). Of course, when you step back, the individual drops forming the arch will change. The largest rainbow (half a circle) appears



when the sun is close to the horizon. However, from airplanes, mountains or tall towers, where one can see raindrops below the horizon, the rainbow can be as large as a full circle.

Two refractions (A, B) and one internal reflection (C) inside the spherical water drops form the primary rainbow. A secondary rainbow, which sometimes appears outside the primary one (at 51 degrees), is caused by two internal reflections instead of just one. An interesting side note: small raindrops remain almost perfectly spherical falling through the air; very large raindrops are deformed but, contrary to popular belief, they are flattened vertically instead of becoming elongated and pear-shaped as the archetypal cartoonish drop.

The color sequence of the rainbow is caused by polarization of the rainbow caused by the internal reflection (C). The rays strike the back surface of the drop close to the Brewster angle, so almost all the light reflected is polarized perpendicular to the incidence plane (perpendicular to the monitor screen). This is similar to the way the glare of the sun on the sea is polarized, except that now the reflecting surface is not horizontal. As the incidence plane is determined for each drop by the plane containing the sun, the drop, and the observer, the rainbow is polarized tangential to the arch. Thus, a vertical polarizing filter will produce a gap at the top of the rainbow while enhancing the contrast of the sides.

The primary rainbow is 96 % polarized while the secondary is 90 % polarized. The extra brightness of the sky inside the primary rainbow (and outside the secondary rainbow) is also polarized tangentially (but to a lesser degree) as it has the same origin as the bows. With a filter pointing radially it disappears together with the rainbows and becomes undistinguishable from the dark Alexander's band between the bows (named after Alexander of Aphrodisius, AD 200).

Task 5. Supply the missing prepositions or adverbs:

1) its perfect geometrical shape _____ the random background of clouds; 2) even if standing side _____ side; 3) when you step _____, the individual drops forming the arch will change; 4) when the sun is close _____ the horizon; 5) contrary _____ popular belief; 6) close _____ the Brewster angle; 7) this is similar _____ the way the glare _____ the sun _____ the sea is polarized; 8) a gap _____ the top of the rainbow; 9) _____ a lesser degree; 10) becomes undistinguishable _____ the dark Alexander's band.

Module 4
LASERS

Texts:

A. Types and comparison of laser sources: introduction
B. Nd:YAG laser vs. ruby laser
C. Free electron laser

Terminology

to irradiate [ɪ'reɪdɪeɪt] – облучать, излучать, испускать лучи;
irradiation [ɪˌreɪdɪ'eɪʃ(ə)n] – иррадиация, лучеиспускание, излучение

flashlamp ['flæʃlæmp] – импульсная лампа, лампа накачки

population inversion [ˌpɔpjə'leɪʃ(ə)nˌɪn'vɜːʃ(ə)n] – инверсная населенность

technique [tek'niːk] – метод, способ;
excitation technique [ˌeksɪ'teɪʃ(ə)nˌtek'niːk] – способ, метод возбуждения

optical pumping ['ɔptɪk(ə)l 'pʌmpɪŋ] – оптическая накачка

collimated ['kɔlɪˌmeɪtɪd] – коллимированный;
collimated beam [biːm] – коллимированный пучок, коллимированный луч

nuclear decay ['njuːklɪəˌdɪ'keɪ] – ядерный распад

dilute electron beam [daɪ'luːt ɪ'lektrɔnˌbiːm] – низкоэнергетический электронный пучок

to scatter ['skætə] – разбрасывать, рассеивать;
nonlinear scattering – нелинейное рассеяние

spectral tuning ['t(j)uːnɪŋ] range – спектральный диапазон перестройки

output waveform ['autput 'weɪvˌfɔːm] – волновой фронт, фронт волнового излучения

power scalability ['pauəˌskeɪlə'bɪlɪtɪ] – диапазон значений (уровень) выходной мощности

gain [geɪn] – усиление, коэффициент усиления;
gain medium ['miːdɪəm] – усиливающая среда

peak power ['piːkˌpauə] – пиковая (импульсная) мощность;
peak power density ['densɪtɪ] – плотность пиковой (импульсной) мощности

pulse energy [ˌpʌls'enəʤɪ] – энергия в импульсе

Word study

1. Read and translate without a dictionary:

emission [ɪ'mɪʃ(ə)n], inversion [ɪn'vɜːʃ(ə)n], chromium ['krəumɪəm], ruby ['ruːbɪ], crystal ['krɪst(ə)l], xenon ['ziːnɔn], decade ['dekeɪd], substance ['sʌbst(ə)ns], neutral ['njuːtr(ə)l], gas [gæs], reaction [rɪ'ækʃ(ə)n], generate ['ʤen(ə)reɪt], periodic [ˌpɪərɪ'ɔdɪk], spectral ['spektr(ə)l], parameter [pə'ræmɪtə], neon ['niːɔn], helium ['hiːlɪəm], unique [juː'niːk], ensemble [ɔn'sɔmb(ə)l], electronic [ˌelek'trɔnɪk], dynamical [daɪ'næmɪk(ə)l], process ['prəuses], structural ['strʌkʧ(ə)r(ə)l], kinetic [kɪ'netɪk], coherent [kə(u)'hɪər(ə)nt], scheme [skiːm], characteristics [ˌkærəktə'rɪstɪks], ion ['aɪən].

2. Translate the word-combinations that follow:

pulse duration, peak power density, beam quality, chromium ions energy levels, laser sources types, laser action, electron beam kinetic energy, magnetic field periodicity, laser gain medium, pump excitation energy.

3. Find equivalent phrases either in Text 4A or in the right-hand column:

1) усиление света с помощью индуцированного излучения	a) this spectacular set of characteristics
2) при облучении (когда кристалл облучается)	b) to generate coherent radiation
3) в течение следующих двух десятилетий	c) the upper laser levels
4) во много раз	d) can be varied
5) чтобы получить (создать) когерентное излучение	e) in the ensuing two decades
6) путем правильного выбора значения кинетической энергии	f) rather than with simple laser oscillators
7) можно изменять	g) listed in this table
8) предельные значения выходных параметров	h) light amplification by stimulated emissions of radiation
9) а не с простыми лазерными генераторами	i) the extrema of laser output parameters
10) приведенные в данной таблице	j) when irradiated with
11) этот впечатляющий набор характеристик	k) by properly choosing the kinetic energy of
12) верхние лазерные уровни	l) manifold

Reading and discussion 1

4. Read Text 4A and answer the following questions.

1. What methods are used for producing population inversion?
2. In what way can the wavelength of the FEL radiation be changed?

Text 4A

TYPES AND COMPARISON OF LASER SOURCES. INTRODUCTION

Light Amplification by Stimulated Emission of Radiation was first demonstrated by Maiman[1] in I960, the result of a population inversion produced between energy levels of chromium ions in a ruby crystal when irradiated with a xenon flashlamp. In the ensuing two decades population inversion and coherent emission have been generated in literally thousands of substances (neutral and ionized gasses, liquids, and solids) using a variety of excitation techniques (optical pumping, electrical discharge, gasdynamic-flow, electron beam, chemical reaction, nuclear decay).

The number and types of laser sources has been further expanded manifold by utilizing one laser source (primary) to generate coherent radiation in a second medium, either by optically producing a population inversion in the second medium or as the result of nonlinear scattering in the second substance. Recently, laser action has even been achieved by passing a dilute electron beam through a periodic magnetic field (free-electron laser, or FEL). By properly choosing the kinetic energy of the electron beam and the periodicity of the magnetic field, the output wavelength of the FEL can be varied, in principle, from the ultraviolet to the far infrared spectral region.

The extrema of laser output parameters which have been demonstrated to date, and the laser media used are summarized in the Table. Note that the extreme power and energy parameters listed in this table were attained with laser systems (such as a master-oscillator-power-amplifier[2], or MOPA system) rather than with simple laser oscillators.

To be sure[3], no single laser source can simultaneously provide this spectacular set of characteristics. Each laser gain medium possesses a unique ensemble of energy levels (electronic, vibrational, rotational), which are dynamically coupled to each other through various radiative and nonradiative processes. These structural and kinetic features determine laser's nominal operating wavelength(s), its spectral tuning range, its possible output

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[1] *Theodore Harold "Ted" Maiman* (1927–2007) was an American physicist who made the first laser. Maiman received many awards and honors for his work, and was the author of a book titled *The Laser Odyssey*, which describes the events surrounding the creation of the first laser.

[2] master oscillator ['ɔsɪleɪtə] power amplifier ['æmplɪfaɪə] (MOPA) – усилитель мощности задающего генератора

[3] to be sure – несомненно, безусловно

Extrema of output parameters of laser devices and systems

Parameter	Value	Laser medium
Peak power	2×10^{13} W (collimated)	Nd:glass
Peak power density	10^{18} W/cm^2 (focused)	Nd:glass
Pulse energy	$>10^4$ J	CO_2, Nd:glass
Average power	10^5 W	CO_2
Pulse duration	3×10^{-13} sec, cw[2]	Rh6G dye, various gasses, liquids, solids
Wavelength	60 nm ↔ 385 nm	many required
Efficiency (nonlaser-pumped)	70 %	CO_2
Beam quality	diffraction limited	various gasses, liquids, solids
Spectral linewidth	20 Hz (for 10^{-1} sec)	neon-helium
Spatial coherence	10 m	ruby

waveforms, and its energy and power scalability. Laser efficiency is determined by the degree to which appropriate pump excitation energy can be generated, fed selectively into the upper laser level(s), and subsequently extracted coherently before deleterious[1] decay processes otherwise remove this excitation energy. It is the very richness of energy level schemes and transition probabilities provided in nature that results in such a large number of lasers with such a wide variety of output characteristics.

Given the considerable diversity in laser properties, it is the purpose of this introductory section to order laser sources into basic classes and to describe the principle characteristics that define the classes and their subdivisions.

Increase your vocabulary

5. In each group find the word that doesn't belong:

1) minimum, maximum, datum, phenomenon, medium, extrema, spectrum;
2) coherent, neutral, efficiency, gasdynamic, nuclear, single, kinetic;
3) ultraviolet, unique, various, possible, incoherent, spectacular, infrared, optical.

[1] deleterious [ˌdelɪˈtɪərɪəs] – вредный, вредоносный

6. Find a synonym for each verb below:

1) produce, enumerate, possess, use, expand, remove, link, achieve, vary, give;
2) extract, enlarge, provide, change, attain, utilize, own, list, generate, couple.

7. Complete the sentences below with the appropriate word-combination.

1. The output wavelength of the FEL can be varied from the ultraviolet to the far infrared spectral region by
   a) utilizing one laser source to generate coherent radiation in a second medium;
   b) properly choosing the kinetic energy of the electron beam and the periodicity of the magnetic field.
2. The extreme power and energy parameters were attained with
   a) simple laser oscillators;
   b) laser systems rather than with simple laser oscillators.

8. Point out the statements which do not correspond to Text 4A.

1. A single laser source can simultaneously provide a spectacular set of characteristics.
2. Light amplification by stimulated emission of radiation was first demonstrated in 1970.
3. Recently laser action has been achieved by passing a dilute electron beam through a periodic magnetic field.

9. Translate the sentences below focusing on the underlined words.

1. As the result of nonlinear scattering in the second substance the number of laser sources has been expanded. 2. The richness of energy level schemes results in a large number of lasers with a wide variety of output characteristics. 3. Light amplification by stimulated emission of radiation was the result of a population inversion produced between energy levels of chromium ions in a ruby crystal. 4. The purpose of this introductory section is to order laser sources into basic classes. 5. One laser source was utilized in order to generate coherent radiation in a second medium. 6. Table 1 provides the list of the extrema of laser output parameters. 7. The parameters listed in the table were attained with laser systems rather than with simple laser oscillators.

10. In each sentence below find the Subject and Predicate groups. Translate the sentences.

1. Solid state semiconductor laser materials exhibit both high heat capacities and thermal conductivities. 2. To extend the average power output substantially beyond these levels appeal is made to laser – diode arrays[1]. 3. Reference 2 is

[1] laser-diode arrays [ə'reɪz] – линейки лазерных диодов

cited in the table as a key literature source dealing with lasers used to illustrate various classes and types of lasers. 4. The costs of lasers and laser systems vary widely and cannot be readily generalized. 5. The major alternative to optical pumping by incoherent sources is pumping by another laser. 6. Excitation into any of these levels decays rapidly down by nonradiative processes because of the relatively small energy gaps between various levels. 7. In Table 1 *cw* stands for continuous wave operation.

11. Answer the questions about Text 4A.

1. Who was the first to demonstrate light amplification by stimulated emission of radiation? 2. In what substances were population inversions and coherent emission generated? 3. What excitation techniques are used to generate coherent emission? 4. What method of generating coherent radiation resulted in the expanding of the number and types of laser sources? 5. Which is a better way of attaining the extreme power and energy parameters: using laser systems or simple laser oscillators? 6. What does laser efficiency depend on?

12. Write an abstract of Text 4A.

Reading and discussion 2

13. Skim Text 4B and answer the following question.

What are advantages of Nd :YAG laser before a ruby laser?

Text 4B

ND : YAG LASER VS. RUBY LASER

The Cr^{3+} iron-group ion doped[1] in Al_2O_3 is the medium in which laser operation was first demonstrated by Maiman in 1960. Cr : Al_2O_3 or ruby operates as a three-level system and thus, per unit volume, has a comparatively high threshold. Fortunately, the thermal conductivity and mechanical strength of Al_2O_3 are both high, superior to any other existing laser host crystal[2], and thus successful operation of the ruby laser is possible. For all but[3] a few specialized applications the much-lower-threshold, higher-average-power-output Nd : YAG laser has replaced the ruby laser, however. Efficient frequency-doubling[4] techniques for 1.06 nm radiation have in many cases eliminated the need for 0.69 μm ruby laser where visible radiation is required.

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[1] to dope – добавлять

[2] host crystal [ˈhəustˌkrɪst(ə)l] – основа, матрица, основной кристалл, кристалл-хозяин

[3] but – кроме

[4] frequency-doubling [ˈfriːkwənsɪ ˈdʌblɪŋ] – удвоение частоты

14. Translate Text 4C in writing using a dictionary.

Text 4C

FREE ELECTRON LASER

In the Free Electron Laser (FEL) gain is generated by the interaction of photons with an electron beam. A freely propagating electron does not interact with an electromagnetic field. To obtain gain the electrons and photons must interact within a perturbing environment that permits the simultaneous conservation of energy and momentum; spontaneous emission from the electron is then possible. The synchrotron radiation that occurs when the trajectory of a high energy electron is bent by a magnetic field is an example of one such process.

The process that generates gain may be viewed as stimulated scattering, as stimulated "free-free" transitions between continuous states of the perturbed electron-photon system, or as the inverse of the interaction that accelerates electrons in an accelerator. If the velocity distribution of the electrons in the beam is carefully selected, the radiation emitted by each electron adds coherently to the radiation from other electrons in the beam. The wavelength of maximum gain is primarily a function of the energy of the beam. With a minimum of constraints, the operation of an FEL should be possible at any wavelength from millimeter wavelengths into the visible and near ultraviolet.

15. Make a PowerPoint presentation on the subject of the module.

Supplementary reading tasks

Task 1. Match the verbs with their definitions:

1) eliminate	a) to have qualities, opportunities etc) that people are likely to want or enjoy
2) allow for	b) to completely get rid of something that is unnecessary or unwanted
3) achieve	c) to try to find out the truth about or the cause of something such as a crime, accident, or scientific problem
4) offer	d) to make it possible for someone to do something, or for something to happen
5) report	e) to successfully complete something or get a good result, especially by working hard
6) investigate	f) to clearly show a particular quality, emotion, or ability
7) exhibit	g) to make it possible for something to happen or for someone to do something, especially something helpful or useful [= permit]
8) enable	h) to officially give information to the public

Task 2. Supply the missing prepositions:

1) allowing _______ longer interaction lengths; 2) this leads _______ higher conversion efficiency ; 3) the advantage of wavelength selective loss dependent _______ bend diameter; 4)_______ our knowledge this is the highest power; 5) while generating very little loss _______938 nm; 6)_______a long time.

Task 3. Read and discuss the text that follows.

469nm fiber laser source

With the continued interest in development of solid-state blue laser sources we would like to show that fiber lasers and nonlinear frequency conversion are an attractive approach. Fiber sources are a good choice for nonlinear frequency conversion because of their good beam quality and high brightness.

Using non-critical phase matching eliminates the problems of spatial walk-off allowing for longer interaction lengths and this leads to higher conversion efficiency.

Our fiber amplifier uses the $^4F_{3/2} - {}^4I_{9/2}$ transition in neodymium and because of the 3-level nature of the transition there is strong competition from the $^4F_{3/2} - {}^4I_{11/2}$ 4-level transition. Optical fiber hosts have the advantage of wavelength selective loss dependent on bend diameter allowing the user to choose a fiber coil diameter to act as a variable short pass filter. In our case we were able to choose a coil diameter that will generate ~10dB of loss for the competing 4-level 1088 nm parasitic transition while generating very little loss at 938nm.

High power levels have been achieved for this neodymium transition in crystal hosts; however to our knowledge this is the highest power achieved for this transition in a silica fiber host. The silica host offers a broader absorption spectrum reducing the precision requirements of the pump and a broader emission spectrum (900nm to 950nm) enabling more applications. We have previously reported multi-watt operation on this transition and continue investigating power scalability.

While the idea of quasi-phase matching has been around for a long time engineered nonlinear materials are starting to gain maturity and are commonly used for nonlinear frequency conversion. A lot of progress has been made in both materials and periodic structure fabrication in recent years.

Fabricating the short periods required for first order frequency doubling into the blue still remains challenging. Because of its anisotropic lattice structure $KTiOPO_4$ (KTP) exhibits very limited domain wall spreading during the poling process leading to the ability to pole very short domain periods. Also the KTP has a coercive voltage about 10 times lower than congruent $LiNbO_3$ enabling electric field poling of thicker materials.

Task 4. Match the phrases from the text above with their Russian equivalents:

1) parasitic transition	a) преобразование частоты
2) silica fiber	b) оставаться сложным
3) be around	c) становиться более совершенным
4) frequency conversion	d) коэрцитивная сила сегнетоэлектрика
5) start to gain maturity	e) удвоение частоты
6) frequency doubling	f) пассивный переход
7) remains challenging	g) быть популярным
8) coercive voltage	h) кварцевое волокно

Task 5. Read and sum up the text that follows.

Good fundamentals

For most applications, the size to which a laser beam can be focused is as important a consideration as the laser output power. Frequency doubling, for example, depends on the square of the intensity of the primary laser. The depth of a hole drilled by an industrial laser depends on the laser intensity and the hole diameter is proportional to the spot size.

Maintaining a consistent beam profile is usually important whether the beam is focused or not. Ophthalmic surgery uses a beam with a flat cross section (a “top hat” profile) that must remain constant during the procedure. All of these applications require a laser designed to produce a consistent and well-characterized beam. To be propagated over a long distance, a laser beam needs to have the lowest divergence possible. Telecommunications combine this requirement with a need to control the spectral content of the beam to ensure data quality. Whenever low divergence or small spot size is required, a laser with TEM_{00} output is specified.

What is TEM_{00}?

It is useful to think of the light inside of a laser as formed by standing waves with distinct vibrational modes. Only a small number of modes will exist in the transverse direction. The fundamental transverse mode is designated as TEM_{00}, where the $_{00}$ indicates no nodes appear in the beam profile. “TEM” stands for “transverse electromagnetic” and refers to the form of the standing waves. The TEM_{00} mode is mathematically described by the familiar bell-shaped Gaussian curve.

Higher-order modes are formed by multiplying the Gaussian by a polynomial with an exponent that corresponds to the order of the laser mode.

These higher-order modes describe the number of nodes that appear in the beam – the TEM_{11} mode of a rectangular resonator, for example, will appear to have a dark cross in the middle of the profile. Higher-order modes add frequency components to the fundamental mode.

The Gaussian function extends to infinity in the radial direction, leaving open the question of the beam diameter. Measuring a laser beam diameter has been compared to using calipers to measure the width of a cotton ball. The accepted definition is the diameter at which the intensity has fallen to $1/e^2$ (13.5 %) of its peak value in the center.

The $1/e^2$ definition works well for Gaussian modes, but is not useful for other profiles. In these circumstances the diameter is calculated using the "second moment" algorithm, a combination of integrals similar to a formula for calculating an rms (root-mean-square) value. The second-moment calculation should be used cautiously because it gives heavy weight to the edges of the beam.

Task 6. Match the phrases from the text above to the Russian equivalents:

1) standing waves	a) колебательная мода
2) vibrational mode	b) мода высшего порядка
3) transverse mode	c) момент второго порядка
4) transverse electromagnetic mode	d) средне-квадратичное значение
5) higher-order mode	e) поперечная мода
6) second moment	f) стационарная волна
7) root-mean-square value	g) поперечная электромагнитная мода

Module 5
CLASSES OF LASER SOURCES

Texts:

A. Classes of laser sources
B. Semiconductor lasers
C. Glass lasers
D. X-ray lasers

Terminology A

transition [træn'zɪʃ(ə)n] – переход;
electronic [ˌelek'trɔnɪk] transition – электронный переход;
vibrational [vaɪ'breɪʃ(ə)nəl] transition – колебательный переход;
rotational [rə'teɪʃ(ə)n(ə)l] transition – вращательный переход
species ['spiːʃiːz] (*sing. + pl.*) – частица, вид, разновидность, род;
active species [ˌæktɪv'spiːʃiːz] – активная среда, активатор, активная частица
gas dynamic expansion [ˌgæsdaɪ'næmɪk], [ɪk'spænʃ(ə)n] – газодинамическое расширение
dye laser ['daɪleɪzə] – лазер на красителе
solid state laser ['sɔlɪdˌsteɪt], ['leɪzə] – твердотельный лазер
glass laser ['glɑːsˌleɪzə] – лазер на стекле
solvent ['sɔlvənt] – растворитель
rare earth ion ['reərˌɜːθ 'aɪən] – ион редкоземельного элемента
rare earth chelate ['kiːleɪt] laser – лазер на редкоземельных хелатах
spectral tunability – спектральная перестройка
insulator ['ɪnsjəleɪtə] – изолятор
impurity [ɪm'pjuərətɪ] – примесь;
impurity-doped crystal – кристалл с примесями
discharge [dɪs'ʧɑːʤ] – разряд;
arc discharge [ˌɑːk dɪs'ʧɑːʤ] – дуговой разряд;
glow discharge [ˌgləu dɪs'ʧɑːʤ] – тлеющий разряд
lattice ['lætɪs] – кристаллическая решетка
junction ['ʤʌŋkʃ(ə)n] – переход

Word study

1. Read and translate without a dictionary:

classify ['klæsɪfaɪ], classification [ˌklæsɪfɪ'keɪʃ(ə)n], basic ['beɪsɪk], atomic [ə'tɔmɪk], ionic [aɪ'ɔnɪk], molecular [mə'lekjulə], expansion [ɪk'spænʃ(ə)n], spontaneously [spɔn'teɪnɪəslɪ], organic [ɔː'gænɪk], inorganic [ˌɪnɔː'gænɪk], chelate ['kiːleɪt], trivalent ['trɪvələnt], dielectric [ˌdaɪɪ'lektrɪk], amorphous [ə'mɔːfəs], stoichiometry [ˌstɔɪkɪ'ɔmɪtrɪ], specific [spə'sɪfɪk], defect ['diːfekt], differentiate [ˌdɪf(ə)'renʃɪeɪt], electron [ɪ'lektrɔn], injection [ɪn'ʤekʃ(ə)n].

2. Combine the numbered and lettered words to obtain terms. Translate them:

1) spectral	5) gasdynamic	a) expansion	e) laser
2) dielectric	6) electrical	b) inversion	f) tunability
3) dye	7) impurity-doped	c) discharge	g) transition
4) vibrational	8) population	d) crystal	h) insulator

3. Find equivalent phrases either in Text 5A or in the right-hand column:

1) состояние активной среды	a) electron beam excitation
2) различающиеся по лазерному действию	b) specific types of lattice defects
3) разнообразные методы возбуждения	c) differentiated by laser action
4) возбуждение электронным пучком	d) solid state lasers have been developed
5) вид используемого твердого вещества	e) a wide variety of excitation methods
6) были созданы твердотельные лазеры	f) state of the active medium
7) особые виды дефектов решетки	g) the type of solid used

Reading and discussion 1

4. Read Text 5A and answer the following question.

What methods are used for gas, liquid and solid state laser pumping?

Text 5A

CLASSES OF LASER SOURCES

Laser sources are commonly classified in terms of the state of the active medium: gas, liquid, and solid. Each of these classes is further subdivided into one or more types.

Gas Lasers. Gas lasers are conveniently described in terms of six basic types, two involving electronic transition in atomic active species (neutral and ionic), three based on neutral molecular active species (differentiated by laser action occurring in electronic, vibrational, and rotational transitions), and one based on molecular-ion active species. Gas lasers are pumped using a wide variety of excitation methods, including several types of electrical discharges (cw, pulsed, dc[1] or rf[2], glow or arc), electron beam excitation, gasdynamic expansion, electrically or spontaneously induced chemical reactions, and optical pumping using primary lasers.

Liquid Lasers. Liquid lasers are commonly described in terms of three distinct types: organic dye lasers which are most well-known for their spectral tunability, rare-earth chelate lasers which utilize organic molecules, and lasers utilizing inorganic solvents and trivalent rare earth ion active centers. Liquid lasers are optically pumped using three basic methods: flashlamps, pulsed primary lasers, or cw primary lasers.

Solid State Lasers. Solid state lasers are subdivided by the type of the solid used – a dielectric insulator or a semiconductor. Dielectric insulators may take the form of an impurity-doped crystal or an impurity-doped amorphous material such as glass. Recently, solid state lasers have been developed using insulating crystals in which the active species has been fully substituted into the lattice (stoichiometric materials) and using insulator crystals in which color centers (specific types of lattice defects) serve as the active centers. Lasers utilizing dielectric insulators are almost exclusively pumped optically, either with flashlamps, cw arc-lamps, or with other laser sources.

Semiconductor lasers are usually differentiated in terms of the means by which the hole-electron pair population inversion is produced. Semiconductor lasers can be pumped optically (usually with other laser sources), by electron beams, or more commonly by injection of electrons in a p-n junction.

Increase your vocabulary

5. Match the synonyms:

distinct, exclusive, usual, specific, common, different, clear, convenient, particular, exceptional, comfortable, differing.

6. Complete the sentences below with the appropriate word-combination according to Text 5A.

1. Gas lasers are conveniently described in terms of
   a) six basic types;
   b) three distinct types: organic dye lasers...;
   c) the solid used.
2. Laser sources are commonly classified in terms of

[1] dc (direct current) discharge – накачка разрядом постоянного тока
[2] rf (radio-frequency) discharge – СВЧ-накачка

a) the type of solid used;
b) the state of the active medium;
c) six basic types.

3. Liquid lasers are pumped
   a) using a wide variety of excitation methods;
   b) optically by electron beam, or by injection of electrons in a p-n junction;
   c) optically by three basic methods: flashlamps, pulsed primary lasers, or cw primary lasers.

7. Bring the sentences below under the following headings.

A. Gas Lasers
B. Liquid Lasers
C. Solid State Lasers

1. These lasers are subdivided by the type of solid used – a dielectric insulator or a semiconductor. 2. They are described in terms of six basic types. 3. They are optically pumped using three basic methods: flashlamps, pulsed primary lasers, or cw primary lasers. 4. Organic dye lasers are most well-known for their spectral tunability. 5. These are pumped using a wide variety of excitation methods. 6. Dielectric insulators may take the form of an impurity-doped crystal or an impurity-doped amorphous material such as glass.

8. Complete the table below according to Text 5A.

Classes of laser sources

Class	Types of laser medium	Methods of pumping
1. ________	1. ________ 2. ________ 3. ________ 4. ________ 5. ________ 6. ________	1. ____________ a) _____b)_____c)_____d)_____ 2. ________ 3. ________ 4. ________ 5. ________
2. ________	____________ ____________ ____________	____________ ____________ ____________
3. ________	1. ____________ a)_____b)_____c)_____	____________ ____________ ____________
	2. ____________	____________ ____________

Terminology B

carrier [ˈkærɪə] – носитель заряда, электрон проводимости;
excess carrier [ɪkˈses] [ˈkærɪə] – возбужденный электрон проводимости, электрон с избыточной энергией
band [bænd] – полоса, зона (уровней энергии);
conduction [kənˈdʌkʃ(ə)n] band – зона проводимости;
valence [ˈveɪl(ə)ns] band – валентная зона;
band-to-band transition – переход с уровня на уровень
gap [gæp] – зазор, промежуток, интервал;
energy gap – запрещенная зона (в полупроводниках), энергетическая зона
bandgap [ˈbændˌgæp] – запрещенная зона, ширина запрещенной зоны;
bandgap semiconductor [ˌsemɪkənˈdʌktə] – полупроводник с запрещенной зоной;
direct bandgap semiconductor – собственный, беспримесный полупроводник;
indirect bandgap semiconductor – примесный, несобственный проводник
momentum [məˈmentəm] – количество движения, импульс, импульсная сила;
to conserve [kənˈsɜːv] momentum – сохранять количество движения
lifetime [ˈlaɪftaɪm] – время жизни;
radiative [ˈreɪdɪətɪv] lifetime – излучательное время жизни
internal [ɪnˈtɜːn(ə)l] quantum [ˈkwɔntəm] efficiency [ɪˈfɪʃ(ə)nsɪ] – внутренняя квантовая эффективность

Word study

9. Read and translate without a dictionary:

practical [ˈpræktɪk(ə)l], photon [ˈfəutɔn], absorption [əbˈzɔːpʃ(ə)n], phonon [ˈfəunɔn], valence [ˈveɪl(ə)ns], vector [ˈvektə], schematic [skiːˈmætɪk], diagram [ˈdaɪəgræm], variation [ˌveərɪˈeɪʃ(ə)n], technological [ˌteknəˈlɔʤɪk(ə)l], interest [ˈɪnt(ə)rəst], radiative [ˈreɪdɪətɪv], coefficient [ˌkəuɪˈfɪʃ(ə)nt], potential [pəˈtenʃ(ə)l].

10. Combine words from the numbered and lettered columns to obtain terms. Translate them:

1) radiative	4) valence	a) gap	d) lifetime
2) quantum	5) energy	b) transition	e) carrier
3) excess	6) band-to-band	c) efficiency	f) band

Reading and discussion 2

11. Read Text 5B and speak about the operating principles of semiconductor lasers.

Text 5B

SEMICONDUCTOR LASERS

Introduction. Semiconductor lasers include injection lasers, where a *p–n* junction or heterojunction is used to inject excess carriers into the active region, optically-pumped lasers, where an external light source produces excess carriers, and electron-beam-pumped lasers, which use high energy electrons to produce excess carriers. Injection lasers, which are the most practical devices, are discussed at length in this review.

Operating principles. In this section, we review a few of the key concepts concerning laser action in semiconductors. Extensive theoretical treatments of this subject can be found elsewhere.

Direct and indirect bandgap semiconductors. In direct bandgap semiconductors (the only ones in which stimulated emission has been observed), both photon emission and absorption can occur without the need for a phonon to conserve momentum. This is because the lowest conduction band minimum and the highest valence band maximum are at the same vector (k) in the Brillouin[1] zone.

In indirect bandgap semiconductors the conduction band minimum and valence band maximum are not at the same k value. Hence, photon emission and absorption require the participation of phonons to conserve momentum.

Lasing in indirect bandgap semiconductors is improbable because the lowest-energy band-to-band transition probabilities are much smaller than in direct semiconductors. Thus, the radiative lifetime is long. Because of the relatively long lifetime of electrons in the indirect minima, there is time for nonradiative recombination processes to occur, thus yielding low internal quantum efficiency. Furthermore, the stimulated recombination rate is related to the band-to-band absorption coefficient. Since the coefficient is lower for indirect than direct transitions, the potential laser gain is correspondingly reduced.

Increase your vocabulary

12. Read the following nouns. Say which verbs they are derived from:

conductor, semiconductor, conduction, conductivity; injection, emission, absorption, participation, composition, treatment, transition, recombination.

[1] *Léon Nicolas Brillouin* (1889 – 1969) was a French physicist. He made contributions to quantum mechanics, radio wave propagation in the atmosphere, solid state physics, and information theory. The Brillouin zone was named after him.

13. Match synonyms:

absorb, conserve, combine, occur, consume, watch, mix, observe, preserve, happen.

14. Translate the adjectives below paying attention to the negative prefixes:

direct – indirect, efficient – inefficient, convenient – inconvenient; probable – improbable, practical – impractical, possible – impossible; radiative – nonradiative, nuclear – nonnuclear, conducting – nonconducting; continuous – discontinuous; fortunate – unfortunate; comfortable – uncomfortable.

15. Translate the following word combinations avoiding prepositions:

внешний источник света, лазеры с накачкой электронным пучком, излучение и поглощение фотонов, зона проводимости, вероятность перехода, переход с уровня на уровень, вероятность перехода с уровня на уровень, коэффициент поглощения.

16. Which of the statements below are true according to Text 5B?

1. In injection lasers high energy electrons are used to produce excess carriers. 2. In indirect bandgap semiconductors both photon emission and absorption can occur without the need for a phonon to conserve momentum. 3. Lasing in indirect bandgap semiconductors is improbable because the lowest energy band-to-band transition probabilities are much smaller than in direct semiconductors. 4. In direct bandgap semiconductors the conduction band minimum and valence band maximum are not at the same k value.

17. Translate the sentences below paying attention to the underlined words.

1. The total amount of radiation absorbed from broadband pump sources clearly <u>increases</u> with ion concentration in a given size host crystal. 2. The growth of the density modulation gives <u>increasing</u> coherence to the scattering process resulting in a growing scattered wave which in turn increases the density modulation still further. 3. Laser diodes' degradation manifests itself primarily in an <u>increase</u> in threshold current although other parameters may also change. 4. <u>Increasing</u> the peak power output of a laser is constrained by the optical damage properties of the laser medium itself or of the optical materials required to make the laser operate. 5. Laser-pumped glass oscillators <u>provided</u> wavelength versatility because of their wide fluorescence bandwidth. 6. <u>Provided</u> the velocity distribution of the electrons in the beam is carefully selected, the radiation emitted by each electron adds coherently to the radiation from other electrons in the beam.

Grammar revision

18. Translate the sentences below focusing on non-finite forms of verbs.

1. If the electron velocity is close to the speed of light, long wavelength imposed fields can be used to build FELs operating in the visible region of the spectrum. 2. As large-scale commercial applications of lasers become more numerous and mature, additional cost scaling models and data bases are sure to become available in the field. 3. By varying the composition of a semiconductor diode it is possible to adjust the wavelength of its spectral gain peak. 4. The purpose of these dye absorption curves is to assist the user in selecting the laser pump source which will most effectively pump the dye laser. 5. Several molecular lasers should be mentioned when discussing tunable lasers. 6. When placed in a suitable cavity, the device (FEL) will radiate coherently. 7. After the discovery of the dye laser by Sorokin and Landkard, numerous reports followed, most of them detailing the study of various classes of fluorescent organic materials.

19. Answer the questions about Texts 5A and 5B.

1. What are the classes of laser sources? 2. What are the types of gas lasers? 3. What excitation methods are used to pump gas lasers? 4. What are the types and methods of pumping liquid lasers? 5. What excitation techniques are used to pump lasers utilizing dielectric insulators? 6. In what way are excess carriers produced in semiconductor lasers (injection lasers, optically pumped lasers, electron – beam pumped lasers)? 7. What is the difference between direct bandgap semiconductors and indirect bandgap semiconductors? 8. In what type of semiconductors do photon emission and absorption require the participation of phonons to conserve momentum? Why? 9. Why is lasing in indirect bandgap semiconductors improbable?

20. Write an abstract of Text 5A or 5B.

21. Use Table 2 and Texts 5A and 5B to talk about:

a) types of lasers;
b) direct bandgap semiconductors vs. indirect bandgap semiconductors.

22. Skim Text 5C and answer the questions that follow.

1. What advantages does glass have ascompared to crystal materials?
2. What disadvantage of glass is mentioned in the text below?

Text 5C

GLASS LASERS

Lasers made from vitreous[1] and crystalline materials comprise the two classes of solid state lasers. Their different material properties are complementary for use in lasers. Because of their lower cross sections, glass lasers store energy well and thus make good short-pulse lasers and amplifiers. On the other hand, crystalline materials are better for cw oscillators and amplifiers because of their higher gain and good thermal conductivity.

Glass has advantages over crystalline materials. It can be cast[2] in a variety of forms and sizes, from small fibers to meter-sized pieces. Tremendous flexibility in choosing glass and laser properties is afforded by the ability to vary the glass composition over very large ranges. Glass is also relatively inexpensive because of the shorter time required for its manufacture and the use of inexpensive chemical components. Further, large pieces of laser glass can be made with excellent homogeneity, uniformly distributed rare earth concentrations, low birefringence, and can be finished[3] easily, even in large sizes. The only major drawback of glass is its low thermal conductivity, which limits its applicability in high average power systems.

23. Translate Text 5D in writing using a dictionary.

Text 5D

X-RAY LASERS

Research toward advancing lasing to the X-ray spectral regions is in an early and progressive state. The challenge of inventing and developing X-ray lasers may be approached by: a) adapting familiar X-ray sources to lasing action; b) extending proven ion laser processes progressively toward shorter wavelengths, perhaps through isoelectronic extrapolation; c) discovering new pumping and emission processes more appropriate to the task.

With potential applications in the vacuum-ultraviolet spectral region seemingly limited as compared to those for the penetrating X-ray region, early thoughts were directed toward making the big leap to the X-ray and perhaps γ-ray regions. Formidable pumping problems were projected. Meanwhile advancements into the ultraviolet regions, accompanied by rising uses and interests as specific devices have emerged, seem to indicate that the more reasonable approach is the continued systematic advance toward shorter wavelengths. Indeed, over the past 12 years the so-called short-wavelength "barrier" has been pushed from 200 nm into the vacuum region – first near 100 nm, and presently it appears that 60 nm has been reached. These advances have been achieved both with cavities and in the amplified spontaneous

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[1] vitreous ['vɪtrɪəs] – стекловидный
[2] cast – придаватъ форму
[3] finish – обрабатывать начисто

emission (ASE) single pass mode, where the latter requires considerably higher gain.

24. Make a PowerPoint presentation on one of the subjects covered in the module.

Supplementary reading tasks

Task 1. Match the phrases from the text below (underlined in the text) with the Russian equivalents:

1) seek	a) получить степень доктора
2) earn a master's degree	b) технический персонал
3) earn PhD	c) учёный, эрудированный, знающий
4) technical staff	d) оставить после себя
5) retire	e) искать, пытаться найти, добиваться
6) learned	f) уходить в отставку, на пенсию
7) be survived by	g) получить степень магистра

Task 2. Read and sum up the text that follows.

Irnee D'Haenens dies; assisted Maiman in building the first laser

January 4, 2008, Los Angeles, CA

Irnee D'Haenens, a physicist who assisted Ted Maiman in making the first laser at Hughes Research Laboratory (Malibu, CA) in 1960, died December 24; he was 73. The two were the only people present when a little ruby rod emitted the world's first pulse of laser light on May 16, 1960. Later, D'Haenens called the laser "a solution looking for a problem," a joke that became common in the early years of the laser era as developers sought laser applications.

Born in Mishawaka, Indiana, the son of a service-station operator, D'Haenens spent his entire professional career at Hughes, starting while he was earning a master's degree from the University of Southern California. He received a Hughes doctoral fellowship and earned his PhD from the University of Notre Dame in 1966. As a member of the technical staff at Hughes, he worked on semiconductor physics, microwave technology, and spectroscopy as well as lasers before retiring in 1989. A long-time Hughes colleague, David Pepper, recalled D'Haenens as "as a wise and learned uncle who helped me travel along my path in life," whose first priority was always his family. He is survived by his wife Shirley, four children, 19 grandchildren, and three great-grandchildren.

Task 3. Combine words from the numbered and lettered columns to obtain word-combinations:

1) thorough	7) contrast	a) instruments	g) wavelengths
2) sophisticated	8) atmospheric	b) system	h) dwarfs
3) state-of-the-art	9) direct	c) planetary systems	i) improvement
4) near-infrared	10) brown	d) understanding	j) processes
5) adaptable	11) extra-solar	e) imaging	k) direct light
6) harsh	12) evolutionary	f) distortion	l) camera

Task 4. Complete the table below.

Verb	*Noun(s)*	*Adjective(s)*	*Verb*	*Noun(s)*	*Adjective(s)*
	locator				investigative
	dedicatee		clarity		
	surrounds				installable
explore					detectable

Task 5. Read the following text to find out the features and applications of the HiCIAO camera.

New camera on Subaru Telescope may directly observe exoplanets

The Subaru Telescope, located on the summit of Mauna Kea, is dedicated to exploring the cosmos, gaining a deeper and more thorough understanding of everything that surrounds us. With an 8.2-meter mirror and a suite of sophisticated instruments, astronomers at the Subaru Telescope explore nearby stars looking for planetary systems. A giant step towards this goal was made recently with the "first-light" inauguration of a new state-of-the-art camera.

Subaru uses eight innovative cameras and spectrographs optimized for various astronomical investigations in optical and near-infrared wavelengths. On the night of December 3, 2007, the High Contrast Instrument for Adaptive Optics (HiCIAO) camera was brought to life. The HiCIAO is a technologically adaptable system that will replace the infrared Coronagraphic Imager with Adaptive Optics (CIAO) unit in operation since April 2000. Both systems are designed to block out the harsh direct light from a star, so that nearby faint objects such as planets can be viewed. The new system benefits from a contrast improvement of ten to 100 times, allowing astronomers glimpses into regions never explored.

A further advantage of the HiCIAO camera is that it will be used in concert with an adaptive optics (AO) system that was recently significantly upgraded, which, in turn, increased the clarity of Subaru's vision by a factor of ten, opening up more of the night sky to observing. The new AO system uses 188 actuators behind a deformable mirror to remove atmospheric distortion, allowing the Subaru Telescope to observe close to its theoretical performance limits. In addition, a laser guide – star system was installed to enable observations of tiny regions of sky without bright stars to steady the AO system on.

The HiCIAO system, initiated in 2004, was developed by a team of scientists and engineers from the Subaru Telescope, National Astronomical Observatory of Japan, and the University of Hawaii's Institute for Astronomy. Dr. Ryuji Suzuki, a Subaru astronomer leading the HiCIAO project, says "the unique instrument was primarily designed for the direct detection of extrasolar planets and disks." The system's design allows for high-contrast coronagraphic techniques in three observing modes: direct imaging, polarization differential imaging, and spectral differential imaging. HiCIAO directly detects and characterizes young extrasolar planets and brown dwarfs, sub-stellar objects that occupy the mass range between that of large gas giant planets (e.g. Jupiter), and the lowest mass stars. With the aid of the laser guide – star AO system, HiCIAO targets dim objects including young stars, protostars, and star-forming regions.

HiCIAO is also extremely useful for detecting faint dust disks around nearby stars, and for studying small-scale and inner disk structures and dust grain properties, both of which lead to a clearer understanding of extra-solar planetary systems and their evolutionary processes. Dr. Suzuki reports that "although we already know of more than 250 extrasolar planets, they have all proven their existence indirectly by the Doppler or transit method. Because the direct imaging of an extrasolar planet has never been done, if it happens, that will be exciting." Subaru Telescope may be the first to directly observe a planet outside our solar system.

Module 6
PROPERTIES OF LASERS

Texts:

A. Properties of some important lasers
B. Soldiers in lockstep
C. Average power scaling

Terminology

ground [graund] state – основное состояние системы;
steady ['stedɪ] state – стационарный режим
self-terminated [self'tɜːmɪneɪtɪd] operation – пичковый режим (в отличие от стационарного);
self-terminated lasing – генерация на самоограниченных переходах
relaxation [ˌriːlæk'seɪʃ(ə)n] time – время релаксации (жизни)
mode [məud] – мода, тип колебаний;
mode-locking ['məudlɔkɪŋ] – синхронизация мод
to store [stɔː] – хранить, запасать, накапливать;
storage – память, накопление
Q-switching ['kjuːswɪtʃɪŋ] – модуляция добротности;
Quality factor (*Q*) ['kwɔlətɪ 'fæktə] – коэффициент добротности
cavity dumping ['kævətɪˌdʌmpɪŋ] – затухающие колебания
curve [kɜːv] – кривая линия;
gain curve – контур усиления
performance [pə'fɔːməns] – работа, рабочие характеристики
to saturate ['sætʃ(ə)reɪt] – насыщать;
saturation [ˌsætʃ(ə)'reɪʃ(ə)n] flux [flʌks] – поток насыщения

Word study

1. Read and translate without a dictionary:

thermal ['θɜːm(ə)l], system ['sɪstəm], stimulate ['stɪmjəleɪt], integrate ['ɪntɪgreɪt], intense [ɪn'tens] , alternately [ɔːl'tɜːnətlɪ], nominal ['nɔmɪn(ə)l], radioactivity [ˌreɪdɪəuæk'tɪvətɪ], combination [ˌkɔmbɪ'neɪʃ(ə)n], diode ['daɪəud], orange ['ɔrɪnʤ], rhodamine ['rəudəmiːn], collectively [kə'lektɪvlɪ].

2. Translate the word-combinations that follow:

medium – laser medium, gain medium, pulse-pumped laser medium, energy-storage medium;
level – laser level, ground level, lower laser level, upper laser level, three-level laser system, upper laser level relaxation time, higher-lying pump level;
density – average power density, population inversion density, input (output) power density.

3. Find equivalent phrases either in Text 6A or in the right-hand column:

1) тип уширения линии (насыщения)	a) spectral gain bandwidth
2) свойства усиливающей среды	b) saturation flux
3) источник накачки	c) stimulated emission cross-section
4) состояние индуцированного излучения	d) properties of gain medium
5) накопленная энергия	e) weak pulse
6) высвобождать энергию	f) colour center laser
7) режим действия	g) pumping source
8) слабый импульс	h) stored energy
9) лазер с окрашенными центрами	i) type of saturation
10) поток насыщения	j) release energy
11) ширина полосы спектрального усиления	k) mode of operation

Reading and discussion 1

4. Read Text 6A and answer the following questions.

1. What does a laser performance mode depend on?
2. Under what conditions does laser operation in a stationary mode take place?

Text 6A

PROPERTIES OF SOME IMPORTANT LASERS

The output energy and/or power obtainable from a given laser medium are determined both by the microscopic properties of the gain medium and by its associated "scaling laws"[1].

In general terms, a laser medium is said to be a "three-level laser system" when the lower laser level is the ground state of the system, the other two levels being the upper laser level and a higher-lying pump level; it is said to be a "four-level system" when the lower laser level is a level lying above the ground level of the system (usually with sufficient energy, so that it is thermally unoccupied).

The relaxation times of the upper and lower laser levels determine the basic modes of operation possible for the laser itself. If the relaxation time of the lower laser level is much shorter than the upper laser level relaxation time (due to stimulated as well as spontaneous processes) then the laser may be operated in the steady state with a cw output. When the inverse relation between level relaxation times is obtained, cw operation is precluded and self-terminated pulsed operation may occur.

A pulse-pumped laser medium is said to be an energy-storage medium when the lifetime of the upper laser level is much longer than the desired pulse duration of the output pulse. In this situation the upper laser level is able to integrate the power supplied by the pumping source. Stored energy can then be released in an output pulse using mode-locking, Q-switching, or cavity dumping techniques; alternatively, pump energy stored in a laser power amplifier can be released in an intense short pulse upon passing a weak short pulse from a master-oscillator through the power amplifier (MOPA).

The key microscopic (intrinsic) laser parameters of the gain medium are: nominal wavelength; stimulated emission cross-section; spectral gain bandwidth and type of saturation (homogeneous/inhomogeneous); saturation fluence or flux; radiative and kinetic lifetimes of upper and lower laser levels; and the characteristic specific excitation parameters are population inversion density; small signal gain coefficient; input and output power (energy) densities.

Spectral tunability is a particularly useful property of many laser sources. Semiconductor diode lasers, organic dye lasers and colour center lasers are particularly known for this property. Using several different dye types and various solvents, the spectral region from 350 to 1000 nm can be spanned with tunable dye lasers. A single dye-solvent combination typically can be tuned several hundred wave numbers away from the spectral peak of the gain curve. Best dye laser performance is currently achieved with the yellow – orange rhodamine dye. Power and energy availability tend to roll off to the blue and to the red, also useful amounts of energy and power can be achieved in these spectral regions.

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[1] scaling [ˈskeɪlɪŋ] law – здесь: закон распределения уровней

Semiconductor lasers of various types collectively span the spectral region from 330 μm to beyond 15μm. Depending on the type of diode tuning can be accomplished using an applied magnetic field, by changing the current passing through the diode, or by applying pressure to the diode.

Increase your vocabulary

5. In each group find the word that doesn't belong:

a) lower, upper, smaller, power, bigger, hotter, shorter, higher;
b) associated, terminated, stored, precluded, released, unoccupied, described, tuned;
c) sufficient, different, coefficient, magnificent, fluorescent, efficient.

6. Find an antonym for each verb below in Text 6A:

lower level, longer than, output power, direct relation, occupied level, released energy, weak pulse, homogeneous saturation, above.

7. Complete the sentences below with the appropriate word or word-combination from Text 6A.

1. When the lower level is above the ground level of the system, a laser medium is said to be________________. 2. When the lifetime of the upper laser is much longer than the desired pulse duration of the output pulse, a laser medium is said to be___________________. 3. When the relaxation time of the lower laser level is much longer than that of the upper lev el,___________________________. 4. The tuning of semiconductor lasers can be accomplished by_________________. 5. Semiconductor lasers, organic dye lasers and colour center lasers are famous for the property of___________________ .

8. Translate the sentences below focusing on the underlined words.

1. The <u>term</u> laser stands for light amplification by stimulated emission of radiation. 2. There are many phenomena of the interaction of light with matter, which are readily described <u>in terms of</u> photon. 3. Continuous systems' modeling should be analyzed <u>in terms of</u> modified curves. 4. <u>In broad terms</u> it is found that optical threshold depends on the wavelength of the incident radiation. 5. Semiconductor lasers are usually differentiated <u>in terms of</u> the means by which the hole-electron pair population inversion is produced. 6. Laser sources are commonly classified in terms of the <u>state</u> of matter of the active medium. 7. Laser oscillation is marked by dramatic narrowing of the spectral and angular distribution of the spontaneous emission radiation. This <u>statement</u> was first made by Maiman in 1960. 8. The United States of America is a Federal Republic of 50 <u>states</u> done together by the pact of 1787. 9. As the engine has a mechanical compression it is capable of operating under <u>static</u> conditions.

9. Answer the following questions abaut Text 6A.

1. What determines the output energy? 2. What is the difference between a three-level laser system and a four-level laser system? 3. How does laser operation depend on the relaxation time? 4. Under what conditions can self-terminated pulsed operation occur? 5. What laser property allows spanning the spectral region from 330nm to beyond 15nm? What types of lasers are known for this property? 6. How can a semiconductor laser be tuned?

10. Write an abstract of Text 6A.

Reading and discussion 2

11. Skim Text 6B and answer the following question.

Why does laser radiation have a very straight direction of wave propagation?

Text 6B

SOLDIERS IN LOCKSTEP[1]

To understand why light from the laser is so concentrated, you must recall that light travels in waves, like ripples on a pond. The distance from the crest of one wave to the crest of the next is the wavelength. Ordinary white light is made up of many wavelengths travelling in every direction. This is known as incoherent light. Laser light, on the other hand, is coherent. It is essentially of one wavelength, with all the waves moving in one direction. Because the laser wavelengths reinforce each other like soldiers marching in lockstep, they can remain in an unbelievably straight narrow beam for long distances instead of fanning out like a flashlight beam. Almost any substance can be forced to "lase" if you work hard with it. Gas lasers give off continuous beams of laser light in contrast to the sharp pulses of the ruby laser. Tiny semiconductor lasers made of bits of such materials as gallium arsenide work best at ultra-cold temperatures. Many lasers give off invisible radiation, either infrared or ultraviolet. The carbon-dioxide laser, one of the most powerful yet invented, shoots a continuous beam of intensely hot but invisible infrared light.

12. Translate Text 6C in writing using a dictionary.

Text 6C

AVERAGE POWER SCALING

Increasing the average power output of a laser as it is made bigger is determined primarily by the rate at which waste heat generated in the laser process can be removed from the laser medium and/or the active volume

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[1] lockstep ['lɔkstep] – шаг в ногу (в строю); шагать в ногу тесным строем

enclosed by the optical resonator. In average power producing lasers of practical interest, removal of waste heat is accomplished by either convection or conduction, the choice depending on the class of laser medium involved. For both gaseous and liquid laser media, scaling to high average power is achieved using convective flow of the waste heat (and spent laser medium) out of the active volume defined by the laser resonator. In the case of gas lasers, the flow may be supersonic (as in the CO_2 gasdynamic laser which has resulted in the highest average output power achieved so far) or it may be subsonic. In the case of liquid dye lasers, significant average power has been obtained using a confined transverse flow of the organic dye laser medium through the optically pumped laser volume, as well as by using a free – flowing transverse jet stream.

In the case of solid state lasers, the laser medium itself cannot be rapidly and continuously moved through the volume of space defined by the laser resonator and the cooling of the laser medium must be accomplished by conduction of waste heat to an exterior surface. This surface can then be cooled using a gaseous or liquid cooling fluid flowing across it. Crystalline materials generally exhibit relatively high thermal conductivities which are strongly temperature dependent compared to those of amorphous glasses which are essentially temperature independent.

13. Make a PowerPoint presentation on one of the subjects covered in the module.

Supplementary reading tasks

Task 1. Supply the missing prepositions:

1) that will help to get rid ______the deflection; 2) according _____ statistics; 3) population suffers _____this defect; 4) an insignificant defect is capable _____ causing big trouble; 5) the technology is based _____directing the laser ray; 6) _____a short time period; 7) the scientists at the institute are engaged _____ developing technology.

Task 2. Match the verbs with nouns to obtain meaningful word-combinations:

1) treat	5) undergo	a) 15—20 minutes	e) discoveries
2) take	6) carry out	b) anesthesia	f) short-sightedness
3) pave	7) have	c) medical equipment	g) side effects
4) make	8) develop	d) the way	h) research

Task 3. Read the text that follows to find out what the new technology is based on.

New laser equipment stops snoring and blindness

Russian physicists at the Institute for Laser Problems and Information Technology have developed medical equipment that will help to get rid of the deflection of the nasal septum[1]. According to statistics, 20 to 30 percent of the world population suffers from this defect.

Even an insignificant defect is capable of causing big trouble from a chronic nasal catarrh[2] and inflammation of the auditory tube[3] to a terrible snore. Until recently, the defect could be corrected only surgically, says the head of the laboratory of the bio-photonics of the institute, Emil Sobol. "This was a major surgical operation with heavy loss of blood and the patient had to undergo anesthesia," says Emil Sobol. "We developed a simple and non-traumatic surgery to get rid of this abnormal condition. The technology is based on directing the laser ray on a small area for a short time period to change the structure and mechanical properties of the nasal septum. This will make the tissues[4] plastic for a short time during which the form of the nasal septum is corrected."

This will take only 15...20 minutes and the nasal septum will remain normal and healthy after the procedure, but it will anatomically have a correct form. The patient can go home calmly. This device was developed in Russia, but it was earlier used for telecommunication purposes. However, the scientists at the institute modified it for use in medicine, says Emil Sobol.

At present the scientists at the institute are engaged in developing technology to correct the form of eye cornea[5] to treat short-sightedness or long-sightedness. The new technology will replace operations, including the widely used laser surgery, which destroys tissues and has side effects. The Russian development paves the way for carrying out such operations without harming cornea and side effects. So far, Russian physicists have not studied dental problems. However, according to Emil Sobol, research in the restoration of tissues, which has been carried out for over 20 years, will help to make discoveries and reveal new capabilities that will be successfully used by dentists too).

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[1] nasal septum [ˌneɪz(ə)l 'septəm] – перегородка носа

[2] nasal catarrh [kə'tɑː] – катаральный ринит

[3] inflammation of the auditory ['ɔːdɪt(ə)rɪ] tube – воспаление евстахиевой (слуховой) трубы

[4] tissue – ткань

[5] cornea ['kɔːnɪə] – роговица (роговая оболочка глаза)

Task 4. Read the text that follows and discuss the use of lasers for spacecraft propulsion.

Laser-propelled spacecraft

Because they are scalable to higher powers, pulse-periodic lasers may be useful for spacecraft propulsion. The Lightcraft, developed by Leik Myrabo of Lightcraft Technologies (Bennington, VT) and tested at White Sands Missile Range (White Sands, NM), is a craft that receives a ground-based laser beam, focusing it to create a detonating plasma from the air just behind it, propelling it upward. A 10-kW CO_2 laser pulsed at 28 Hz and with a pulse duration of a few microseconds has propelled a small Lightcraft to a height of 128 ft.

"Victor Apollonov's regenerative-amplifier gas-dynamic-laser experiments look very promising, and particularly so for applications that demand rapid scaling into the multimegawatt level, kilohertz pulse-repetition frequencies, and submicrosecond pulse durations – all attractive for the current laser Lightcraft engine design," says Myrabo.

Module 7
LASER OPERATION

Texts:

A. Laser operation
B. Stoichiometric lasers
C. Laser safety

Terminology

host [ˈhəust] crystal [ˈkrɪst(ə)l] – матрица, основной кристалл, кристалл-хозяин
terminal [ˈtɜːmɪn(ə)l] state – нижний рабочий уровень
thermal [ˈθɜːm(ə)l] excitation [ˌeksɪˈteɪʃ(ə)n] – тепловое возбуждение
zero-phonon [ˈfəunɔn]-line energy – нулевой энергетический уровень фонона
phonon-assisted [ˈfəunɔnˌəˈsɪstɪd] transition [trænˈzɪʃ(ə)n] – переход с наличием фонона, переход с участием фононов
cavity [ˈkævətɪ] – полость, резонатор;
intracavity [ˌɪntrəˈkævətɪ] – внутрирезонаторное устройство, кювет
mirror-folded [ˈmɪrəˌfəuldɪd] cavity [ˈkævətɪ] design – зеркальная конструкция с изломом оси
quasi [ˈkwɑːzɪ] continuum [kənˈtɪnjuəm] – квази-непрерывный
coupler [ˈkʌplə] – выходной элемент связи
flight time [ˈflaɪtˌtaɪm] – время пролета
losses [ˈlɔsɪz] – потери
spatial coherence [ˈspeɪʃ(ə)lˌkə(u)ˈhɪər(ə)ns] – пространственная когерентность

Word study

1. Read and translate the following words:

practice [ˈpræktɪs], factor [ˈfæktə], criteria (pl.) [kraɪˈtɪərɪə], criterion (sing.) [kraɪˈtɪərɪən], ignore [ɪgˈnɔː], focus [ˈfəukəs], horizontal [ˌhɔrɪˈzɔnt(ə)l], vibrational [vaɪˈbreɪʃ(ə)nəl], vibronic [vaɪˈbrɔnɪk], fluorescence [flɔːˈres(ə)ns], selective [sɪˈlektɪv], microsecond [ˈmaɪkrə(u)ˌsek(ə)nd].

2. Match the words in the left-hand column with their definitions in the right-hand column:

1) operation	a) a transposition in the relative numbers of atoms, molecules, etc. occupying particular energy levels
2) application	b) the process in which an atom or other particle adopts a higher energy state when energy is supplied
3) inversion	c) the fact or condition of functioning or being active
4) combination	d) the factors or prevailing situation influencing the performance or the outcome of a process
5) excitation	e) the emission of energy as electromagnetic waves or as moving subatomic particles, especially high-energy particles which cause ionization
6) absorption	f) the use of something in a particular situation
7) solution	g) a reduction of the intensity of any form of radiated energy as a result of energy conversion in a medium, such as the conversion of sound energy into heat
8) radiation	h) a change of an atom, nucleus, electron, etc. from one quantum state to another, with emission or absorption of radiation
9) transition	i) a joining or merging of different parts or qualities in which the component elements are individually distinct
10) conditions	j) a liquid mixture in which the minor component (the solute) is uniformly distributed within the major component (the solvent)

3. Find equivalent phrases either in Text 7A or in the right-hand column:

1) ограниченное множество (ряд)	a) long compared to
2) не в состоянии удовлетворить	b) with respect to
3) лазер общего назначения	c) intracavity reflection losses
4) идеально четырехуровневый	d) gain medium for amplification
5) внутрирезонаторные потери на отражение	e) continuously operating laser

6) лазер непрерывного излучения	f) high velocity jet
7) длительный по сравнению	g) fail to satisfy
8) полностью определяется требованием	h) strict four-level
9) струя, летящая с большой скоростью	i) limited variety
10) среда для получения усиления	j) general purpose laser
11) относительно чего-то	k) is entirely determined by the requirement

Reading and discussion 1

4. Read Text 7A and answer the following questions.

1. What condition is necessary for a given ion or host to operate effectively?
2. What are the main properties of a dye laser?

Text 7A

LASER OPERATION

General. A great many different combinations of transitions, paramagnetic ions, and hosts exhibited laser operation. In practice, however, only a limited variety of paramagnetic ion lasers are commonly used for either research or industrial applications. Many factors determine whether or not a given ion and host will operate effectively as a laser, and many of the lasers fail to satisfy all the necessary criteria for practical systems.

Of major importance for any system is the need for a low pump-power or energy threshold for stimulated emission. It is desirable to have a minimum initial population of ions in the desired laser level or terminal state. In strict four-level laser this population is sufficiently small such that the effect on threshold of absorption from the lower state can be ignored. At the other extreme, in a three-level laser, the terminal level is the ground state of the ion and the threshold is almost entirely determined by the requirement that more ions be in the upper laser level than the ground state. Many paramagnetic-ion lasers fall in the region between the two extremes; in some cases laser operation may be four-level in nature at low temperature, where thermal excitation of the terminal level is negligible, but tend toward three-level operation at higher temperatures. For vibronic or phonon-assisted transitions, four-level operation is obtained between two electronic levels when vibronic absorption is negligible in the vibronic emission region. This condition is achieved when the difference between zero-phonon-line energy and the desired emission energy is large compared to the thermal energy.

The first suggestion that organic materials might be useful in laser applications was made by Rautian[1] and Sobelman[2]. After the discovery of the dye laser by Sorokin and Lankard[3], numerous reports followed which detailed the study of various classes of fluorescent organic materials. These lasers provide maximum user flexibility, producing cw or pulsed output across the visible spectrum and into the infrared. They are designed for convenient and reliable operation over a broad range of wavelengths and are found to be reliable sources of intense tunable laser light.

It is a linear laser based on three mirror-folded cavity design. A fourth mirror focuses the incoming pump laser beam into a high velocity horizontal dye jet. This jet is placed at Brewster's angle with respect to the dye laser beam to minimize intracavity reflection losses. Upon excitation with the intense pump beam, a population inversion between ground and first excited state of the complex is ac hieved. The dye solution then can act as a gain medium for amplification of the spontaneous emission (fluorescence) of dye molecules returning to the ground state. Since this relaxation occurs into the quasi continuum of ground state vibrational levels, the fluorescence has a continuous character and laser action can be obtained over a broad wavelength range, often 100 nm or more. By inserting a wavelength selective element in the large intracavity space near the output coupler the dye laser can be tuned over this wavelength range with linewidths down to a few GHz. The high velocity jet restricts the flight time of dye molecules through the active area to less than a microsecond, which is long compared to the fluorescence process but is short compared to other processes like phosphorescence that would reduce the dye laser efficiency.

Increase your vocabulary

5. In each group find the word that doesn't belong:

a) effectively, entirely, sufficiently, relatively, efficiency, generally, commonly, practically;
b) initial, usual, electrical, negligible, horizontal, thermal, removal.

6. Match:

a) *synonyms* — gain, occur, large, rate, general, amplification, take place, broad, velocity, common;

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[1] *Sergei Glebovich Rautian* (1928–2009) was a Soviet and Russian physicist specializing in optics, spectroscopy, quantum electronics and atomic physics.

[2] *Igor Ilyich Sobelman* (1927–2005) was a Russian physicist known, among other things, for his papers in quantum electronics.

[3] *Peter P. Sorokin* is an American physicist and co-inventor of the dye laser. Sorokin and his colleague *J.R.Lankard*, at IBM Research Laboratories, used a ruby laser to excite a near infrared laser dye.

b) *antonyms* — low, simple, general, excitation, short, specific, initial, relaxation, high, long, complex, terminal.

7. Complete the sentences below with the appropriate word or word-combination from Text 7A.

1. There are a lot of substances operating as a laser but only some of them are effectively used for ______________. 2. As for the four-level lasers the effect on the threshold of absorption from the lower state can be ignored because ______________. 3. For vibronic transitions, 4-level operation is obtained when ________________. 4. A population inversion in the dye laser is excited with _______________. 5. Rautian and Sobelman were the first to suggest that ________________. 6. The dye laser can be tuned over a wavelength range of 100nm or more by ________________. 7. The flight time of dye molecules is restricted by _________________________.

8. Translate the sentences below focusing on the underlined words.

1. Laser oscillation has been observed in a wide <u>variety</u> of gas systems. 2. Holes of <u>various</u> shapes can be cut by focused radiation of pulsed or cw lasers. 3. The ability <u>to vary</u> the lasing ion concentration over a wide range allows further optimization of a particular laser design. 4. <u>Variations</u> in the dye flow rate can cause variations in the output power. 5. The output from a radar receiver can be viewed as a random process and the models of this process as random <u>variables.</u> 6. <u>As for</u> increasing the peak-power output of a laser, it is limited by the optical damage properties of the laser medium itself. 7. <u>As</u> shown in the Figure different tuning elements may be utilized in the general purpose dye laser. 8. In the dye laser both tuning elements are available <u>as</u> separate modules <u>as well</u> and can be installed in the laser at any time. 9. In order to achieve flashlamp pumping of organic dye lasers, the strictest attention must be paid to the attainment of very short pulses <u>as well as</u> determination of the actual limit.

9. Answer the questions about Text 7A.

1. Why do many lasers fail to satisfy all the necessary criteria for practical systems? 2. What condition is considered to be of great importance for any system? 3. Is the initial population of ions in the 4 and 3 – level lasers equal? 4. Describe conditions for vibronic transition. 5. Give any details about the dye laser performance?

10. Speak about dye laser structure and operation.

11. Write an abstract of Text 7A.

Reading and discussion 2

12. Skim Text 7B and answer the following question.

What are the differences between stoichiometric lasers and the common solid ones?

Text 7B

STOICHIOMETRIC LASERS

A stoichiometric crystal laser is by definition a laser whose gain medium contains the lasing[1] ion as an intrinsic constituent[2] of the insulating crystal lattice. In such laser crystals the active ion may be partially replaced by other ions; however the pure or truly stoichiometric form of such mixed crystal must have demonstrated laser action. Although not exactly synonymous, the term 'high-concentration' is often used to describe such lasers. In scientific literature these lasers are frequently referred to as 'self-activated'. The major distinction to be made between this type of laser material and the more common solid state laser crystals developed earlier is that the active ions in the latter case occur in the lattice as impurities[3] with concentrations generally less than a few percent. The first reported stoichiometric laser was HoF_3[4]. Interest in this field was stimulated in 1972–1973 by the achievement of lasing in NdP_3O_{14}, (neodymium pentaphosphate). The significance of this development lies in the utilization of Nd, a lasing ion of great practical importance but whose concentration in earlier hosts had been severely limited, since then many other stoichiometric laser crystals have been synthesized and the potential for future development seems very promising.

13. Translate Text 7C in writing using a dictionary.

Text 7C

LASER SAFETY

The health and safety hazards associated with the use of lasers are often broken into three general categories: laser radiation hazards, electrical hazards, and hazards from associated contaminants. This text is therefore divided into three sections which emphasize these three types of hazards.

The hazards from laser radiation are confined largely to the eye and, to a smaller extent, the skin. Few serious eye injuries due to lasers have been reported since the appearance of commercial devices. The accident rate is not

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[1] lasing – зд: активный

[2] an intrinsic [ɪn'trɪnzɪk] constituent [kən'stɪtjuənt] – неотъемлемая составная часть

[3] impurities [ɪm'pjuərətɪz] – (легирующие) примеси

[4] HoF_3 – Гольмий $Фтор_3$

that low because the ocular exposure limits are overly conservative; they are not. Instead, the possibility of accidental exposure of the eye to a collimated beam is extremely remote if a few rudimentary commonsense precautions are followed.

Electrical hazards so far have proven more serious. At least five laser workers have been electrocuted. Procedures for handling high voltages safely are to be found elsewhere.

Hazards from airborne contaminants, such as vaporized target materials, cryogenic fluids, noise and explosive mixtures are also of concern in some specialized applications and in some research laboratories. Some of the solvents used in dye solutions have the ability to carry their solutes through the skin and into the body chemistry.

14. Make a PowerPoint presentation on one of the topics covered in the module.

Supplementary reading tasks

Task 1. Reorder the passages below to obtain a logical text.

Light is a thing and it travels from one point to another

1. A more convincing way to decide in which category light belongs is to find out if it takes time to get from the candle to your eye; in Newtonian physics, action at a distance is supposed to be instantaneous. The fact that we speak casually today of "the speed of light" implies that at some point in history, somebody succeeded in showing that light did not travel infinitely fast. Galileo tried, and failed, to detect a finite speed for light, by arranging with a person in a distant tower to signal back and forth with lanterns. Galileo uncovered his lantern, and when the other person saw the light, he uncovered his lantern. Galileo was unable to measure any time lag that was significant compared to the limitations of human reflexes.	2. An important issue that few people have considered is whether a candle's flame simply affects your eye directly, or whether it sends out light which then gets into your eye. Again, the rapidity of the effect makes it difficult to tell what's happening. If someone throws a rock at you, you can see the rock on its way to your body, and you can tell that the person affected you by sending a material substance your way, rather than just harming you directly with an arm motion, which would be known as "action at a distance." It is not easy to do a similar observation to see whether there is some "stuff" that travels from the candle to your eye, or whether it is a case of action at a distance.

3. Based on these measurements, Roemer estimated the speed of light to be approximately $2 \cdot 10^8$ m/s, which is in the right ballpark compared to modern measurements of $3 \cdot 10^8$ m/s. (I'm not sure whether the fairly large experimental error was mainly due to imprecise knowledge of the radius of the earth's orbit or limitations in the reliability of pendulum clocks).	4.Newtonian physics includes both action at a distance (e.g. the earth's gravitational force on a falling object) and contact forces such as the normal force, which only allow distant objects to exert forces on each other by shooting some substance across the space between them (e.g., a garden hose[1] spraying out water that exerts a force on a bush).
5. One piece of evidence that the candle sends out stuff that travels to your eye is that intervening transparent substances can make the candle appear to be in the wrong location, suggesting that light is a thing that can be bumped off course[2]. Many people would dismiss this kind of observation as an optical illusion, however. (Some optical illusions are purely neurological or psychological effects, although some others, including this one, turn out to be caused by the behavior of light itself).	6. The earth does not, however, stay at a constant distance from Jupiter and its moons[3]. Since the distance is changing gradually due to the two planets' orbital motions, a finite speed of light would make the "Io[4] clock" appear to run faster as the planets drew near each other, and more slowly as their separation increased. Roemer did find a variation in the apparent speed of Io's orbits, which caused Io's eclipses[5] by Jupiter to occur about 7 minutes early when the earth was closest to Jupiter, and 7 minutes late when it was farthest.
7. The first person to prove that light's speed was finite, and to determine it numerically, was Ole Roemer[6], in a series of measurements around the year 1675. Roemer observed Io, one of Jupiter's moons, over a period of several years. Since Io presumably took the same amount of time to complete each orbit of Jupiter, it could be thought of as a very distant, very accurate clock.	8. A practical and accurate pendulum clock had recently been invented, so Roemer could check whether the ratio of the two clocks' cycles, about 42.5 hours to 1 orbit, stayed exactly constant or changed a little. If the process of seeing the distant moon was instantaneous, there would be no reason for the two to get out of step[7]. Even if the speed of light was finite, you might expect that the result would be only to offset[8] one cycle relative to the other.

[1] garden hose – садовый шланг

[2] off course – в сторону от принятого курса

[3] moon – спутник планеты

[4] Io ['aɪəu] – Ио́ (один из спутников Юпитера)

[5] eclipse [ɪ'klɪps] – затмение

[6] Ole Christensen Römer (1644, Ärhus – 1710) was a Danish astronomer who in 1676 made the first quantitative measurements of the speed of light. In scientific literature alternative spellings such as "Roemer", "Römer", or "Romer" are common.

[7] get out of step – выпадать из синхронности, не соответствовать

[8] offset – компенсировать, уравновешивать

Task 2. Choose the correct definition for these words and expressions (underlined in the text):

Para 2:

to affect means (a) to make something happen, (b) to do something that produces an effect or change in something or in someone's situation, (c) to destroy or remove something;

send out means (a) to make something lose value, (b) to make a person or a group of people or things go from one place to various other places, (c) to broadcast or produce a signal, light, sound etc.;

Para 4:

to spray out means (a) to force liquid out of a container so that it comes out in a stream of very small drops and covers an area, (b) to become known about or used by more and more people, (c) to cover a large area;

Para 5:

a piece of evidence means (a) information that is given in a court of law in order to prove that someone is guilty or not guilty, (b) a way of finding out whether something is as good as people say it is, whether it works, or whether it is true, (c) facts or signs that show clearly that something exists or is true;

to bump off course means (a) to move something into a different direction, (b) to move up and down, (c) to hit or knock against something;

to dismiss means (a) to remove someone from their job, (b) to fail to hit or catch an object, (c) to refuse to consider someone's idea, opinion etc., because you think it is not serious, true, or important;

to turn out means (a) to happen in a particular way, or to have a particular result, especially one that you did not expect, (b) to move your body so that you are looking in a different direction , (c) to make or let someone or something go out from where they are;

Para 1:

a more *convincing* way means (a) friendly and pleasantly cheerful, (b) making you believe that something is true or right, (c) sudden, violent, and impossible to control;

to find out means (a) to get information, after trying to discover it or by chance, (b) to discover, see, or get something that you have been searching for, (c) to discover or learn something by study, tests, etc.;

to succeed in means (a) to continue to do something that has already been planned or started, (b) to be the next person to take a position or job after someone else, (c) to do what you tried or wanted to do;

to fail means (a) to not succeed in achieving something, (b) to move or drop down from a higher position to a lower position, (c) to go down to a lower level, amount, price etc.;

back and forth means (a) once again, (b) going out from a place or point, (c) going in one direction and then in the opposite direction, and repeating this several times;

Para 8:

pendulum means (a) a long metal stick with a weight at the bottom that swings regularly from side to side to control the working of a clock, (b) a special ability to understand things very clearly and completely, (c) the ability of a machine to always continue moving without getting energy from anywhere else, which is not considered possible;

Para 6:

to draw near means (a) to make someone notice something, (b) to approach, come closer, (c) to be similar to something;

Para 3:

a ballpark means (a) a field for playing baseball with seats for watching the game, (b) an idea, method, or quality that is typical of a particular person or thing, (c) a range of values.

Task 3. Combine the numbered and lettered words to obtain verb + noun word-combinations:

1) adjust	5) capture	a) the burden	e) a signal
2) provoke	6) justify	b) the high beams	f) the mirror position
3) pick out	7) face	c) different reactions	g) the headlights
4) remove	8) turns off	d) the use	h) a light source

Task 4. Combine the numbered and lettered words to obtain noun/adjective + noun word-combinations:

1) lightly used	7) rearview	a) car	g) roads
2) oncoming	8) windshield	b) wipers	h) accuracy
3) automatic	9) mirror	c) discharge lamps	i) CMOS imaging chip
4) headlamp-dimming	10) mercury-vapor	d) high-beam systems	j) mount
5) high	11) alternating	e) mirror	k) analysis
6) miniature	12) Fourier	f) system	l) current

Task 5. Read the text below and discuss the functioning of automatic high-beam systems.

High-beam[1] switcher recognizes cars

Driving at night on lightly used roads and having to face the headlights[2] of an oncoming car provokes different reactions in different people. Out of fear of annoying[3] the other driver, some never switch on their high beams in the first place. Others decide there is no better place for a game of chicken[4] and keep their own high beams blazing, waiting for capitulation. The most common reaction is a moderate underuse[5] of high beams, resulting in a subtle loss of safety – a US Department of Transportation study found that, on average, drivers use their high beams less than 25 % of the time during which conditions justify their use. Automatic high-beam systems have been developed that sense[6] oncoming headlights with a photodiode and then switch the car's beams from high to low, removing the burden of decision from the driver. Unfortunately, these systems also react to streetlights.

Now a headlamp-dimming system developed by Gentex Corp. (Zeeland, MI) relies on a complementary metal oxide semiconductor (CMOS) imaging sensor rather than a single photodiode, and can discriminate between oncoming headlights and other light sources with high accuracy. In addition, the forward-facing system senses taillights[7] up ahead, switching beams from high to low then back to high. The system responds faster than a human can – important when an oncoming car appears quickly over a rise.

A miniature CMOS imaging chip is at the heart of an automatic automobile high-beam control system. The chip, optics, and image-processing electronics are integrated into the car's rearview mirror. This location is roughly the same as that of the driver, has a view cleared by windshield wipers[8], and is protected from weather. A low-cost 16-bit microcontroller unit fits within the body of the mirror, while the sensor and inexpensive optics reside in the mirror mount, allowing the mirror position to be adjusted by the driver without changing the orientation of the sensor.

The system uses a variety of techniques to distinguish between relevant and irrelevant light sources. Although not full-color, the sensor does have color capability, differentiating between red (to identify taillights) and all other colors. To recognize and exclude streetlights, the system relies on the fact that sodium and mercury-vapor discharge lamps connected to the electricity grid run on 60-Hz alternating current, which produces a 120-Hz flicker. The

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[1] high beam – дальний свет фар

[2] headlights ['hedlaɪts] – передние фары

[3] annoy [ə'nɔɪ] – раздражать

[4] a game of chicken – игра в труса (игра, в которой два игрока осуществляют опасное действие, ведущее к негативному исходу)

[5] underuse [ʌndə'ju:z] – неполное использование

[6] sense – обнаруживать, реагировать на

[7] taillight ['teɪllaɪt] – задняя фара

[8] windshield ['wɪn(d)ʃi:ld] wipers – щётка стеклоочистителя, дворники

CMOS sensor's windowing capability – where a subset of pixels can be caused to capture a signal at an increased rate – comes into play[1] here. As described by Stam, the sensor and electronics pick out a light source and zoom in[2] on it with a 3 × 3 pixel window, imaging at 480 frames per second. A Fourier analysis done on the resulting signal looks for a 120-Hz frequency component; if it is present, the light source is deemed irrelevant.

To make the transition from low to high beams and back again more esthetically pleasing, the system slowly fades the high beams on and off. When an oncoming car appears over a hill or around a corner, the system overrides the fade and turns the high beams off instantly. Those night drivers playing high-beam games of dominance can thus turn their energies to some other endeavor – perhaps a calming breathing exercise to erase that last vestige of road rage.

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[1] come into play – начать действовать, вступать в действие; обнаружиться, проявиться

[2] zoom in on – увеличивать, детализировать изображение

Module 8
OPTICAL FIBRES

Texts:

A. Communication with lasers. Introduction
B. Optical fibre data transmission systems
C. Optical fibre video transmission systems
D. Optical fibre public telecommunication systems

Terminology A

communication system [kəˌmjuːnɪˈkeɪʃ(ə)n ˈsɪstəm] – система связи;
optical fibre [ˈɔptɪk(ə)l ˈfaɪbə] communication system – волоконно-оптическая система связи (ВОЛС);
metal-wire [ˈmet(ə)lˌwaɪə] communication system – кабельная система связи
propagation loss [ˌprɔpəˈgeɪʃ(ə)nˌlɔs] – потери при распространении
emitter [ɪˈmɪtə] – излучатель;
semiconductor light emitter – полупроводниковый излучатель света
to detect [dɪˈtekt] – обнаруживать, регистрировать;
detector [dɪˈtektə] – приемник;
semiconductor light detector – полупроводниковый приемник света
transmission capacity [trænzˈmɪʃ(ə)n kəˈpæsətɪ] – пропускная способность;
long-distance (long-haul [ˌlɔŋˈhɔːl]) transmission – передача на дальние расстояния
channel [ˈʧæn(ə)l] – канал
signal leakage [ˈsɪgn(ə)l ˈliːkɪʤ] – утечка сигналов, потеря сигнала
cross talk [ˈkrɔsˌtɔːk] – взаимные помехи, перекрёстная помеха
repeater [rɪˈpiːtə] – повторитель, репитер, ретранслятор, промежуточный усилитель

Word study

1. Underline prefixes and suffixes:

fundamental, summarize, reshape, freedom, mainly, optical, specific, configuration, bandwidth, capacity, immunity, realize, interconnection, development, voltage, exchange, harmful, classify, environment, noisy, relatively.

2. State what verbs these nouns are derived from:

conductor, oscillator, detector, repeater, amplifier, emitter, propagation, communication, connection, transmission, isolation, application, interference, distribution, information, modulation, classification, difference, introduction.

3. Translate the word combinations with nouns:

propagation loss, optical fibre communication system, semiconductor light emitter, metal-wire communication system, light detector, system's transmission capacity, low system channel cost, data path, signal leakage.

4. Choose the correct form of each word to complete the sentences that follow:

1) *relative*, *relatively*, *relationship*, *unrelated*
   In 1970 an optical fibre with _________ low propagation loss was developed.
2) *transmitter*, *transmit*, *transmission*, *transmitted*
   Repeaters are installed for long haul__________ in both systems.
3) *convert*, *converted*, *converting*, *conversion*
   In the repeater of optical fibre communication systems, optical signals are _______to electrical signals by the light detector.
4) *unamplified*, *amplified*, *amplifier*, *amplification*
   The electric signals _________by an electronic________are then applied to the light emitter.

Reading and discussion 1

5. Read Text 8A and discuss the questions on page 82.

Text 8A

COMMUNICATION WITH LASERS. INTRODUCTION

Continuous wave oscillation of a semiconductor laser at room temperature was achieved in 1970, the same year in which an optical fibre with relatively low propagation loss was realized. Since then marked progress has been made in the development of optical fibre communication systems, including semiconductor light emitters and detectors, optical fibres and cables, and interconnections, as well as system concepts.

The fundamental configuration of an optical fibre communication system is compared with that of a metal-wire communication system. The main three components in optical fibre communication systems, namely the light emitter, the optical fibre, and the light detector, correspond to the oscillator, the metal-wire or cable, and the detector in metal-wire communication systems, respectively.

Repeaters are installed for long-haul transmission in both systems. In the repeater of optical fibre communication systems, optical signals are converted to electrical signals by the light detector after propagation in the optical fibre. The electrical signals amplified with the electronic amplifier are then applied to the light emitter. Thus, the optical signals are emitted from the repeaters which are reshaped to the original waveform. The advantages of the optical fibre communication system are summarized as follows, compared with the metal-wire communication system based mainly on the specific features of optical fibres, semiconductor light emitters, and semiconductor light detectors:

– smaller size and lighter weight;
– wider bandwidth with lower propagation loss;
– longer distance between repeaters;
– higher transmission capacity in system;
– lower system cost per channel;
– electrical isolation of output from input in data paths;
– immunity to electromagnetic interference;
– freedom from signal leakage and cross talk.

Questions to Text 8A.

1. When was the continuous wave oscillation of a semiconductor laser achieved? At what temperature?
2. What advances have been made in the development of optical fibre communication systems since 1970?
3. What are the main components of an optical fibre communication system? What parts of metal-wire communication systems do these components correspond to?
4. What is the function of a repeater?
5. Describe the functioning of an optical fibre communication system.
6. What are the advantages of an optical fibre communication system compared with a metal-wire communication system? What are these mainly based on?

Increase your vocabulary

6. Match the expressions on the left with those on the right:

1) соответственно	a) at room temperature
2) следующим образом	b) since this time
3) в обеих системах	c) the electrical signals amplified
4) помехи	d) namely
5) усиленные электрические сигналы	e) respectively
6) с этого времени	f) in both systems
7) а именно	g) as follows
8) при комнатной температуре	h) mainly
9) главным образом	i) cross talk

7. Read the following statements and say whether they are true or not. Correct the false ones.

1. Since 1970, marked progress has been made in the development of metal-wire communication systems, including semiconductor light emitters and detectors, etc. 2. Repeaters are installed for long-haul transmission in both systems. 3. In optical fibre communication systems the electrical signals amplified with the electronic amplifier are applied to the oscillator. 4. Optical fibre communication systems are not free from signal leakage and cross talk.

8. Study the following items of Text 8A's plan and reorder them according to the text.

1. The functioning of an optical fibre communication system.
2. The advantages of an optical fibre communication system.
3. The main components of the system.
4. Progress in the development of optical fibre communication systems.
5. The fundamental configuration of an optical fibre communication system compared with a metal-wire communication system.

Terminology B

data ['deɪtə trænz'mɪʃ(ə)n 'sɪstəm] transmission system (data highway ['haɪweɪ] system) – система передачи данных (магистральная шина передачи данных, магистраль передачи данных)

cable ['keɪbl] – кабель;

electric power cable [ɪ'lektrɪk ˌpauə 'keɪbl] – электрический кабель;

high voltage electric power cable [ˌhaɪ 'vəultɪʤ ˌpauə 'keɪbl] – высоковольтный электрический кабель

long-distance communication system [ˌlɔŋ'dɪst(ə)ns kəˌmjuːnɪ'keɪʃ(ə)n 'sɪstəm] – система связи на большие расстояния

terminal ['tɜːmɪn(ə)l] – терминал;

terminal node ['tɜːmɪn(ə)l ˌnəud] – вывод терминала, концевая вершина

high (low) bit rate ['bɪtˌreɪt] – высокая (низкая) скорость передачи информации

main highway loop ['haɪweɪˌluːp] – основная коммуникационная сеть компьютера

Word study

9. Give as many derivatives of the following words as you can:

possible, different, advantage, noise, transmit, electric, compute, apply, class, relate, leak, wide, distant, origin, amplify, communicate, transmit, volt, power, specify, require, harm, require.

10. Translate the word combinations with nouns:

transmission system, data transmission system, electric power cable, high-voltage electric power cable, communication system, long-distance communication system, data highway system, optical fibre data highway system, short-distance paths, main highway loop.

11. Choose the correct form of each word to complete the sentence that follows:

1) *specific*, *specifically*, *specified*, *special*
   Optical fibre communication systems are ___________ advantageous in plant control.
2) *immunity*, *immune*, *immunize*, *immunization*
   Optical fibre communication systems are __________to electromagnetic interference.
3) *advantage*, *advantageous*, *disadvantage*, *disadvantageously*
   Optical fibre communication systems are___________ in data highway systems.

4) *requirement*, *required*, *require*, *requiring*

Semiconductor lasers are applied in the main highway loop ________ a relatively high bit rate and long-distance transmission.

Reading and discussion 2

12. Read Text 8B and answer the questions below.

Text 8B

OPTICAL FIBRE DATA TRANSMISSION SYSTEMS

Data transmission systems are classified into two main types: control systems and computer systems. For control systems, optical fibre communication systems are specifically advantageous in plant control, where metal-wire communication systems suffer from severe electromagnetic interference arising from high-voltage electric power cables or from harmful environment. Since the optical fibre communication system is immune to electromagnetic interference, it is possible to lay optical fibre cables for data transmission close to high-voltage electric power cables. Semiconductor lasers make it possible to realize a long-distance communication system.

For computer systems, optical fibre communication systems are advantageous in data highway systems, where metal-wire communication systems suffer from noise and difference of ground potentials. Data highway systems involve a relatively high bit rate and long-distance transmission, a large amount of data being exchanged through many terminal nodes. Since the output and the input are isolated electrically in data paths, optical fibre data highway systems are advantageous. Semiconductor lasers are applied in the main highway loop requiring a relatively high bit rate and long-distance transmission) Light-emitting diodes are applied to low bit rate, and short-distance paths between the terminal and the terminal node.

1. What are two main types of data transmission systems?
2. Why are optical fibre communication systems more advantageous in plant control than metal-wire communication systems?
3. Why is it possible to lay optical fibre cables for data transmission close to high-voltage electric power cables?
4. What makes optical fibre communication systems advantageous in data highway systems?
5. What type of laser is used in the main highway loop?

13. Read the following statements and say whether they are true or not according to Text 8B. Correct the false ones.

1. There are two main types of data transmission systems: control systems and computer systems.
2. For control systems metal-wire communication systems are specifically advantageous in plant control.
3. Optical fibre communication systems are immune to electromagnetic interference.
4. It is impossible to lay optical cables for data transmission close to high-voltage electric power cables.
5. Data highway systems involve a relatively low bit rate and short-distance transmission.

14. Study the following items of Text 8B's plan and reorder them according to the text.

1. The application of optical fibre communication systems in data highway systems. 2. The main types of data transmission systems. 3. The advantages of optical fibre communication systems over metal-wire communication systems for control systems. 4. The application of optical fibre communication systems for control purposes. 5. The advantages of optical fibre communication systems over metal-wire communication systems for computer systems.

15. Read Text 8C and answer the following questions.

1. What are the advantages of optical fibre ITV systems?
2. In what way do CATV systems operate?
3. Why is optical fibre more advantageous in this application than metal-wire systems?

Text 8C

OPTICAL FIBER VIDEO TRANSMISSION SYSTEMS

Optical fibre video transmission systems are applied to industrial television (ITT) and CATV systems. Generally, analogue modulation is preferred in short-distance transmission for economic reasons. However, digital modulation is applied in long-distance transmission because of reduced problems on noise and linearity.

The advantages of optical fibre ITV systems are the same as those of optical fiber plant control systems mentioned in Text B.

In CATV systems, cables tend to be laid under harmful environments. When broadcasting TV information in some cases microwave signals are received by an antenna at the top of a mountain. Signals are transmitted to a station in a city from where they are distributed to subscribers[1]) Metal-wire systems are damaged occasionally by lightning[2]. However, optical fibre communication systems are free from such damage because the optical fibre is an electric insulator, as mentioned above.

Optical fibre CATV systems using semiconductor lasers allow economical system operation in thinly populated and large area districts because the number of repeaters is decreased by at least an order of magnitude due to the low propagation loss of optical fibres.

High-density optical signal transmission is realized using semiconductor lasers. Several TV channels are transmitted using a semiconductor laser and a single optical fibre.

16. Translate Text 8D in writing.

Text 8D

OPTICAL FIBER PUBLIC TELECOMMUNICATION SYSTEMS

Telecommunication systems consist of a subscriber loop, an intra-city network or an inter-city network, and an international network.

Generally, the information density is relatively low in a subscriber loop. However, intra-city and inter-city networks require relatively high bit rates and long-distance transmission spans, so optical fibre telecommunication systems with semiconductor lasers are preferred. When more telecommunication channels are required in a metropolis[3], the optical fibre telecommunication system is quite effective because a large number of optical fibres can be installed by withdrawing an existing metal-wire cable from a duct. Long-distance telecommunication systems have practical advantages in terms of economy and maintenance.

In submarine systems, which require ultimately high reliability, it is quite important to reduce the number of repeaters. Long repeater spacings ranging from 20 km to 50 km can be implemented in optical fibre submarine systems and a single-mode fibre. Thus, there is hope of optical fibre international telecommunication systems to appear soon. Optical fibre submarine systems without a repeater are also effective for telecommunication between a remote island and a big city or between remote islands.

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1 subscriber [səb'skraıbə] – абонент

2 lightening ['laıtənıŋ] – молния

3 metropolis [mə'trɔpəlıs] – крупный город

Review

17. Group the following sentences according to topics A, B or C.

A. Optical fibre communication systems. Configuration and operation.
B. The applications of optical fibre communication systems.
C. Metal-wire communication systems and their disadvantages.

1. These systems are occasionally damaged by lightning.
2. Since this system is immune to electromagnetic interference, it is possible to lay cables for data transmission close to high-voltage electric power cables.
3. The main three components of this system are the light emitter, the optical fibre, and the light detector.
4. When used for control these systems suffer from severe electromagnetic interference.
5. The electrical signals amplified with the electronic amplifier are then applied to the light emitter.
6. Submarine systems without a repeater are also effective for telecommunication between remote islands.
7. The main components of this system are the oscillator, the metal wire or cable, and the detector.
8. These systems are free from the damage by lightning because of the fibre's being an electric insulator.
9. Optical signals are emitted from the repeater and are reshaped to the original waveforms.
10. Long-distance telecommunication systems have practical advantages in terms of economy and maintenance.
11. In the repeater optical signals are converted to electric signals by the light detector.
12. When used in computer systems they suffer from noise and the difference of ground potentials.

18. Use exercise 17 to speak on one of the topics above.

19. Make a PowerPoint presentation on one of the topics above.

20. Translate the abstract below into English. Use the following words and word-combinations:

air communication, *to show superior characteristics*, *through the air*, *atmospheric disturbances*, *to cover a wide area*.

При использовании в ВОЛС наилучшие характеристики даёт полупроводниковый лазер. В открытых линиях связи, в которых лазерный луч проходит через атмосферу, для уменьшения влияния атмосферных искажений требуется большая оптическая мощность. Поэтому применяются мощные полупроводниковые лазеры, а также газовые и твердотельные лазеры с внешним модулятором. Оптическая связь с помощью лазеров занимает важное место в области связи.

Supplementary reading tasks

Task 1. Arrange the paragraphs of the text below in a logical order.

Production of fiber lasers in Russia

1. IRE-Polus develops and manufactures fiber lasers and amplifiers, optical components, modules, instruments, subsystems, and systems for fiber, atmospheric, and free-space optical communication; cable television; optical radar; remote control of industrial objects and atmospheres; industrial complexes for laser welding, tempering, thermal processing, and marking; control and measurement systems; sensors; scientific research; surgery; and biomedicine.	2. Fiber lasers offering a broad range of power (from 5 watts to 50 kilowatts) are gradually replacing gas and many solid-state lasers. A diode pump and nano-structured fiber make it possible to reach high output power, gain and efficiency factor of up to 30 percent in commercial production, and reduce cost of ownership up to 50 percent.
3. IRE-Polus is expected to earn most of its income under the project from sales of high-power fiber amplifiers and lasers with broad applications and from telecommunications equipment. The company will manufacture communications systems that use proprietary fiber optic technology: 40-Gbps DWDM-transponders, reconfigurable optical multiplexers, optical amplifiers, multiport 10-Gbps multiplexer/transponders, and other communications equipment.	4. The Russian Corporation of Nanotechnologies will invest in expansion of Russian production of advanced fiber lasers for cutting, welding, deposition, and engraving of metal items and high-technology telecommunications equipment for long-distance trunk communication at IRE-Polus, a subsidiary of US-based IPG Photonics Corporation.
5. "This is our first partnership with a US listed company. The technology used in the project is a great breakthrough. Its power, compactness, and low cost of ownership open doors to more and more new applications for fiber lasers. Already they can be used in solar batteries, medicine and electronics. Domestic production of laser complexes based on these innovations will enable Russia to refit strategic sectors — telecommunications, mechanical engineering, and medicine with the latest equipment and instruments," said RUSNANO managing director Konstantin Demetriou.	6. Founded by Russian scientists, IPG Photonics Corp. has, over the last five years, become the world leader in high-performance fiber lasers and amplifiers and systems based on them.

Task 2. Sum up the contents of the text in Task 1.

Task 3. Match the following words and word-combinations with their definitions in the right-hand column:

1) by extension	a) a countless or extremely great number of people or things
2) available	b) able to be used or obtained; at someone's disposal
3) workstation	c) having or involving several parts, elements, or members
4) multiple	d) the place to which someone or something is going or being sent
5) ubiquitous	e) receive or detect something
6) myriad	f) taking the same line of argument further
7) destination	g) by hand
8) pick up	h) able to adapt or be adapted to many different functions or activities
9) manually	i) present, appearing, or found everywhere
10) versatile	g) a desktop computer terminal, typically networked and more powerful than a personal computer

Task 4. Read the text below and discuss advances in optical fiber technology.

New sources and fibers combine to deliver flexible fiber-optic lighting

Using optical fibers as a light source is a convenient way to get light to where it is needed. And by extension, those same fibers can be used for picking up reflected light and transporting it to various sensing elements for analysis. Although the principles of "light guides" were already known in the mid-19th century, practical applications would have to wait until the late 1950s when glass fibers (mostly borosilicate with a bandwidth from 400 nm to 1.5 μm and 50 μm diameter) became available in volume and at reasonable prices.

The first applications focused on bundling fibers to get light "from A to B" by means of a flexible optical connection between a light source such as an incandescent lamp to its destination – a workstation, microscope stage[1], or a readout array for a punched card in "Hollerith" card readers[2]. The advantages of optical-fiber-based illumination are obvious: "cold" and very well defined, shadowless ringlights[3] with mechanically flexible (gooseneck) positioners for workstations instead of warm/hot incandescent-lamp-based illumination. For early computer peripheral applications, then dominated by ancient technologies such as card- and paper-tape-based input/output technology, the concept of feeding light from a central light source to multiple locations precisely where needed was embraced because the miniature incandescent light arrays used in such applications had unpredictable aging rates[4], did not last very long, and were difficult to service.

Marks on cards could be read easily by guiding the light reflected from a card or sheet of paper back to a sensor through a second bundle integrated with the light-carrying fibers, very close to the surface with the mark. The light footprint of the probe could be shaped geometrically to optimize the contrast obtained between a mark and a space, such as a skinny rectangle. Moreover, marks could be printed or manually applied such as in the ubiquitous "Scantron" readers.

As a result of these successes, various illumination and reflective probe schemes found their way into myriad applications and a versatile and thriving fiber-optic manufacturing base developed. The light-emitting diodes (LEDs) that appeared later on the scene turned out to be perfect companions, amplifying the usefulness and versatility of light guides.

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1 microscope stage ['maɪkrəskəupˌsteɪʤ] – предметный столик микроскопа
2 card reader ['kɑːdˌriːdə] – устройство считывания перфокарт
3 ringlight ['rɪŋlaɪt] – кольцевой светильник
4 aging rate ['eɪʤɪŋˌreɪt] – скорость старения

Module 9
HOLOGRAPHY

Texts:

A. Fundamentals of holography
B. Recording and reconstruction processes
C. Denisyuk's discovery
D. Holographic information storage

Terminology A

holography [hɔ'lɔgrəfɪ] – голография, получение голограмм
three-dimensional image [ˌθriːdɪ'menʃ(ə)n(ə)l 'ɪmɪʤ] – трехмерное изображение
optical scene [ˌɔptɪk(ə)l 'siːn] – оптический объект, картина
photographic technique [ˌfəutə'græfɪkˌtek'niːk] – фототехника
photographic emulsion [ˌfəutə'græfɪk ɪ'mʌlʃ(ə)n] – фотоэмульсия
irradiance [ɪ'reɪdɪəns] – излучение, облучение, интенсивность излучения
electric field intensity [ɪ'lektrɪk ˌfiːld ɪn'tensətɪ] – напряжённость электрического поля
object beam [ˌɔbʤɪkt 'biːm] – объектный луч, объектный пучок
converging lens [kənˌvɜːʤɪŋ'lenz] – конвергирующая линза, собирающая линза
development [dɪ'veləpmənt] – зд.: проявление, проявка
transparency [træn'spær(ə)nsɪ] – прозрачность; прозрачная плёнка; коэффициент пропускания

Word study

1. Underline the suffixes:

viability, emulsion, reference, researcher, diffusiveness, referable, radiant, exposed, dimensional, diffusive, commonly, uniformly, quietly, directly, obscurely, efficiently.

2. In eachh grooup find the word that doesn't belong:

a) creatively, distinctly, separately, obscurely, uniformly, quietly, invariably, conventionally, virtually, commonly;
b) emulsion, development, variation, observant, distinction, separation, application, displacement, exposure.

3. Complete the table using a dictionary if necessary.

Verb	*Noun(s)*	*Adjective(s)*	*Adverb*
research			
		complete	
			transparently
develop			
	variation		
		distinct	
	displacement		
arrange			
		observant	
			separately
	applicability		
		creative	

4. Choose the correct form of each word to complete the following sentences:

1) *creation*, *creator*, *creating*, *creative*
A hologram can be considered to be an optical device capable of _________ three-dimensional images.

2) *expose*, *exposure*, *exposed*, *exposer*
In real-time holographic interferometry the photographic plate after development is placed back in the same position it occupied during _____________.

3) *converge*, *converging*, *convergence*, *convergent*
In conventional photography a ____________ lens is used for focusing the light reflected from a scene.

Reading and discussion 1

5. Read Text 9A and answer the questions below.

Text 9A
FUNDAMENTALS OF HOLOGRAPHY

Dennis Gabor[1] published the first papers on holography in 1948. From 1948 through 1960 progress in the use and development of holography was slow because researchers working in this discipline did not have a light source available that could produce intense light with a long coherence length. Emmett Leith[2] and Juris Upatnieks[3] working at the University of Michigan Institute of Science and Technology in the early 1960s produced the first holograms using a laser. In doing so Leith and Upatnieks transformed holography from an obscure concept to a viable scientific and engineering tool. In 1965 Powell and Stetson published the first paper on holographic interferometry. Dennis Gabor received the Nobel Prize in physics for his work in 1972.

For our purposes, a hologram can be thought of as an optical device produced by using photographic techniques and laser light that is capable of creating three-dimensional images. The word *hologram* stems from the Greek root “holos”, which means whole, complete, or entire, and “gram”, which means message. Thus a hologram is a complete record of an optical scene. In conventional photography the light reflected from a scene is focused – using a converging lens system – onto photographic emulsion. Variation of the irradiance due to the image being focused on the emulsion is related only to the electric field intensity amplitude of the light. In holography photographic emulsion, usually on a glass plate, is exposed to an interference pattern produced by two coherent laser beams. One beam called the object beam is reflected from an object or scene to the photographic emulsion. The other beam called the reference beam is reflected directly from the laser to the photographic emulsion by using mirrors. Using this technique both the amplitude and the phase information about the electric field due to the light reflected from the scene can be recorded. After photographic development the resulting transparency is a hologram. By shining laser light – in some cases, white light – through a hologram, three-dimensional images can be produced.

1. Who was the inventor of holography? 2. Why couldn't Dennis Gabor produce a hologram in 1948? 3. What source of light was used to produce the first holograms? 4. How was D. Gabor's work appreciated? 5. What does the

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[1] *Dennis Gabor* (1900 – 1979) was a Hungarian-British electrical engineer and physicist, most notable for inventing holography, for which he later received the 1971 Nobel Prize in Physics.

[2] *Emmett Leith* (1927 – 2005) was a professor of electrical engineering at the University of Michigan and, with Juris Upatnieks of the University of Michigan, the co-inventor of three-dimensional holography.

[3] *Juris Upatnieks* (born 1936 in Riga) is a Latvian-American physicist and inventor, and pioneer in the field of holography.

word "hologram" mean? What is the origin of this word? 6. What is the difference between recording images by conventional photography and holography? 7. How are three-dimensional images produced?

Increase your vocabulary

6. Match the parts of sentences in the two columns below to produce true statements.

1. Holography is a way of	a) complete or entire message
2. A hologram is a device	b) recording and then reconstructing waves
3. The word "hologram" means	c) both about its amplitude and its phase
4. The physical foundation of holography is	d) the reference beam
5. A beam reflected from the laser to the photoemulsion is called	e) the science of waves, their interference and diffraction
6. Holography records complete diffraction information about a wave	f) capable of creating three-dimensional images

7. Read the following sentences and say whether they are true or not. Correct the false ones.

1. Holography was invented in 1948 by Professor Dennis Gabor, 1972 Nobel Prize winner. 2. Using a laser as a source of light he ran his experiments in the Research Laboratory in England. 3. Since then, holography began to develop at a very rapid rate. 4. A hologram just like conventional photography regenerates not a two-dimensional image of an object but the field of the wave which it scatters. 5. Emulsion in holography is exposed to an interference pattern produced by two coherent laser beams. 6. The beam reflected from an object or scene to the photoemulsion is called a reference beam.

8. Make sentences by matching the dates with the events listed in the text:

1) in 1948	a) first holograms
2) from 1948 through 1960	b) photographic interferometry
3) in the early 1960s	c) the first papers on holography
4) in 1965	d) the Nobel Prize
5) in 1972	e) slow development of holography

9. Rewrite the sentences to make a logical paragraph.

In holography photographic emulsion is exposed to an interference pattern produced by two coherent laser beams. Thus it is a complete record of an optical scene. By shining laser light we see the object from different angles sensing its three-dimensional and realistic nature. The word "holography" originates from the Greek "holos" meaning *the whole*. These are the object beam and the reference one. Thus it is a complete record of an optical scene.

Terminology B

to mount [maunt] – устанавливать, монтировать, закреплять на плоской поверхности, собирать
split [splɪt] – расщеплять; splitter [ˈsplɪtə] – расщепитель
pinhole [ˈpɪnhəul] – пиксель, точечная диафрагма, отверстие
bias [ˈbaɪəs] – смещать
spatial filter [ˈspeɪʃ(ə)l ˈfɪltə] – пространственный фильтр, фильтр пространственных частот
amplitude transmittance [ˈæmplɪt(j)uːd trænzˈmɪtəns] – коэффициент пропускания
quiescent point [kwɪˈes(ə)ntˌpɔɪnt] – рабочая (неподвижная) точка
exposure curve [ɪkˈspəuʒəˌkɜːv] – характеристическая кривая
virtual image [ˌvɜːtʃuəl ˈɪmɪʤ] – мнимое изображение
real image [ˌrɪəl ˈɪmɪʤ] – действительное изображение

Word study

10. Give as many derivatives of the following words as you can:

transit, space, finite, quiet, curve, unify, photo, image, consider, develop, reflect, observe.

11. Give more examples of each prefix meaning:

not (in-, un-, im-, ir-): inappropriate, incalculable, unnecessary, irrelevant, improbable...
again (re-): reassure, recover, refresh...
without (dis-): disability, disbelief, disorder...

12. Choose the correct word to complete the sentences that follow:

1) *split*, *splitter*, *splitting*, *splitted*
By means of a beam __________ the laser beam is divided into two different beams.

2) *dust*, *duster*, *dusty*, *dustiness*
The rings and stripes a hologram often contains are due to the diffraction of light on particles of _________ getting onto the mirrors.

3) *scatter*, *scattering*, *scattered*, *scatterer*
The colour of the sky is due to the small amount of sunlight __________ by molecules of air.

4) *virtual*, *virtualization*, *vitality*, *virtually*
Apparently, images from which the light is diverging are termed __________ images.

Reading and discussion 2

13. Read Text 9B and answer the questions on ***page 98.***

Text 9B

RECORDING AND RECONSTRUCTION PROCESSES

Recoding process

All the optical elements used in the production of optical holograms are mounted on an essentially vibration-free surface. Usually a heavy table with a steel or granite top isolated from floor vibration by air tubes provides this surface. A continuous or pulsed laser operating in the TEM_{00} mode at a wavelength within the visible portion of the electromagnetic spectrum is used for holography. Pulsed ruby lasers are used to produce holograms of transient phenomena or when vibration is a problem.

To produce a hologram a laser beam is first split into two teams by a beam splitter. The reference beam is reflected by a mirror and then spread by a converging lens to illuminate uniformly a photographic emulsion on a glass plate. The object beam is spread by a converging lens and then reflected to the object by a mirror so that the object is uniformly illuminated as seen from the position of the photographic plate. Pinholes are used in the focal planes of the converging lenses as spatial filters to remove optical noise from the laser beams. The optical noise is primarily due to light scattered by dust and flaws on the optical element surfaces. Maximum coherence of the two beams at the photographic plate is obtained by making the object and reference beams of equal length.

It is desirable that objects used in holography have diffusive surfaces. Flat white paint is often used to give industrial parts uniform diffusive surfaces. When illuminated, each point on these surfaces will act as point sources scattering light in all possible directions. Thus optical information about every point on the object facing the photographic plate can be recorded on an infinite number of points on the photographic emulsion.

To obtain a linear recording, the emulsion is “biased” to establish a quiescent point in the linear portion of the transmittance versus exposure curve. By making a linear recording it can be assumed that the amplitude transmittance of the emulsion after development is a linear function of the irradiance incident on the emulsion during exposure. That is, $t = t_0 + \beta(I_0 + U_gU_0/2z + U_gU_0/2z)$, where t_0 is the “bias” transmittance established by the reference beam and β is the product of the slope of the transmittance versus exposure curve at the quiescent point and the exposure time.

Reconstruction

Holograms produced by using the optical system described above can be used to form virtual and real images. To “play back” a virtual image a reconstruction beam is used that is identical to the reference beam used in the production of the hologram. In most industrial applications a laser is used for reconstruction. When a reconstruction beam, which is identical to the reference beam, is used to illuminate the hologram, much of the light passes straight through the hologram. Some light is diffracted by the fringes recorded in the emulsion due to its exposure to the reference pattern produced by the object and reference beams.

An observer viewing the diffracted light will see a virtual image of the object in space behind the hologram. This image is three-dimensional and in the same location as the object relative to the emulsion. The image will appear to be the same as if the observer were looking at the original object illuminated by the light used for reconstruction through a window the size of the hologram.

Questions to Text 9B.

1. Why is it necessary to mount all optical elements used in producing a hologram on a vibration-free surface? 2. What kind of laser is commonly used in holography? 3. Why is it desirable that objects used in holography have diffusive surface? 4. What kind of material is used to make such surfaces? 5. Under what conditions is maximum coherence of the two beams obtained? 6. How is linear recording obtained?

Review

14. Match the parts of sentences in the two columns below to produce true statements.

1. For producing a hologram all optical elements are mounted	a) pulsed ruby lasers are used to produce holograms
2. In case of vibration	b) pinholes are used in the focal planes of lenses as spatial filters
3. To remove optical noise from the laser beams	c) its exposure to the interference pattern
4. Optical information about every point on the object can be recorded	d) on a heavy table providing vibration-free surface
5. In reconstructing a hologram some light is diffracted by the fringes recorded in the emulsion due to	e) on an infinite number of points on the photographic emulsion

15. Read the following sentences and say whether they are true or not. Correct the false ones.

1. In order to provide a vibration-free surface all elements used to produce holograms are mounted on a heavy table. 2. Pulsed ruby lasers are commonly used for holography. 3. As a result of splitting a laser beam both the reference beam and the object beam are reflected by a mirror simultaneously. 4. Diffusive surfaces of objects are provided by thick layers of a silver halide. 5. Before and after development the light amplitude transmittance of the emulsion is identical. 6. To reconstruct a real image a reconstruction beam opposite the reference beam is used to illuminate the hologram. 7. To reconstruct a virtual image a collimated reconstruction beam is used.

16. Read Taxt 9C and answer the following questions.

1. What are Lippmann layers? 2. What contribution into holography was made by Yu. Denisyuk? 3. Think of a good title for the text.

Text 9C

DENISYUK'S DISCOVERY

In 1962, just before the "holography explosion" the Russian physicist Yu.N. Denisyuk[1] published an important paper in which he combined holography with the ingenious method of photography in natural colours, for which Gabriel Lippmann[2] received the Nobel Prize in 1908. Lippmann produced a very fine-grain emulsion with colloidal silver bromide and backed the emulsion with mercury serving as a mirror, light falling on the emulsion was reflected at the mirror, and produced a set of standing waves. Colloidal silver grains were precipitated in the maxima of the electric vector in layers spaced by nearly half a wavelength. After development, when the complex of layers illuminated with white light reflected only a narrow waveband around the original colour did the wavelets scattered at the Lippmann layers add up in phase.

Denisyuk's suggestion is as follows. The object wave and the reference wave fall in from opposite sides of the emulsion. Again standing waves are produced in Lippmann layers, but these are no longer parallel to the emulsion surface, they bisect the angle between the two wavefronts. If now, and this is Denisyuk's principle, the developed emulsion is illuminated by the reference wave, the object will appear in the original position and (unless the emulsion has shrunk. in the original colour.

Though Denisyuk showed considerable experimental skill, lacking a laser in 1962 he could produce only an "existence proof". A colour reflecting hologram which could be illuminated with white light was first produced in 1965 by G.V. Stroke and A. Labeyrie.

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[1] *Yuri Nikolaevich Denisyuk* (1927–2006) was a Soviet physicist known for his contribution to holography, in particular for the so-called "Denisyuk hologram".

[2] *Jonas Ferdinand Gabriel Lippmann* (1845–1921) was a Franco-Luxembourgish physicist and inventor, and Nobel laureate in physics for his method of reproducing colours photographically based on the phenomenon of interference.

17. Translate text 9D in writing.

Text 9D

HOLOGRAPHIC INFORMATION STORAGE

The application of holography which is certain to gain high importance in the next years is information storage. Holography allows storing 100–300 times more printed pages in a given emulsion than ordinary microphotography. Even without utilizing the depth dimension the factor is better than 50. The reason is that a diffused hologram represents almost ideal coding, with full utilization of the area and of the gradation of the emulsion, while printed matter uses only about 5–10% of the area, and the gradation not at all. A further factor arises from the utilization of the third dimension, the depth of the emulsion. This possibility was first pointed out in an ingenious paper by P.J. van Heerden in 1963.Theoretically it appears possible to store one bit of information in about one wavelength cube. This is far from being practical but the figure of 300 previously mentioned is entirely realistic.

However, even without this enormous factor, holographic storage offers important advantages. A binary store, in the form of a checkerboard pattern on microfilm can be spoiled by a single grain of dust, by a hair or by a scratch, while a diffused hologram is almost insensitive to such defects. The holographic store is according to its author L.K. Anderson (1968) only a modest beginning, yet it is capable of accessing, for instance, any one of 64 x 64 printed pages in about a microsecond. Each hologram, with a diameter of 1.2 mm can contain about 104 bits. Reading out this information sequentially in a microsecond would of course require an impossible waveband but powerful parallel reading means can be provided. One can confidently expect enormous extensions of these “modest beginnings” in the near future.

18. Render the text given below in English. Use the following words:

to improve, *resolving power*, *to assume*, *considerable*, *unperturbed*, *to be neglected*

В 1947 г. Габор заинтересовался электронной микроскопией. Пытаясь усовершенствовать разрешающую способность электронного микроскопа, он предложил метод получения оптического изображения. Объект освещается когерентной волной. Предполагается, что объект находится в таком состоянии, что значительная часть волны проникает через него невозмущенной. Это означает, что, если волну выразить в виде суммы падающей и дифракционной волны, рассеяние последней незначительно.

19. Make a PowerPoint presentation on holography.

Supplementary reading tasks

Task 1. Think of possible applications of holography and compare your ideas with the applications in the text below.

Applications of holography

A hologram can be made not only with the light waves of a laser, but also with sound waves and other waves in the electro-magnetic spectrum. Holograms made with X-rays or ultraviolet light can record images of particles smaller than visible light, such as atoms or molecules. Microwave holography detects images deep in space by recording the radio waves they emit. Acoustical holography uses sound waves to "see through" solid objects. Holography's unique ability to record and reconstruct both light and sound waves makes it a valuable tool for industry, science, business, and education. The following are some applications:

- A telephone credit card used in Europe has embossed surface holograms which carry a monetary value[1]. When the card is inserted into the telephone, a card reader discerns[2] the amount due and deducts[3] (erases. the appropriate amount to cover the cost of the call).
- Supermarket scanners read the bar codes[4] on merchandise for the store's computer by using a holographic lens system to direct laser light onto the product labels during checkout[5].
- Holography is used to depict the shock wave made by airfoils to locate the areas of highest stress. These holograms are used to improve the design of aircraft wings and turbine blades[6].
- Holography is ideal for archival recording of valuables or fragile museum artifacts[7].
- The arrival of the first prototypical optical computers, which use holograms as storage material for data, could have a dramatic impact on the overall holography market. The yet-to-be-unveiled optical computers will be able to deliver trillions of bits of information faster than the current generation of computers.
- Independent projects at IBM and at NASA's Jet Propulsion Laboratory have demonstrated the use of holograms to locate and retrieve information without knowing its address in a storage medium, but by knowing some of its content.
- Facial surgery[8] and forensic science[9] are benefiting from a portable holography system that can capture the shape and texture of faces in an instant) Following chemical development, the hologram is digitized to create a three dimensional computer model that is an exact replica of the patient's face. The model is then used to aid surgical planning or forensic science investigations.

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[1] monetary value [ˌmʌnɪt(ə)rɪ 'væljuː] – сумма денег на карте
[2] discern [dɪ'sɜːn] – распознавать, определять
[3] deduct [dɪ'dʌkt] – вычитать, удерживать, списывать
[4] bar code ['bɑːˌkəud] – штриховой код
[5] checkout ['ʧekaut] – расчёт
[6] turbine blade ['tɜːbaɪnˌbleɪd] – лопасть турбины, лопатка турбины
[7] fragile museum artifacts ['fræʤaɪl mjuː'ziːəm 'ɑːtɪfækts] – хрупкие музейные экспонаты
[8] facial surgery [ˌfeɪʃ(ə)l 'sɜːʤ(ə)rɪ] – пластическая хирургия лица
[9] forensic science [fəˌrensɪk 'saɪəns] – судебная наука, судебная экспертиза

- Imagine being able to record 100 movies on a disk the size of a CD – or one day recording the contents of the Library of Congress on such a disk. These are the promises of holographic data storage.
- A unique holographic teaching resource which captures mouth shapes in 3D has been developed by experts at De Montfort University (DMU) in Leicester and could become a vital tool for speech therapists[1].

Task 2. Read the text that follows to find out the purposes and prospects of the SHIVA experiment.

Space holography used for real-world science

A holographic technique intended for[2] use in space has recently demonstrated the existence and behavior of a force called the history drag – a phenomenon predicted in 1887, but never before observed directly. The measurements were performed by researchers at MetroLaser (Irvine, CA) as part of a program called Spaceflight Holography Investigation in a Virtual Apparatus (SHIVA). The research was intended to allow scientists on the ground to control and monitor microgravity experiments in space, thus reducing the number of people required to staff missions[3].

In a holographic setup for the SHIVA history-drag experiment, a 10-mW HeNe-laser beam is diffracted by particles in an oscillating chamber, and the resulting patterns are acquired for further processing by a 1-megapixel CCD camera.

A hologram contains both phase and intensity information about an entire wavefront reflected from (or transmitted through) an object of interest. As such, it is the ideal way to transmit image information from an experiment without prejudging what may be important. With a high-quality holographic recording, a scientist can examine the object of interest by putting it under a microscope at different levels of magnification, or change angular perspective on it, all without the object actually being present.If a sequence of holograms is recorded, then incidents[4] in time can be played, replayed, slowed down, and reversed. It is as if the researcher is being provided with a window on the object in time and space-the Earth-bound scientist has a virtual laboratory in space.

The major drawback[5] for most applications is that the amount of information in a hologram is much larger than conventional 2D imaging techniques. The interference fringes that have to be recorded have features that extend down to a fraction of a wavelength of light, or tens of nanometers. For this reason, the resolution of holographic recording film is 10 to 100 times finer than that used for photography) This poses enormous problems when trying to record images for digital transmission – the large size and relatively small number of pixels in electronic cameras mean that holographic television (in the everyday sense of the word television) is impractical today.

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[1] speech therapist ['spiːtʃˌθerəpɪst] – логопед
[2] intended for [ɪn'tendɪd fə] – предназначенный для
[3] mission ['mɪʃ(ə)n] – космический полёт, программа полёта
[4] incident ['ɪnsɪd(ə)nt] – случай, эпизод
[5] major drawback [ˌmeɪʤə'drɔːbæk] – основной недостаток

However, according to SHIVA principal investigator[1] James Trolinger of MetroLaser, electronic holography for scientific purposes is not so problematic, particularly when the object to be imaged is small. Instead of trying to acquire all the data in a single exposure, the experimenter can wait for it to be built up over time. This system that he and his colleagues have developed for use in space reduces the amount of information acquired still further by recording diffraction patterns and comparing them digitally, rather than creating an optical interference pattern between an object and reference wave. The SHIVA concept was originally destined for use in the Space Station, but deployment there has now been suspended indefinitely[2] because of the shift of focus caused by President George W. Bush's "new vision for space exploration." However, unlike many other programs, it has survived and is now being adapted for possible deployment on a Moon base or mission to Mars.

Task 3. Read the text that follows and sum up Thomas Young's experiment as described by Denis Gabor in his Nobel Lecture.

From the history of holography

Holography is based on the wave nature of light, and this was demonstrated convincingly for the first time in 1801 by Thomas Young, by a wonderfully simple experiment. He let a ray of sunlight into a dark room, placed a dark screen in front of it pierced with two small pinholes, and beyond this, at some distance, a white screen. He then saw two darkish lines at both sides of a bright line, which gave him sufficient encouragement[3] to repeat the experiment, this time with a spirit flame as light source, with a little salt in it, to produce the bright yellow sodium light. This time he saw a number of dark lines, regularly spaced; the first clear proof that light added to light can produce darkness. This phenomenon is called interference. Thomas Young had expected it because he believed in the wave theory of light. His great contribution to Christian Huygens' original idea was the intuition that monochromatic light represents regular sinusoidal oscillations in a medium which at that time was called the "ether"[4]. If this is so, it must be possible to produce more light by adding wave crest to wave crest, and darkness by adding wave crest to wave trough.

Light which is capable of interference is called "coherent", and it is evident that in order to yield many interference fringes it must be very monochromatic. Coherence is conveniently measured by the path difference between two rays of the same source, by which they can differ while still giving observable interference contrast. This is called the coherence length, an important quantity in the theory and practice of holography; Lord Rayleigh and Albert Michelson were the first to understand that it is a reciprocal measure[5] of the spectroscopic line width. Michelson used it for ingenious methods of spectral analysis and for the measurement of the diameter of stars.

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[1] principal investigator [ˌprɪnsəp(ə)lɪn'vestɪgeɪtə] – главный исполнитель, научный руководитель

[2] suspend indefinitely [sə'spend ɪn'defənətlɪ] – отложить на неопределённый срок

[3] give encouragement [ˌgɪv ɪn'kʌrɪʤmənt] – воодушевлять, стимулировать

[4] ether ['iːθə] – эфир

[5] reciprocal measure [rɪ'sɪprək(ə)l 'meʒə] – взаимно-обратная величина

Module 10
LASER RANGEFINDING

Texts:

A. Pulsed laser rangefinding systems
B, C. Cooperative and non-cooperative targets
D. Atmospheric aerosol pollution monitoring

Terminology

range [reɪnʤ] – диапазон; расстояние;
ranging ['reɪnʤɪŋ] – измерение расстояния, определение дальности;
pulsed laser rangefinding system (rangefinder) [ˌpʌlst'leɪzə 'reɪndʒˌfaɪndɪŋ 'sɪstəm] (['reɪndʒˌfaɪndə]) – импульсный дальномер;
modulated beam (modulated continuous wave) rangefinder ['mɔdjəleɪtɪdˌbiːm 'reɪndʒˌfaɪndə]) – фазовый дальномер;
range resolution [reɪnʤˌrez(ə)'luːʃ(ə)n] – разрешение по дальности

heterodyne detection ['het(ə)rəudaɪn dɪ'tekʃ(ə)n] – гетеродинный прием

sighting channel [ˌsaɪtɪŋ 'ʧæn(ə)l] – визирный канал;
sighting telescope [ˌsaɪtɪŋ 'telɪskəup] – визирная труба;
bore sighting (harmonization) [ˌbɔːˌsaɪtɪŋ] ([ˌhɑːmənaɪ'zeɪʃ(ə)n]) – установка направления, юстировка

transmitter (receiver) optical train [trænz'mɪtə] ([rɪ'siːvə]) [ˌɔptɪk(ə)l 'treɪn] – система оптических элементов передатчика (приемника)

effective focal length [ɪˌfektɪv 'fəuk(ə)lˌleŋθ] – полезное (эквивалентное, эффективное) фокусное расстояние

energy-storage capacitor ['enəʤɪˌstɔːrɪʤ kə'pæsɪtə] – емкостный конденсатор, накопительный конденсатор

high-speed counter [ˌhaɪ'spiːd 'kauntə] – высокоскоростной счётчик, быстродействующий счётчик

head amplifier [ˌhed 'æmplɪfaɪə] – предварительный усилитель, выносной усилитель, предусилитель

threshold comparator ['θreʃ(h)əuld kəm'parətə] – пороговое устройство (компаратор)

false alarm [ˌfɔːlsə'lɑːm] – ложная тревога, сигнал ложной тревоги

clock frequency ['klɔkˌfriːkwənsɪ] – тактовая частота, частота синхронизации

pulse mode ['pʌlsˌməud] – режим излучения импульсов, вид импульсов;
first (last) pulse mode [fɜːst] ([lɑːst]) ['pʌlsˌməud] – измерение дальности по первому (последнему) импульсу

low-impedance output [ˌləu ɪmˈpiːd(ə)ns ˈautput] — низкое выходное сопротивление

Word study

1. Pick out the words that do not belong:

1) radar, filter, receiver, amplifier, transmitter, lunar, rangefinder, resonator, splitter, detector;
2) distant, electronic, visible, coincident, circuit, focal, effective, radial, appreciable, additional;
3) accuracy, circuitry, equipment, detection, majority, source, precise, ratio, magnification, target.

2. Combine the numbered and lettered words to obtain terms:

1) electronic	7) last-pulse	a) alarm	g) ranging
2) beam	8) heterodyne	b) telescope	h) resolution
3) false	9) sighting	c) velocity	i) detection
4) lunar	10) focal	d) divergence	j) effect
5) Doppler	11) range	e) circuitry	k) laser
6) Q-switched	12) target radial	f) length	l) mode

3. Choose the correct words to complete the sentences that follow:

1) *pumping*, *pumped*, *pump*
   The overwhelming majority of laser rangefinders use an optically ________ solid-state laser as the source of transmitter power.
2) *effectuate*, *effective*, *effectively*, *ineffective*
   The field of view of the receiver channel is determined by the ratio of the size of the detector to the ____________ focal length of the receiver objective lens.
3) *effect*, *affect*, *affected*, *affecting*
   The transmitted spot is often made 20 to 30% smaller than the receiver field of view so that small differences between the two optical axes do not ____________ the overall system accuracy.
4) *future*, *farther*, *furthermore*, *further*
   The signal level is then ____________ increased in the main amplifier.
5) *whether*, *weather*, *whatever*, *whereas*
   This technique allows the operator to choose ____________ to display the first or the last range value received.

4. Match the terms on the left to those on the right:

1) precise lunar or satellite ranging	a) поле зрения приемного канала
2) visible laser rangefinders	b) источники питания электронного оборудования
3) the magnification of the transmitter telescope	c) лазерные дальномеры видимого диапазона
4) the field of view of the receiver channel	d) точное измерение расстояния до Луны и спутников
5) quartz-controlled oscillator	e) расстояние до требуемой цели
6) threshold value	f) спектрально-селективный фильтр
7) storage register	g) кварцованный генератор
8) the range of the wanted target	h) увеличение телескопа передатчика
9) wavelength-selective filter	i) регистр памяти
10) electronic supplies	j) пороговое значение

Grammar revision

5. Fill in the blanks in the following text with the, a/an or zero article.

Rookie[1] mistakes

Making __power measurement is often __simple process – just place __photodetector __head into __laser beam and read __digital display from ___power meter[2]. This simplicity commonly leads to ___novice mistakes, however. The sensitivity of __detector can easily vary by ±5% or more over its surface. Even __miniscule[3] reflections from __detector surface back into __laser will cause __power fluctuations. Another commonly overlooked factor is __effect of __transmissive optics on some measurements. And for __low light levels or fast pulses, care must be taken to keep connecting cables short to avoid __noise pickup or added capacitance, which slows __dynamic response. __operation of other instruments, particularly when measuring low signal levels, can also cause __spurious results.

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1 rookie (novice) ['rukı] (['nɔvıs]) – неопытный работник, новичок
2 power-meter ['pauəˌmiːtə] – ваттметр, измеритель мощности
3 miniscule ['mınəskjuːl] – очень маленький

Reading and discussion 1

6. Read Text 10A and answer the questions on page 108.

Text 10A
PULSED LASER RANGEFINDING SYSTEMS

Introduction

The overwhelming majority of laser rangefinders in operation at the present time use an optically pumped solid-state laser as the source of transmitter power, but pulsed CO_2 laser systems are now also making an appearance. The principles upon which these systems work are common to all, and the differences between various instruments lie in the fine details of the optical design and of the electronic circuitry. Pulses of duration 10 to 50 ns (giving accuracies of a few metres) are usual, but shorter pulses may be used for precise lunar or satellite ranging, and longer pulses are used in heterodyne CO_2 laser systems.

The principal optical elements

Rangefinding systems generally have three optical channels; these are the sighting telescope, and the transmitter and receiver optical trains. It is normal practice, at least for visible or near-visible laser rangefinders, to combine two channels together in a single optical train and some designs even combine all three functions using polarization to separate the transmitted and received beams and a wavelength -selective filter to separate out the sighting channel.

The beam divergence produced by the laser resonator is decreased by the magnification of the transmitter telescope, and is usually in the region of 0.5 mrad for instruments operating in ranges up to 10 km. The field of view of the receiver channel is determined by the ratio of the size of the detector to the effective focal length of the receiver objective lens. The size of the transmitted beam and the image of the detector at the target are usually made to be about the same order of size although the transmitted spot is often made 20 to 30% smaller than the receiver field of view so that small differences between the two optical axes do not affect the overall system accuracy. The process of aligning the three optical axes of the system to be coincident is referred to as bore sighting or harmonization.

Electronics

Upon a command from the operator, the electronic supplies are turned on and the energy storage capacitor charged to its working voltage. Then, when the sighting telescope has been carefully aligned to point at the target, the transmitter pulse is initiated. A small fraction of the energy from the pulse is picked off and fed to a fast photodiode; the output from the diode initiates a high-speed counter which is clocked by pulses from a quartz-controlled oscillator. A small fraction of the energy reflected from the target is collected by the receiver lens which is focused onto the detector.

The output from the detector is fed to a head amplifier which converts the current developed by the detector in a high impedance to a low-impedance output while minimising the additional noise introduced by the conversion process. The signal level is then further increased in the main amplifier. The amplified signal is applied to a threshold comparator; if the signal exceeds an internally set voltage, the clock is stopped. The threshold has to be set so that noise signals alone only very rarely cross the threshold to create false alarms, and yet must not be set so high that there is an appreciable probability that true signals will be missed.

If the clock frequency is chosen correctly, the number of clock periods stored in the counter can be simply related to the range of the target. For example, if the clock frequency is set at 29.978 MHz, light will travel 10 m in one clock cycle and thus the range resolution of the instrument will be ±5. Some designs can cope with more than one pulse exceeding the threshold value; in this case the clock is not actually stopped by the signal crossing the threshold level but instead the clock count at each occurrence is fed into a set of storage registers, which are read out in sequence at the end of the ranging operation.

It is then left to the judgment of the operator to decide which is the true range to the target. A simpler variant of this technique allows the operator to choose whether to display the first or the last range value received. For example, when operating under conditions where smoke or haze is present it would be advantageous to use last-pulse mode, whereas when operating in clear conditions with a target outlined against a more distant hillside, the first pulse is most likely to correspond to the range of the wanted target.

Questions to Text 10A.

1. What types of lasers are mainly used in the present-day rangefinding systems as the source of transmitter power? 2. List the three optical channels of a typical rangefinding system. 3. What is the function of a wavelength-selective filter? 4. In what way can the field of view of the receiver channel be determined? 5. What is bore sighting? 6. List the principal circuit elements of a pulsed laser rangefinder. 7. In what way is the threshold set? 8. In what cases does the operator choose the last-pulse mode?

Reading and discussion 2

7. We distinguish between two types of target: those giving deliberately enhanced return called cooperative targets, and other targets referred to as non-cooperative. Read Text 10B and 10C and find out which of them deals with rangefinders using cooperative targets.

COOPERATIVE AND NON-COOPERATIVE TARGETS

Text 10B

The optical depth of natural targets (trees, buildings and vehicles) is in the range of a few metres. This sets a limit to the accuracy that is useful, and thus sets a lower limit to useful pulse length of the order of 25ns. This length of pulse fits well with those produced by Q-switched solid-state lasers or Q-switched gas lasers.

Even if the accuracy requirement were relaxed, there is an energy advantage in keeping to as short a pulse as the detector will handle. This may be readily seen for a receiver that detects individual photo-events (e.g. a photomultiplier). One is trying to distinguish a weak return from random counts due to noise, background, etc. Clearly if the photoevents from the return are concentrated into the smallest possible time interval, they will have a maximum statistical significance compared with background photoevents, especially when the probability of a background event in the time interval becomes very small. For a receiver incapable of detecting individual photoevents, a similar conclusion applies; for detecting weak returns it is advantageous to compress the available energy into the shortest pulse.

Text 10C

The prime aim is accuracy.The use of retroreflectors provides not only a precise target distance but makes signal strength a secondary problem (at least up to several kilometres range). Measurement speed is also a secondary consideration. The precision attainable in a phase measurement accurate to within 0.1% at 50 MHz (corresponding to 3 mm range uncertainty) corresponds to a timing accuracy of 20 ps, which would clearly be difficult to attain by direct measurement because detector response times are usually inadequate. The advantage in energy terms of long duration transmission for direct detection systems is, therefore, outweighed by the accuracy advantage attainable with modulated waveforms lasting many seconds.

8. Read Text 10D and answer the following questions.

1. What technique is this text concerned with?
2 What are its practical applications?
3. What types of laser are usually employed? Why?

Text 10D

ATMOSPHERIC AEROSOL POLLUTION MONITORING

By using a pulsed transmitter it is possible to obtain detailed range-resolved data on the distribution of atmospheric aerosols; this technique is generally referred to as lidar, from light detection and ranging by analogy with radar.

Equipments usually employ visible lasers, either ruby, frequency-doubled Nd, or dye lasers to take advantage of the larger scattering coefficients at shorter wavelengths and the high sensitivities of photomultiplier tubes. Since signals produced by scattering from the atmosphere are much less than those from solid targets, high transmitter powers and large receiver optics (250 to 500 mm diameter) are employed) Such systems can be used to study the distribution of pollution aerosols, the evolution of natural cloud formations, the effluent[1] from smoke stacks[2], the tracking of insecticide clouds, etc. Returns from particles at altitudes as high as 15 to 20 km can be obtained. By making observations at a series of different elevations[3] it is possible to build up a picture of the aerosol particle distribution around a single station at a given time. Alternatively, the temporal evolution[4] of pollution can be studied by firing the laser beam vertically upwards and recording the variation of aerosol distribution as a function of time. This has been used, for example, to study the pollution build-up[5] in the vicinity of motorways.

9. Render the text given below in English. Use the following words and word-combinations:

time-of-flight, *Fizeau*, *Michelson*, *modulated-beam rangefinders*, *pre-laser days*, *to stem from*, *fast high-energy pulses*, *to revolutionize the capabilities*

Время прохождения оптического луча от источника до удаленной точки и обратно измерялось Физо, Майкельсоном и другими учеными в период с 1850 по 1930 г. с целью определения скорости света. В настоящее время измерение периода прохождения оптического луча лежит в основе целого класса оптических дальномеров, включающего фазовые дальномеры, которые появились до создания лазера, а также импульсные лазерные дальномеры, в основе которых лежат системы, впервые продемонстрированные в 1961 г. вскоре после создания лазера. Импульсные дальномеры, использующие некогерентные источники, были изучены до I960 г., но применение коротких высокоэнергетических импульсов и высоко-коллимированных монохроматических лучей, получение которых стало возможным с созданием лазеров с модулируемой добротностью, открыло новые огромные возможности. Позже сообщалось о появлении дальномеров, использующих CO_2 лазер с гетеродинным детектированием; эти дальномеры аналогичны микроволновым радиолокаторам и используют доплеровский эффект для нахождения радиальной скорости цели.

10. Unscramble the following text, add punctuation marks.

Thetimeoffligthofanopticalbeamfromasoursetoadistantpointandbackwas measuredbyFizeauMichelsonandothersintheperiod1850to1930todeterminethe velocityoflightNowadaysthetimeofflightmeasure mentisthebasisofaclassofopti calrangefindersthatincludesmodulatedbeamequipmentwithoriginsinprelaserda ysaswellasthepulsedlaserrangefindersthatstemfromthesystemsfirstdemonstrate din1961soonafterthediscoveryoflaserPulsedrangefindersusingincoherent sourc eshadbeenstudiedbefore1960butthefasthighenergypulsesandhighlycollimate dmonochromaticbeamsavailablefromQswitchedlaserrevolutionizedthecapabili tiesMorerecentlyCO$_2$laserrangefindingsystemsusingheterodynedetectionhaveb eenreportedthesehavemanyanalogieswithmicrowaveradarsandusetheDopplere ffecttogivetargetradialvelocity.

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1 effluent ['efluənt] – сброс, фильтрат

2 smoke stack ['sməukˌstæk] – дымоход

3 elevation [ˌelɪ'veɪʃ(ə)n] – высота, возвышенность

4 temporal evolution ['temp(ə)r(ə)lˌiːvə'luːʃ(ə)n] – эволюция во времени

5 pollution build-up [pə'luːʃ(ə)n 'bɪldʌp] – накопление выбросов

11. Make a PowerPoint presentation on one of the topics covered in the module.

Supplementary reading tasks

Task 1. Combine the numbered and lettered words to obtain terms:

1) ground-based	7) payload	a) spacecraft	g) bay
2) angular	8) space	b) monitoring	h) alignment
3) mother	9) bring	c) a rendezvous maneuver	i) shuttle
4) docking	10) satellite	d) rates	j) applications
5) spaceborne	11) closure	e) maneuver	k) radars
6) perform	12) careful	f) spacecraft	l) two spacecraft together

Task 2. Match the word-combinations with their Russian equivalents:

1) angular alignment	a) бортовая радиолокационная станция
2) mother spacecraft	b) грузовой отсек
3) payload bay	c) выполнять сближение и стыковку
4) closure rate	d) угловое выравнивание
5) on-board radar	e) космический аппарат-носитель
6) perform rendezvous and docking maneuvers	f) скорость сближения

Task 3. Read the text below dating back to the 1970s and then try to find some information on the current developments in on-board radars.

Spaceborne laser radar

Laser radar systems are being developed for various spaceborne applications. At present the greatest need for spaceborne radars is as an accurate guidance aide for spacecraft that are performing rendezvous and docking maneuvers. Precise knowledge of the relative position between two spacecraft performing a rendezvous maneuver is difficult and often impractical to obtain from ground-based radars and therefore accurate radars located on board the spacecraft are desirable. Also two spacecraft performing docking maneuvers require careful monitoring of closure rates and angular alignment, thus precision on-board radars can be a valuable aid in bringing them together safely. On-board radars can also be useful for continuous or periodic surveillance[1] of small satellite spacecraft that are parked in orbits nearby their

[1] surveillance [sɜːˈveɪləns] – наблюдение, контроль

mother spacecraft. Laser radar systems are presently being considered for use on future spacecraft such as the NASA space shuttle and space station. Space shuttles can use laser radar to aid the transferring of cargo into and out of their payload bay. Laser radar can also be used to aid the rendezvous and docking of space shuttles with space stations and can allow space stations to monitor the location of small satellite spacecraft.

Task 4. Arrange the paragraphs of the text below in a logical order.

Apollo 11 experiment still going strong after 35 years

1. Once the laser beam hits a reflector, scientists at the observatories use sensitive filtering and amplification equipment to detect any return signal. The reflected light is too weak to be seen with the human eye, but under good conditions, one photon – the fundamental particle of light – will be received every few seconds.	2. The experiment consists of an instrument called the lunar laser ranging reflector, designed to reflect pulses of laser light fired from the Earth. The idea was to determine the round-trip travel time of a laser pulse from the Earth to the Moon and back again, thereby calculating the distance between the two bodies to unprecedented accuracy. Unlike the other scientific experiments left on the Moon, this reflector requires no power and is still functioning perfectly after 35 years.
3. On the afternoon of July 20, 1969, Apollo 11 astronauts Neil Armstrong and Edwin “Buzz” Aldrin explored the surface of the Moon for two and a half hours, collecting samples and taking photographs while Michael Collins orbited in the command module Columbia. On July 21, about an hour before the end of their final moonwalk, they left an experiment on the lunar surface which, after 35 years, continues to work as well as it did the day it got there. Called the lunar laser ranging experiment, it studies the Earth-Moon system and returns data to scientific centers around the world, including NASA’s Jet Propulsion Laboratory.	4. Scientists know the average distance between the centers of the Earth and the Moon is 385,000 kilometers (239,000 miles), implying that the modern lunar ranges have relative accuracies of better than one part in 10 billion. This level of accuracy represents one of the most precise distance measurements ever made and is equivalent to determining the distance between Los Angeles and New York to one hundredth of an inch. “Technical improvements at the observatories rejuvenate the lunar laser ranging effort,” Williams said. “When the range accuracy improves, it is like getting a new experiment on the Moon.”
5. Three more reflectors have since been left on the Moon, including two by later Apollo 14 and 15 missions and one (built by the French) on the unmanned Soviet Lunokhod 2 rover. Each of the reflectors rests on the lunar surface in such a way that its flat face points toward the Earth.	6. The lunar laser ranging experiment is the only lunar investigation continuously operating since the Apollo project. Improvements in lasers and electronics over the years have led to measurements currently accurate to about 2 centimeters (less than one inch).

7. It was the summer of ‘69. Director John Schlesinger’s “Midnight Cowboy” had won the Oscar for Best Picture; the Rolling Stones’ newly released “Honky Tonk Women” was climbing the charts; 400,000 people were gearing up to attend Woodstock... and America landed on the Moon, making “one giant leap for mankind.”	8. The Apollo 11 laser reflector consists of 100 fused silica half cubes, called corner cubes, mounted in a 46-centimeter (18-inch) square aluminum panel. Each corner cube is 3.8 centimeters (1.5 inches) in diameter. Corner cubes reflect a beam of light directly back toward its point of origin; it is this fact that also makes them so useful in Earth surveying.

Task 5. Choose the correct definition for these words and expressions (underlined in the text):

Para 7:

to climb the charts means (a) reach a particular position on the charts, (b) move to a higher position in popularity lists, (c) go over a geographical map;

to gear up means (a) be prepared to do a particular activity, (b) change to a higher gear; (c) equip with gears;

Para 3:

a sample means (a) a small boat of a kind used in East Asia, (b) a sound or piece of music created by sampling, (c) a specimen taken for scientific testing or analysis;

moonwalk means (a) an act or period of walking on the surface of the moon, (b) a dance with a gliding motion, in which the dancer appears to be moving forward but in fact is moving backwards, (c) the launching of a spacecraft, rocket, etc), to the moon;

Para 2:

round-trip means (a) not saying what is meant clearly and directly, (b) a journey to one or more places and back again, (c) done all day and all night without stopping;

Para 8:

a corner cube means (a) right-angle collimator, (b) corner selector, (c) a retroreflector;

Para 5:

a mission means (a) an important task, (b) an expedition into space, (c) an ambition or aim;

Para 1:

to hit means (a) arrive at a place, (b) come into contact with something stationary forcefully, (c) make or become hot or warm;

Para 6:

accurate means (a) correct in all details; exact, (b) punctual, (c) neat;

Para 4:

to imply means (a) make a formal application or request, (b) suggest something as a logical consequence, (c) bring or put into operation or use;

to rejuvenate means (a) restore unity, (b) come together a period of separation, (c) make something more lively and more efficient.

Module 11
Q-SWITCHING

Texts:

A. Q-Switching. Choosing the best alternative
B. Acousto-optic Q-switches
C. FO strain sensor to watch for quakes

Terminology A

Quality factor (Q) [ˈkwɔlətɪˌfæktə] – коэффициент добротности;
Q-switching [ˈkjuːswɪʧɪŋ] – модуляция добротности;
Q-switch [ˈkjuːswɪʧ] – модулятор добротности;
acousto-optic Q-switch [əˌkuːstəuˈɔptɪkˈkjuːswɪʧ] – акустооптический модулятор добротности;
electro-optic Q-switch [ɪˌlektrəuˈɔptɪkˈkjuːswɪʧ] – электрооптический модулятор добротности;
rotating-element Q-switch [rəuˈteɪtɪŋˈelɪməntˈkjuːswɪʧ] – модулятор добротности с помощью вращающегося элемента
shutter [ˈʃʌtə] – затвор;
intracavity shutter [ˌɪntrəˈkævətɪˈʃʌtə] – внутрирезонаторный (внутриполостной) затвор
energy storage capacity [ˈenəʤɪˌstɔːrɪʤ kəˈpæsətɪ] – количество запасенной энергии, энергоёмкость аккумулятора
cell [sel] – ячейка;
dye-cell Q-switch [ˈdaɪsəlˈkjuːswɪʧ] – модуляция добротности на ячейке с красителем;
Kerr-cell Q-switching – модуляция добротности с помощью ячейки Керра;
Pockels cell – ячейка Поккельса
two-state saturation [ˈtuːˌsteɪtˌsæʧ(ə)ˈreɪʃ(ə)n] – двухуровневое насыщение;
saturable absorber [ˈsæʧərəbl əbˈzɔːb(ə)] – насыщающийся поглотитель

Word study

1. Choose the correct words to complete the sentences that follow:

1) *longer, no longer, any more, any longer*
Stimulated emission ___________ occurs, and lasing stops.

2) *rise, raise, rose, risen, raised*
If pumping continues, more atoms can be ________ to the upper laser level.

3) *in use, in operation, in question*
Operating parameters for each type of Q-switch depend on the material ________.

4) *accessible, saturable, available, favorable*
If the Q-switch is suddenly opened, the excess energy is _________ for immediate transmission.

2. Combine the numbered and lettered words to obtain terms:

1) intracavity	6) dye-cell	a) Q-switch	f) shutter
2) quality	7) power	b) time	g) density
3) upper	8) decay	c) holography	h) energy
4) excess	9) population	d) inversion	i) factor
5) double-pulse	10) range	e) finding	j) laser state

Reading and discussion 1

Read Text 11A and answer the questions on page 118

Text 11A

Q-SWITCHING. CHOOSING THE BEST ALTERNATIVE

Short pulses of high peak power are useful in many applications of lasers – materials processing, rangefinding, and double-pulse holography are just a few examples. Some lasers generate such pulses as a matter of course. Others do not. Some of these other lasers can be induced to generate nanosecond pulses with peak powers of hundreds of megawatts by changing, i.e. switching. the quality factor, Q, of the laser cavity during pumping.

The key to Q-switching is energy storage capacity, a combination of optical gain and decay time. Generically, a Q-switch can be thought of as an intracavity shutter. Under normal laser excitation and with the Q-switch open atoms are pushed into the upper laser state at some given rate, spontaneous emission begins to occur, optical feedback is provided by the two laser mirrors, and stimulated emission (laser action. ensues. Without getting deeply involved in rate-equation analysis, if the optical gain is larger than the optical losses and the various upper- and lower- level decay times are favorable, a steady-state lasing equilibrium can be achieved.

If the Q-switch is closed, the optical feedback is eliminated, stimulated emission no longer occurs, and lasing stops. But if pumping continues more atoms can be raised to the upper laser level than are found there under the condition of operational equilibrium just described. Stated simply, under the "closed-shutter" condition, excess energy is stored in the upper laser level. If the Q-switch is suddenly opened, that excess energy is available for immediate emission. The instantaneous rate of stimulated emission is quite high for the first photons reflected from the rear mirror, and a large laser pulse is emitted) This depletes the upper level and lasing stops until more energy can be placed in the upper laser level again.

The best laser candidates for energy storage are several types of solid-state lasers – Nd:YAG, Nd:glass, ruby, and so on. At the other extreme, ion lasers cannot be Q-switched: the population inversion in an ion laser decays so quickly that these lasers are unable to store energy. Other types of gas lasers, such as carbon dioxide lasers, however, can be Q-switched.

Several types of Q-switches can be used.The three most common in terms of market penetration are acousto-optic, electro-optic and dye-cell Q-switches. The advantages and disadvantages of each are described in subsequent texts. Operating parameters for each type depend on the material in use.

At least two other types of Q-switches had been used in the past but they have little market presence today. Kerr-cell Q-switching, similar to electro-optic Q-switching but with a single polarizer, isn't used very often anymore because of difficulties in dealing with materials like nitrobenzene and problems associated with component damage.

The other infrequently encountered type of Q-switching is the rotating-element Q-switch. If the rear mirror of the cavity were rotated in the plane of the paper (see Figure 1) for a brief portion of each complete rotation, it would form a return path for optical feedback and lasing would occur. If this brief portion of rotation coincides with the period of peak energy storage in the laser medium, maximum peak power in the Q-switched pulse can be obtained. For the rest of each complete rotation, the cavity is nonresonant and lasing is inhibited (a retroreflective prism could also be used as the rotating element).

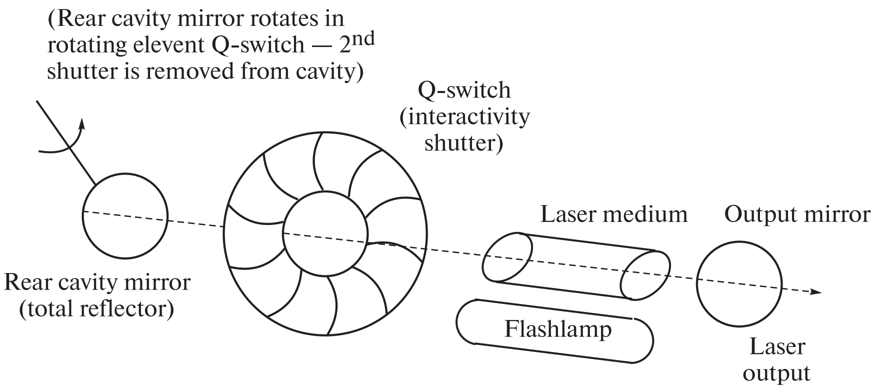

Figure 1. An acousto-optic Q-switched laser cavity

With good optical coatings, rotating-element Q-switches can withstand higher power densities than can other types of Q-switches. However, difficulties in synchronization can make these devices difficult to work with, to the point where the user synchronizes the experiment to the Q-switch rather than vice versa. Another problem concerns angular velocity: top speeds of several hundred hertz lead to minimum pulse duration of the order of 30 nanoseconds. However, in the middle infrared, where materials capable of sustaining high-power operation are available for use as electro-optic or acousto-optic Q-switches, the rotating-element Q-switch still has a place. The recent interest in the erbium-doped YAG laser, which operates near 3 micrometers, may lead to a comeback for the rotating-element Q-switch.

Review

3. Match the numbered and lettered parts of the following sentences to produce true statements.

1. Generally, a Q-switch can be thought of	a) the optical feedback is eliminated and lasing stops
2. If the Q-switch is open,	b) these lasers are unable to store energy
3. If the Q-switch is closed,	c) as an intracavity shutter
4. The best laser candidates for energy storage	d) spontaneous emission begins to occur
5. The population inversion in an ion laser decays so quickly that	e) is energy storage capacity, a combination of optical gain and decay time
6. With good optical coatings, rotating-element Q-switches	f) are several types of solid-state lasers: Nd:YAG, Nd:glass, ruby, etc
7. The key to Q-switching	g) can often withstand higher power densities than can other types of Q-switches

4. Pick out the words that do not belong to the following groups:

1) Nd:YAG, carbon, Nd:glass, ion, ruby;
2) dye-cell, rangefinding, electro-optic, acousto-optic, Kerr-cell, rotating-element;

3) rear cavity mirror, intracavity shutter, laser medium, energy storage capacity, flashlamp, output mirror, laser output;
4) feedback, comeback, cavity, gain, emission.

5. Reorder the items of Text 11A's plan according to the text.

1. Types of Q-switches.
2. The rotating-element Q-switch operation.
3. Basic concepts of Q-switching.
4. Advantages and disadvantages of the rotating-element Q-switch.
5. Processes that occur under different positions of a Q-switch.
6. Kerr-cell Q-switching.
7. Q-switching characteristics of different materials (types of lasers).

6. Answer the following questions.

1. List the applications of lasers with short pulses of high peak power. 2. What do changes in the quality factor result in? 3. What is a Q-switch? 4. Explain what happens under normal laser excitation with the Q-switch open. What is the position of the Q-switch for lasing to stop? 5. What are the best laser candidates for energy storage? 6. Explain why ion laser cannot be Q-switched. 7. Enumerate the types of Q-switches described in the text. Which are the most common types? 8. Describe the operation of rotating-element Q-switches. What are their advantages? What makes these devices difficult to work with?

7. Use exercises 5 and 6 to sum up the contents of Text 11A.

Terminology B

strain waves [ˈstreɪnˌweɪv] – волны упругости (упругие волны), волны деформаций

laser beam deflector [ˈleɪzəˌbiːm dɪˈflektə] – лазерный дефлектор

optical signal processor [ˈɔptɪk(ə)lˌsɪgn(ə)l ˈprəusesə] – устройство оптической обработки сигнала

laser frequency shifter [ˌleɪzəˈfriːkwənsɪ ˈʃɪftə] – устройство сдвига лазерной частоты

mode-locking [ˈməudlɔkɪŋ] – синхронизация мод;
mode-locker [ˈməudlɔkə] – синхронизатор мод;
mode-locked laser system – лазерная система в режиме синхронизации мод

bulk damage [ˌbʌlkˈdæmɪʤ]] – объёмное разрушение, объёмное повреждение; разрушение (стойкость к разрушению) кристалла

r. f. drive power – радиочастотный источник сигнала

Word study

8. Match the terms on the left with the Russian equivalents on the right:

1) mechanically induced strain waves	a) плотность мощности на выходе
2) tunable optical filters	b) лазерный дефлектор
3) single-pulse bulk-damage threshold intensity	c) длительность импульса лазера с акустооптической модуляцией добротности
4) laser cavity configuration	d) перестраиваемые оптические фильтры
5) output power density	e) плавленый кварц
6) laser beam deflector	f) волны упругости, наводимые механическим путем
7) fused quartz	g) инверсная населенность в устойчивом состоянии
8) steady-state population inversion	h) повреждение покрытия
9) coating failure	i) схема лазерного резонатора
10) acousto-optic Q-switched pulse duration	j) пороговая мощность разрушения при моноимпульсном излучении

9. Match the verbs on the left with the definitions on the right:

1) to mature	a) to think about something carefully, to ponder, to study, to observe or examine
2) to inhibit	b) to say that something will happen, before it happens; to foretell
3) to predict	c) to become ripe, to reach completion
4) to provide	d) to prevent something from growing or developing well, to restrain, to hinder
5) to consider	e) to bring about or ensure, to arrange for something or prepare beforehand, to supply something

Reading and discussion 2

Read Text 11B and answer the questions on page 122.

Text 11B
ACOUSTO-OPTIC Q-SWITCHES

The term “acousto-optic” describes the interaction of optical waves with mechanically induced strain waves, which vary the index of refraction in an optical interaction medium. This type of interaction was first predicted by

Brillouin in 1922. But it was not until after the development of the laser in the early 1960s that acousto-optic devices began maturing into the products of today. The acousto-optic interaction has led to the development of many useful devices: laser modulators, laser beam deflectors, optical signal processors, tunable optical filters, laser frequency shifters, modelockers, and Q-switches.

Of particular interest is the acousto-optic Q-switch; consider the laser cavity configuration shown in Figure 2. If the laser medium is continually pumped without any optical feedback mechanism, a steady-state population inversion will be established in the laser transition level. An excess population of this level can be obtained if the radiative lifetime is long and the pumping intensity is high. The addition of the two end mirrors will form a cavity and provide the required feedback for lasing. The properties of the laser cavity are characterized by the quality factor, *Q*. A high value of *Q* means that energy is stored in the cavity with only very small losses. A low value of *Q*, conversely, indicates the presence of large energy losses in the cavity, and the lasing will be inhibited.

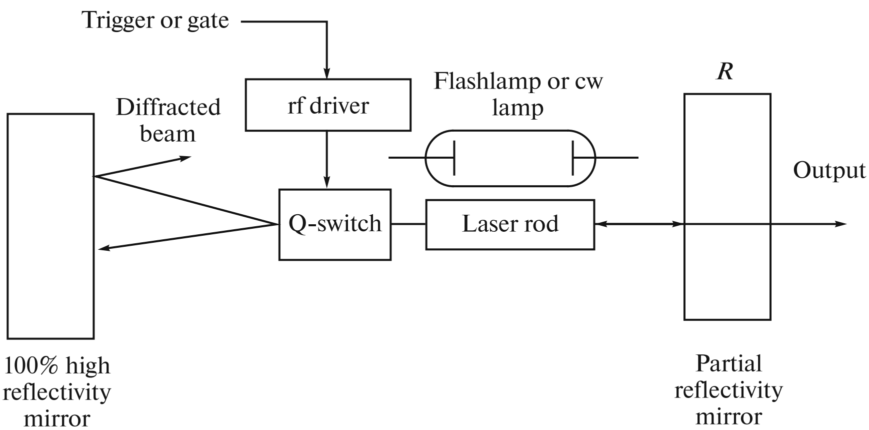

Figure 2. Simplified schematic of an acousto-optic Q-switched laser cavity

For the acousto-optic Q-switched laser configuration shown in Figure 2, the *Q* factor is given by the expression $Q = 2d\omega/(I - R + R\eta)c$[1], where *R* is the reflectivity of the output mirror, d is the distance between the mirrors, ω is the angular frequency of the light, c is the velocity of light, and ŋ is the fraction of light diffracted out of zero order when the Q-switch is on.

With rf drive power applied to the Q-switch, ŋ is high and the value of *Q* is held low, preventing lasing. In this state the laser medium has time to build up an excessive population in the laser transition level. After pumping the laser rod to the maximum population the rf drive is switched off and all the light is allowed to pass between the mirrors. This allows the laser pulse intensity to build up rapidly to the maximum and then decay as the excited states are depleted. This cycle is repeated at the desired laser pulse rate as limited by the optical and electrical time constants.

[1] For Greek alphabet see *Appendix 1.*

Acousto-optic Q-switches are commonly used in continuous-wave, modelocked, and pulsed laser systems to generate intense bursts of laser light. Q-switching usually reduces the energy of the pulses but at the same time the pulse length is shortened so much that the peak power is increased considerably. Acousto-optic Q-switched pulse durations typically range from 40 to 200 nanoseconds, depending on the laser design, acousto-optic Q-switched ruby and Nd:YAG lasers produce output power densities of 10^7 to 10^8 watts per square centimeter; measurements as high as $4 \cdot 10^9$ W/cm^2 have been reported in simultaneously Q-switched and modelocked systems. By using a variety of optical interaction materials Q-switches have been designed to work in laser systems operating at wavelengths ranging from 300 nanometers to 11 micrometers.

Fused quartz is the most commonly used acousto-optic Q-switch medium for operation between 300 nm and 2 μm. The single-pulse bulk-damage threshold intensities at wavelengths of 1064 and 532 nm are 110 and 90 GW/cm^2, respectively. Multi-pulse bulk damage occurs at about 80 percent of threshold at 1064 nm and 60 percent of threshold at 532 nm, as reported by Merkle et al. of the University of Southern California. Interestingly, quartz optical elements typically suffer coating failure before bulk damage occurs. For applications requiring low optical power more efficient materials, such as lead molybdate ($PbMoO_4$) and flint glass are used in some devices operating between 600 and 1200 nm. However, these materials find limited use because of their high internal optical absorption.

Constant improvements in acousto-optic Q-switch design and fabrication techniques are leading to more efficient, reliable and more stable systems. However, the final Q-switch choice will be dictated by the user's system requirements and economic tradeoffs.

Review

10. Match the parts of sentences in the two columns to produce true statements.

1. The term "acousto-optic" describes	a) the presence of large energy losses in the cavity
2. It was not until after the development of the laser in the early 1960s	b) energy is stored in the cavity with only very small losses
3. An excess population of the laser transition level can be obtained	c) the interaction of optical waves with mechanically induced strain waves
4. A high value of *Q* means that	d) because of their high internal optical absorption
5. A low value of *Q* indicates	e) range from 40 to 200 nanoseconds, depending on the laser design
6. Acousto-optic *Q*-switched pulse durations typically	f) that acousto-optic devices began maturing into the products of today
7. These materials find limited use	g) if the radioactive lifetime is long and the pumping intensity is high

11. Pick out the words that do not belong to the following groups:

1) continually, conversely, rapidly, commonly, reflectivity, considerably, typically, simultaneously, respectively, interestingly;
2) shorten, reduce, limit, deplete, build up, decay;
3) transition level, interaction medium, drive power, pulse rate, time constant, index of refraction, bulk damage, power density;
4) inhibit, prevent, stop, hinder, provide.

12. Reorder the items of Text 11B's plan according to the text. Pick out the items that are not mentioned in this text.

1. Lasers using acousto-optic Q-switches.
2. Operation difficulties of dye-cell Q-switching.
3. The expression for the Q factor.
4. Prospects of developing more stable systems.
5. Acousto-optic Q-switch operation. Simplified version.
6. Outstanding electro-optic crystals.
7. Acousto-optic interaction. Background.
8. The most commonly used acousto-optic Q-switch media.

13. Write an abstract of Text 11B.

14. Answer the questions to Text 11B.

1. Who was the first to predict acousto-optic interaction? What does the term mean? What devices are based on this interaction? 2. Use Figure 2 and the expression for Q factor to describe the operation of the acousto-optic Q-switch. 3. What types of laser systems commonly use acousto-optic Q-switches? 4. What is the most commonly used acousto-optic medium? What applications require the use of other materials? Why?

15. Compare the configuration and operation of the rotating element Q-switch (Text 11A, Figure 1) with those of the acousto-optic Q-switch (Text 11B, Figure 2).

16. Render the text given below in English.

Коэффициент добротности *Q* определяется потерями лазерного резонатора; чем меньше потери, тем выше значение *Q*. Рассмотрим лазерный резонатор, в котором перед одним из зеркал помещен затвор. При условии постоянной накачки активной среды и при закрытом затворе инверсная населенность активной среды в резонаторе продолжает увеличиваться и достигает максимального значения. Если затвор закрыть, то величина инверсной населенности будет соответствовать начальному, гораздо выше порогового, значению; энергия, накопленная в резонаторе, будет выделяться в виде короткого импульса света с высоким максимальным значением интенсивности. Поскольку при открывании затвора значение *Q* возрастает от очень малой величины до очень большой, этот метод получения короткого интенсивного импульса света получил название мгновенной модуляции добротности.

17. Unscramble the following text, add punctuation marks.

The qualities of detectors

importantdetectorqualitiessuchasspectralresponserisetimeandsensitivitydiffern otonlybetweentypesbutalsobetweendifferentdetectorsofthesametypethesequali tiesarealsoinfluencedbythedesignoftheoverallmeasurementsystemincludingco mponentspecificationseveralparametersareusedtocharacterizedetectorperform ancequantumefficiencythenumberofelectronsgeneratedperincidentphotonisaf undamentalparameterthatunderliestheperformanceofmanytypesofdetectorssig naltonoiseratiowhichwillbediscussedinnextmonthsarticleistheultimatefigureof meritforadetector

18. Read Text 11C and answer the questions.

1. What is the sensitivity of the system described?
2. What types of laser are used in the system? Why?
3. List possible applications of the fiber strain sensor.

Text 11C

FO STRAIN SENSOR TO WATCH FOR QUAKES

A fiberoptic strain sensor[1] being developed at the Los Alamos National Laboratory will watch for small strain in the earth's crust[2], which may precede earthquakes[3]. The system can detect strains as small as 10–10, which can develop over a period of years.

To achieve that sensitivity Los Alamos geophysicist Fred Homuth turned to an interferometric sensor based on two parallel single-mode fibers installed without cabling in a hole in the ground. One is isolated from the influence of the surrounding rock; the second is cemented to the rock so it experiences strains in the surrounding rock. Strain-induced alterations[4] in the effective path length of the second fiber are detected by comparing its output with that of the reference fiber interferometrically and continually monitoring the output with a computer.

The sensing system will use about 200 meters of a special single-mode fiber with wavelength of 1095 nm. That special fiber is needed because Homuth is using helium-neon laser sources emitting at 1152 nm. Those lasers were selected for their high stability and the low fiber losses at that wavelength.

Homuth noted that the fiber strain sensor could find other applications including detecting underground nuclear explosions, monitoring ground

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[1] strain sensor ['sensə] – датчик деформаций

[2] the earth's crust [krʌst] – земная кора

[3] precede [prɪ'siːd] an earthquake ['ɜːθkweɪk] – иметь место перед землетрясением

[4] alteration [ˌɔːlt(ə)'reɪʃ(ə)n] – изменение

stability near waste storage[1] and nuclear reactor sites, and monitoring stability of structures such as pipelines built on permafrost.

Supplementary reading tasks

Task 1. Complete the table using a dictionary if necessary.

Verb	*Noun(s)*	*Adjective(s)*	*Adverb*
—			virtually
evolve			—
	attainability		—
prevent	preventing	preventing	
			applicably
lose			—
—	spontaneity		
	storage		—

Task 2. Read the following text and discuss the differences between photometry and radiometry.

Radiometry and photometry

Radiometry is the measurement of optical radiation at wavelengths between 10 m and 1 mm. Photometry is the measurement of light that is detectable by the human eye, and is thus restricted to wavelengths from about 360 to 830 nm. Photometry has an added layer of complexity – measurements are factored by the spectral dependence of human vision. Also, as a practical matter, displays and sources of illumination often have a spatial dependence not found in most nondiode laser sources.

Early measurements of light power compared what the eye perceived to the artificial sources then available. Modern units in the science of photometry are derived from this "standard candle" and are used in the characterization of displays and illumination. The candela is the fundamental SI unit of optical measurement, equivalent in kind to the kilogram and the second.

Most optoelectronic measurements use radiometric units of power and energy familiar from electrical measurements – watts, joules, and so forth. The lumen is the photometric analog of the watt. There are 683 lumens per watt at 555 nm, at which the spectral responsive of the human eye is a

[1] waste storage [ˈweɪstˌstɔːrɪʤ] – хранилище отходов

maximum (the luminosity curve is set to unity). At other wavelengths, the conversion is scaled to the standard luminosity curve.

The candela can be thought of as the product of lumens and solid angle. There exists a bewildering variety of photometric and radiometric quantities and associated units (Talbots, nits, and blondels, for example). Modern instruments are capable of displaying whatever units are best suited to the application, reducing the burden on the user.

Communication applications such as telecom often use the decibel (dB) to characterize the attenuation of signal transmission. The decibel is a logarithmic ratio of powers: $dB = 10\log(P_{signal}/P_{ref})$. The negative sign in attenuation is ignored. When the reference is set to be 1 mW, the signal is then measured in "dBm" units (decibels relative to 1mW). Decibels are useful units because system losses can be simply added.

Task 3. Combine the numbered and lettered words to obtain terms, translate them:

1) thermal	5) noise	a) performance	e) effect
2) coated	6) pyroelectric	b) applications	f) pulses
3) continuous-wave	7) ferroelectric	c) detector	g) crystal
4) multijoule	8) military	d) surface	h) power

Task 4. Read the text that follows and discuss the advantages of thermal detectors.

Thermal detectors

The first measurements of light were made using simple thermometers, and today thermal detectors are still the only practical way to measure some wavelengths and levels of energy. A thermopile consists of a heat-absorbing coated surface connected to a series of thermocouples. The junctions of the thermocouples alternate between a constant temperature reference and the coating (the more thermocouples in series, the greater the sensitivity of the thermopile). The voltage of the thermocouples is calibrated with a known light source incident on the coating.

Given a coating with linear absorption across the spectrum, the thermopile is an all-wavelength detector. Its sensitivity can handle from microwatts of continuous-wave power up to multijoule pulses, with excellent noise performance. The drawback of the thermopile is that it is very slow.The pyroelectric detector, on the other hand, while more expensive and complex, is a fast, broad-spectrum instrument.

The pyroelectric effect refers to the generation of a voltage by heating a ferroelectric crystal. This voltage is capable of producing a current proportional to the change in temperature, and hence to the power incident on the crystal) Since the voltage vanishes when the crystal reaches equilibrium at the new temperature, the signal light must be from a pulsed source, or chopped if the source is continuous.

Unlike semiconductor-based detectors, thermal detectors do not need to be cooled to work in the infrared. Miniature versions of these detectors, such as "microbolorimeters," are being tested in military imaging applications.

Task 5. Match the numbered and lettered words to obtain terms:

1) single-mode	6) predictable	a) decay	f) number
2) subatomic	7) radioactive	b) prediction	g) drive
3) climate	8) chaotic	c) control	h) gaming
4) air traffic	9) thumb	d) output	i) behavior
5) electronic	10) random	e) laser	j) particle

Task 6. Arrange the paragraphs of the text below in a logical order.

Random-number generator gets its input from quantum vacuum fluctuations

1. In collaboration with QuintessenceLabs, an Australian quantum-technology company, the ANU team is now looking into commercializing the system. The team hopes to have this technology miniaturized down to the size of a thumb drive.	2. To overcome this issue, random number generators relying on inherently random physical processes, such as radioactive decay and chaotic behavior in circuits, have been developed. The ANU random-number-generation process is the fastest true-random-number generation scheme yet.
3. The random number generator is online and can be accessed from anywhere at any time around the world. Anyone who downloaded live random numbers from the ANU website will get a fresh and unique sequence of numbers that is different from all other users.	4. Random number generation has many uses in information technology. Global climate prediction, air traffic control, electronic gaming, encryption, and various types of computer modeling all rely on the availability of unbiased, truly random numbers. To date, most random-number generators are based on computer algorithms. Although computer-generated random numbers can be useful, knowing the input conditions to the algorithm will lead to predictable and reproducible output, thus making the numbers not truly random.

5. Researchers at The Australian National University (ANU) are generating true random (not quasirandom) numbers from a single-mode laser setup that makes broadband measurements of the vacuum field. And, based on this setup, they have a website that anyone who needs live random numbers can access.	6. The vacuum is actually an extent of space that has virtual subatomic particles spontaneously and randomly appearing and disappearing. The setup ANU makes measurements of the vacuum field contained in radio-frequency sidebands of a laser; the resulting photocurrents are then transformed by an algorithm into a string of random numbers that are generated at up to 2 Gbit/s.

Task 7. Discuss the principle behind and possible uses of random number generators.

Module 12
NONLINEAR OPTICS

Texts:

A. Intense laser beams bring nonlinearity to light
B. The cutting edge of NLO
C. Unwanted effects
D. Raman to the rescue

Terminology A

a deflected light beam [dɪˈflektɪd ˈlaɪtˌbiːm]] – отклонённый луч (пучок)
an optic [ˈɔptɪk] – линза (оптического прибора), объектив, окуляр
second-harmonic generation [ˌsek(ə)nd hɑːˈmɔnɪkˌʤenəˈreɪʃ(ə)n] – генерация второй гармоники
multiphoton absorption [ˌmʌltɪˈfəutɔn əbˈzɔːpʃ(ə)n] – многофотонное поглощение
stimulated scattering [ˈstɪmjəleɪtɪd ˈskæt(ə)rɪŋ] – вынужденное (индуцированное) рассеяние
withstand high irradiance [wɪðˈstændˌhaɪ ɪˈreɪdɪəns] – выдерживать излучение высокой интенсивности
a dissociated molecule [dɪˈsəuʃɪeɪtɪd ˈmɔlɪkjuːl] – диссоциированная молекула
intermediate state [ˌɪntəˈmiːdɪətˌsteɪt] – переходное состояние (промежуточное) состояние
optical networking [ˈɔptɪk(ə)l ˈnetwɜːkɪŋ] – оптоволоконные (волоконно-оптические) сети
margin for error (error margin) [ˈmɑːʤɪn fərˈerə] –предел погрешности, допустимая погрешность
stimulated Brillouin scattering [ˈskæt(ə)rɪŋ]– вынужденное рассеяние Мандельштама–Бриллюэна
backward-traveling wave [ˈbækwədˌtræv(ə)lɪŋˈweɪv] – обратная бегущая волна
stimulated Raman scattering – вынужденное комбинационное рассеяние
wavelength-division multiplexing (WDM) [ˈweɪvleŋθ dɪˈvɪʒ(ə)n ˈmʌltɪˌpleksɪŋ] – спектральное мультиплексирование
a comb [kəum] – гребенка, гребенчатая структура
leading edge [ˈliːdɪŋˌeʤ] – передний фронт волны (импульса)
trailing edge [ˈtreɪlɪŋˌeʤ] – задний фронт волны (импульса)

self-phase modulation [ˈselfˌfeɪzˌmɔdjəˈleɪʃ(ə)n] – фазовая автомодуляция
four-wave mixing [ˈfɔːˌweɪv ˈmɪksɪŋ] – четырехволновое взаимодействие (смешение)
fiber core [ˈfaɪbəˌkɔː] – центральная жила оптического волокна, сердцевина волокна
a long-haul network [ˌlɔŋˈhɔːl ˈnetwɜːk] – сеть дальней связи

Word study

1. Find equivalent phrases either in Text 12A or in the right-hand column:

1) не вредоносный, невредный	a) bring smth to light
2) относиться к; ссылаться на	b) benign
3) постепенно	c) place constraints on smth
4) обнаружить, выявить, раскрыть	d) refer to smth
5) создавать изображение	e) come from smth
6) Нет худа без добра	f) cover a wide domain
7) быть результатом чего-либо	g) bring smth about
8) накладывать ограничения	h) in a stepwise fashion
9) приводить к чему-либо	i) to build up an image
10) перекрёстные помехи	j) exceed a threshold
11) превышать порог	k) crosstalk
12) охватывать широкую область	l) Every cloud has a silver lining

2. Combine the numbered and lettered words to obtain meaningful noun/adjective + noun word-combinations. Translate them:

1) startling	12) nonlinear	a) networks	l) fashion
2) intense	13) ultrafast	b) effects	m) wave
3) unexpected	14) stepwise	c) generation	n) value
4) widespread	15) micron-sized	d) NLO effects	o) multiplexing systems
5) high-speed	16) backward-traveling	e) scattering	p) modulation

6) high-power	17) threshold	f) lasers	q) integrity
7) second-harmonic	18) pump	g) laser beam	r) absorption
8) coherent	19) wavelength-division	h) ultraviolet light	s) fiber core
9) significant	20) self-phase	i) harmonics	t) processes
10) higher-order	21) four-wave	j) phenomena	u) level
11) stimulated	22) data	k) consequences	v) mixing

Reading and discussion 1

3. Read Text 12A and discuss the questions on page 132.

Text 12A

INTENSE LASER BEAMS BRING NONLINEARITY TO LIGHT

Perhaps the most startling of all the effects made possible by an intense laser beam are those that result from changes in an optic caused by the beam itself. In the familiar realm of linear optics, a light beam can be deflected, absorbed, and so on, but its wavelength remains the same. Intense beams of light, however, can interact with a material to produce entirely new wavelengths, as well as other unexpected phenomena – and not all of them are benign. In this realm of nonlinear optics (NLO) there are problems as well as opportunities. Currently, the NLO problems found in optical fibers have the most widespread consequences, placing constraints on the performance of high-speed networks.

First light

Nonlinear optics refers to a specific class of effects – those that occur when the energy in an electric field applied to a material under illumination approaches the energy that binds its electrons to its molecules. The electric field can come from the illumination itself (an intense laser beam) or it may be applied separately.

A few consequences of NLO have been known since the 19th century, such as those that occur when a high DC voltage is applied to an illuminated dielectric. But it took the extreme fields of high-power lasers to bring NLO phenomenon to light. Second-harmonic generation (SHG) was first demonstrated in 1961, when researchers focused a pulsed ruby laser into quartz and produced coherent ultraviolet (UV) light.

The prospects for generating new coherent wavelengths were obvious, and within a few years all of today's most significant NLO effects had been discovered, including the generation of higher-order harmonics, stimulated scattering, self-focusing, and nonlinear absorption. Nonlinear optics covers a wide domain, and it is not possible to mention all of its effects in a brief review. A few important examples follow.

Spectroscopy of life

The spectroscopy of nonlinear absorption phenomena has brought about a revolution in biological analysis. The basic idea of multiphoton absorption is to excite a sample to high energy levels without using UV. Many organic molecules can withstand high irradiance in the infrared, but are easily dissociated by UV.

At high intensities, however, virtual energy states in the material can be excited by infrared photons, and these intermediate states can then further absorb infrared photons to reach the final state of excitation in a stepwise fashion. Analysis of these states provides important information about a variety of processes in the life sciences, as evidenced by the number of Nobel prizes awarded for research based on these techniques.

Multiphoton confocal laser imaging is one such technique. A high-peak-power, tunable laser can excite resonances in a wide variety of substances, even living tissue. Scanning a microscope along different axes builds up an image of the sample, and correlation of the fluorescence with the laser pulses allows investigation of ultrafast processes in proteins.

Every silver lining has a cloud

Data rates that now exceed 1Tbit/s leave little margin for error in optical networking. Nonlinear optical effects cause four main problems in optical fibers, all resulting from the long reach of a fiber network and the confinement of the optical signal in the micron-sized fiber core.

Stimulated Brillouin scattering (SBS) generates a backward-traveling wave in silica fiber at 1.55 μm. Once the threshold for SBS is exceeded, the intensity of this wave grows exponentially as the pump level increases.This threshold value might be as low as 1 mW.

Stimulated Raman scattering (SRS) is a particular problem for wavelength-division multiplexing (WDM) systems, as it takes signal power from shorter wavelengths and adds it to the longer data wavelengths in the WDM comb. Because SRS occurs when different channels are simultaneously transmitting a '1' (that is, a pulse is present), crosstalk results. As a pulse propagates through a fiber, its leading and trailing edges experience a different index of refraction brought about by the intensity of the pulse itself. This is the phenomenon of self-phase modulation (SPM). Self-phase modulation is a significant problem for long-haul networks that rely on optical amplifiers.

When at least three beams are transmitted in a fiber, the process of four-wave mixing generates a new beam at a different frequency. In the case of

WDM, a very large number of beams can be generated. The frequencies of these beams usually match those of the input, so data integrity is not only reduced by loss of power from a signal, but also by the addition of this power to other signals as noise.

Questions to Text 12A.

1. What is nonlinear optics as compared to linear optics?
2. What are the most significant effects associated with NLO?
3. In what way is multiphoton absorption achieved?
4. Explain the headline of the last section of the text.

Increase your vocabulary

4. Combine the numbered verbs with lettered nouns to obtain meaningful verb + noun word-combinations. Translate them:

1) interact with	12) withstand	a) DC voltage	l) the final state of excitation
2) produce	13) absorb	b) coherent ultraviolet light	m) a Nobel prize
3) place	14) reach	c) a material	n) the threshold for SBS
4) apply	15) provide	d) entirely new wavelengths	o) a different index of refraction
5) bring	16) award	e) a ruby laser into quartz	p) high irradiance
6) focus	17) build up	f) a wide domain	q) little margin for error
7) produce	18) leave	g) constraints on performance	r) important information
8) generate	19) cause	h) a revolution	s) a backward-traveling wave
9) cover	20) generate	i) a sample	t) an image of the sample
10) bring about	21) exceed	j) new coherent wavelengths	u) problems in optical fibers
11) to excite	22) experience	k) NLO phenomenon to light	v) infrared photons

5. Match the phrasal verbs below with their equivalents:

1) come from	a) to cause something to happen
2) bring about	b) occur or follow as the consequence of something
3) rely on	c) depend on with full trust or confidence
4) build up	d) originate in; have as its source
5) result from	e) to construct gradually, systematically, and in stages
6) result in	f) have a specified end or outcome

6. Complete the blanks with the phrasal verbs from exercise 5.

1. Process efficiency is also improved by better beam quality, which can ______________ higher manufacturing throughput.
2. These advances have ___________largely __________ improvements to CO_2 optics, which use materials including zinc selenide (ZnSe), gallium arsenide (GaAs), and germanium (Ge) for lenses, and gold or silver on silicon substrate for mirrors.
3. Even at lower concentrations, the aluminum in the junction region tends to oxidize and ______________________the lattice-defect lifetime problems that plagued early diode lasers.
4. Most NLO effects ______________ intensities that can only be produced by high-power lasers.
5. The ability to___________ optical intensity in the confined volume of a microresonator reduces the input power required to achieve a given energy density.
6. The most elaborate results _________________ the second-harmonic generation of light in piezoelectric crystals.

7. Supply the missing prepositions or adverbs:

1) interact _____a material;
2) place constraints ____the performance of high-speed networks;
3) a material ______ illumination;
4) refer ____ a specific class of effects;
5) ...when a high DC voltage is applied ____an illuminated dielectric;
6) to bring NLO phenomenon _____ light;
7) The spectroscopy of nonlinear absorption phenomena has brought ______a revolution;
8) to excite a sample to high energy levels _______using UV;
9) to reach the final state of excitation ____a stepwise fashion;
10) Scanning a microscope ____different axes builds ____an image of the sample;
11) leave little margin _____error;
12) a different index of refraction brought ____ by the intensity of the pulse;
13) long-haul networks that rely ____optical amplifiers.

8. Rearrange the items of the plan according to Text 12A.

1. Effects of nonlinear optics.
2. Problems in this realm of nonlinear optics.
3. Nonlinear phenomena in life sciences.
4. NLO vs. linear optics.

9. Speak about one of the topics in exercise 7.

Terminology B

an order of magnitude [ˈɔːdərəvˈmægnɪt(j)uːd] – порядок величины
a phase conjugate mirror (PCM) [ˌfeɪz ˈkɔnʤugət ˈmɪrə] – фазово-сопряжённое зеркало
time-reversed reflection [ˌtaɪm rɪˈvɜːst rɪˈflekʃ(ə)n] – инвертированное (обращённое) во времени (встречное) отражение
a distorting medium [dɪˈstɔːtɪŋ ˈmiːdɪəm] –деформирующая (искажающая) среда
optical phase conjugation (OPC) [ˌɔptɪk(ə)l ˈfeɪz ˌkɔnʤuˈgeɪʃ(ə)n] – оптическое фазовое сопряжение
squeezed light [ˈskwiːzdˌlaɪt] – сжатый (сдавленный) свет
entangled light [ɪnˈtæŋgld ˌlaɪt] – запутанный свет
optical bistability [ˌɔptɪk(ə)lˌbaɪstə ˈbɪlɪtɪ] – оптическая бистабильность
a soliton [ˈsɔlɪtɔn] – солитон; уединённая волна, одиночная волна
scanning probe microscopy (SPM) [ˈskænɪŋˌprəub maɪˈkrɔskəpɪ] – сканирующая зондовая микроскопия (СЗМ)

Word study

10. Find equivalent phrases either in Text 12A or in the right-hand column:

1) по сути	a) equally dramatic
2) удалённые фотоны	b) all-optical transistor
3) обуславливаться различными эффектами	c) to defy limitations
4) чисто оптический транзистор	d) taken together
5) передовые исследования	e) maintain the pulse shape
6) сохранять форму (профиль) импульса	f) cutting edge
7) в совокупности	g) leading edge of research
8) пренебрегать ограничениями	h) rely on different effects
9) снижать потери	i) reduce losses
10) столь же значительный	j) inherently
11) передовой край	k) distant photons

11. Combine the numbered and lettered words to obtain word combinations:

1) motion	6) organic	a) of relativity	f) beam
2) distorting	7) optical	b) communication	g) medium
3) classical	8) incoming	c) compounds	h) devices
4) instantaneous	9) limitations	d) pictures	i) coefficients
5) nonlinear	10) practical	e) approach	j) networking

Reading and discussion 2

12. Read Text 12B and discuss the questions on page 136.

Text 12B

THE CUTTING EDGE OF NLO

Organic NLO materials have nonlinear coefficients that for some processes are orders of magnitude greater than traditional crystals, allowing the use of lower power, less expensive lasers. The optical quality of these materials is a drawback. Someday, however, microscopic structures of organic compounds may help make practical devices from today's leading edge of research.

Applications of "optical phase conjugation" can appear almost magical – the phase conjugate mirror (PCM), for example, which produces a time-reversed reflection of an incoming beam. A beam that has passed through a distorting medium and is then reflected by a PCM back through the same medium will have the distortion removed. Other OPC effects, such as holographic motion pictures, appear equally dramatic.

Some NLO phenomena are inherently quantum mechanical and cannot be studied using a classical approach. "Squeezed light" and "entangled light" are such phenomena. Entangled light appears to defy the limitations of relativity by demonstrating that two distant photons are in instantaneous communication about their states of polarization.

The goal of devices based on "optical bistability" is to control light using only light. It is possible to use optical bistability to construct an all-optical transistor. Optically bistable devices have two different outputs for the same input, and can switch rapidly between them.

A soliton pulse is a uniquely nonlinear phenomenon that relies on two different effects (such as SPM and dispersion. that individually distort the pulse. But taken together, the effects can maintain the pulse shape in time and space through the distorting medium. Solitons can interact through nonlinear optical processes to reduce their losses even further. Such solitons can translate through thousands of kilometers of fiber with no loss without the need for amplification. Solitons are the subject of intense research in optical networking.

Questions to Text 12B.

1. How do organic nonlinear optical materials compare with common crystals?
2. Give an example of applications of optical phase conjugation.
3. Why can't we use a traditional approach to study entangled light?
4. What is a soliton pulse?

13. Formulate questions to match the following answers.

1. A time-reversed reflection of an incoming beam.
2. To control light using only light.
3. SPM and dispersion.
4. A soliton pulse.

Review

14. Rearrange the items of the plan according to Text 12B.

1. Entangled light.
2. Solitons.
3. Optically bistable devices.
4. Optical quality of NLO materials.
5. Optical phase conjugation effects.

15. Speak about one of the topics in exercise 14.

16. Look through Text 12C and answer these questions.

1. What effects hinder the development of lasers as directed energy weapons?
2. What problems associated with SRS are researchers faced with?

Text 12C

UNWANTED EFFECTS

Like other nonlinear optical effects, the unintended appearance of the Raman effect[1] can cause problems for some applications. Atmospheric SRS[2] is one of the impediments in the development of lasers as directed energy weapons. Likewise, the coupling of laser light with plasmas is one of the key issues facing inertial fusion. SRS changes the efficiency and location of the deposition of laser energy in the target capsules.

But the most conspicuous problems caused by Raman scattering arise in optical networking. The tight confinement of light in the core of silica fiber causes the signal itself to achieve intensities sufficient to pump a surprising

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[1] Raman effect – рамановское рассеяние

[2] SRS = stimulated Raman scattering – вынужденное (комбинационное) рассеяние

variety of nonlinear optical effects, SRS among them. SRS results in the creation of spurious signals that can interfere in a number of ways with wavelength division multiplexing (WDM) to degrade signal quality.

SRS in silica creates a Stokes wave[1] that is down-shifted from the pump about 100 nm in the band around 1550 nm that is used in long-haul communications. The Stokes wave propagates forwards in the fiber along with the pump wave. If the pump is actually one signal channel of a WDM system, then the Stokes wave can overlap and interfere with another channel at a longer wavelength.

Raman amplification depletes the power of shorter wavelength WDM signals to pump the longer wavelength channels. This results in a reduced signal-to-noise ratio for some channels, and skewed values of the relative signal levels.Curiously enough, SRS can also be part of the solution to nonlinear problems caused by intense signals in WDM.

17. Translate Text 12D with a dictionary.

Text 12D

RAMAN TO THE RESCUE

A distributed Raman amplifier (DRA) uses as its gain medium the very silica fiber that forms the network. A DRA launches a continuous-wave beam from the receiver end of the fiber back towards the transmitter, pumping the Raman transition in the fiber itself and thus providing amplification along the transmission length. These results in a more gradual amplification than in a conventional system in which the signal is launched at its peak level, and can reduce problems caused by other nonlinear effects, such as four-wave mixing.

The spectrum of the gain bandwidth in a Raman amplifier is determined by the pump wavelength. The peak of the Raman gain in long-haul networks is about 100 nm below the pump wavelength; typically several pump sources at wavelengths spaced 20 nm apart are used so as to broaden and smooth the gain. A single amplifier can thereby span a wavelength range of more than 100 nm.

Raman amplification can cover all bands of optical communication, including wavelengths not readily amplified by other means. The broader and flatter gain spectra of these amplifiers can also have lower effective noise. Noise from the pump lasers themselves, however, which must be relatively high-power devices, is a consideration.

The current workhorse for network amplification is the erbium-doped fiber amplifier (EDFA). These amplifiers need less-powerful pumps than Raman devices and are adequate in themselves for many applications. But DRAs can be used together with EDFAs in high-end applications, such as

[1] Stokes wave – волна Стокса

submarine installations and transmission rates at 10 Gbit/s and above, to lengthen the space between regeneration and improve signal quality.

Discrete Raman amplifiers, which pump their own separate coil of optical fiber to provide gain, can be used in optical networking in a fashion similar to EDFAs. One application that may grow in importance is boosting signals in the short-wavelength telecom band between 1480 and 1525 nm, where conventional EDFAs are inefficient. When carriers fill the WDM channels in the longer-wavelength bands, they may still be able to add new capacity in the same fibers if proponents of these amplifiers are correct in their expectations.

18. Make a PowerPoint presentation on one of the subjects covered by Nonlinear Optics.

Supplementary reading tasks

Task 1. Match the terms in the left-hand column with their Russian equivalents:

1) beam power density	a) преобразование с повышением частоты
2) phase matching	b) преобразование частоты
3) damage threshold	c) суммарная частота
4) frequency conversion	d) совпадение по фазе
5) sum frequency	e) преобразование с понижением частоты
6) frequency up-conversion	f) плотность энергии пучка
7) frequency down-conversion	g) с угловой или температурной перестройкой
8) angle or temperature tuned	h) романовское (комбинационное) смещение
9) middle infrared	i) порог лучевой стойкости
10) Raman shifting	j) оптическая однородность
11) optical homogeneity	k) средневолновая инфракрасная область спектра

Task 2. Read the text below and discuss the most important factors underlying material selection.

Choosing a nonlinear crystal

The key factors for material selection depend not only upon the laser conditions – beam size, beam quality and beam power density – but also upon the crystal's properties, such as phase matching, transparency, damage threshold and temperature stability.

Tunable laser sources ranging from the ultraviolet to the infrared may be achieved by frequency conversion of fixed-wavelength or tunable lasers by using nonlinear crystals. Second harmonic generation (SHG), third harmonic generation (THG) and sum frequency mixing (SFM) have been widely used for frequency up-conversion (i.e. the shifting of an optical beam to shorter wavelengths). Optical parametric oscillation (OPO), on the other hand, provides a means for frequency down-conversion with continuously angle or temperature-tuned output) Shorter-wavelength (100 to 200 nm) and middle-infrared coherent sources may also be obtained by further Raman-shifting of the nonlinear-crystal-converted output.

Using the direct output of commercial lasers or their harmonics as the pumping sources, OPO in nonlinear crystals provides a very wide tuning spectrum, from the far infrared to the vacuum ultraviolet.

Materials selection rule

The key issues of materials selection for frequency conversion may be summarized as follows:

- high conversion efficiency;
- high damage threshold,
- wide phase-match and transparency range;
- large size with good optical homogeneity;
- low cost and easy fabrication;
- chemically (free of moisture) and mechanically stable.

Task 3. Look through the text that follows and sum up the features of the BBO crystal.

Features of the BBO[1] crystal

The salient features of the BBO crystal may be readily summarized. First, it has a very wide transparency and phase-matching, angle-tuning range: 190 to 300 nm. Second, it has a high damage threshold – up to 13 GW/cm^2 at 1.06 m and a 1-ns pulsewidth – and a wide temperature acceptance width of 55 °C. This temperature acceptance width is about ten times as large as that of

[1] beta-barium-borate crystal – кристалл бета-бората бария

PDP[1] and twice that of PTP[2]. Third, BBO has a very high non-linear coefficient. BBO's effective figure of merit is 3 to 14 times better that that of KDP for second harmonic generation at 1064 nm.

Fourth, BBO is chemically stable and nearly free of moisture. Fifth, good-quality BBO crystals are commercially available at reasonable prices in sizes as large as l0 × 10 × 10 mm) BBO crystal has been identified as a prime candidate for frequency doubling dye lasers to generate deep-ultraviolet sources. Efficient (relatively speaking, of course), tunable sources in the 201 to 310-nm range have been reported for phase-matching at room temperature. More recently, a 195-nm source has been achieved using BBO at low temperature for sum frequency mixing the outputs of dye lasers. Commercial dye laser systems with excimer lasers as pumps using BBO crystals for internal frequency-doubling, are also available. A vacuum-ultraviolet source at 71 nm was recently reported; it involved third harmonic generation, in neon gas, of the BBO-generated 213-nm fifth harmonic of a Nd:YAG laser. Peak output powers of 1 to 2 W from this fifteenth-harmonic generator have been measured.

Nonlinear crystals play an essential role for the generation of coherent sources in spectral regimes where useful levels of direct output from existing lasers cannot be achieved. An ideal crystal should include all the features of transparency and phase-matching over a wide spectral range; wide angular, temperature and spectral acceptance widths; high damage threshold, high nonlinear coefficient; high degree of homogeneity over relatively large volumes; and chemical and mechanical stability. Finally, crystal cost, in terms of efficiency per dollar, should be reasonable.

Task 4. Match the words and word-combinations in the left-hand column with their Russian equivalents:

1) take pains	a) простой в эксплуатации
2) user-friendly	b) прилагать все усилия
3) bit-error rate	c) подверженный чему-либо
4) underlying	d) повторяемость
5) repeatability	e) повседневная поверка
6) a rule of thumb	f) приближенный метод, метод «научного тыка»
7) routine calibration	g) лежащий в основе
8) prone to	h) коэффициент ошибок по элементам

[1] potassium-dihydrogen-phosphate crystal – кристалл дигидрофосфата калия
[2] potassium titanyl phosphate (PTP) – калий-титанил-фосфат, фосфат калия-титанила

Task 5. Arrange the paragraphs of the text below in a logical order.

Taking the measure of light

1. As a rule of thumb, the accuracy of an instrument is about ten times greater than its repeatability. Accuracy typically is needed for the most demanding applications. Scheduling routine calibration is particularly important for accurate measurement of optical power and energy, as these instruments in general are more prone to drift over time than other types.	2. In the early history of the laser, a common method of measuring peak power was to count the number of razor blades through which a pulse could burn. These units were called "Gillettes", and they serve to illustrate how measuring the brightness of light, one of the most intuitive quantities for humans, has long been a problem for technology.
3. The capabilities of an instrument are specified by its resolution, repeatability, and accuracy. Resolution or sensitivity is the minimum quantity that can be discerned in a measurement. The noise present in an instrument during a measurement is a major factor limiting sensitivity. Repeatability quantifies how well an instrument can make one measurement, make a different one, and then return to repeat the first measurement. Accuracy is the ability of an instrument to make a measurement relative to an absolute standard.	4. Manufacturers of instruments that measure power and energy have taken pains to make them user-friendly. Complex optoelectronic measurements – such as bit-error rate, crosstalk ratio, and so on – can be obtained with a push of a button. But underlying all such complex relationships are fundamental measurements of energy, power, pulse duration, and wavelength. Understanding the physical details of these measurements is particularly essential at the boundaries of current technology – for ultrafast pulses, very high or low light levels, and very short or long wavelengths.

Task 6. Discuss requirements to measuring instruments.

LITERATURE

Born M., Wolf E. Principles of Optics. 7th ed. Cambridge University Press, 1999. ISBN 0 521 642221.

Crowell B. Optics. Ed. 2.2. Fullerton, California, 2007. ISBN 0-9704670-5-2.

Drobshoff A., et al. 469nm Fiber Laser Source. SPIE Photonics West 2005 Symposium San Jose, CA, United States. Available at: http://www.osti.gov/energycitations/index.jsp.

Forrester P.A., Hulme K.F. Laser rangefinders. Optical and quantum electronics, vol. 13, no. 4, 259–293. DOI:10.1007/BF00619793. Available at: http://www.springerlink.com;

Flom T. Spaceborne Laser Radar. Applied Optics, 1972, vol. 11, issue 2, pp. 291–299. Available at: http://dx.doi.org/10.1364/AO.11.000291

Gudishe K. Combining RAS and TAS Techniques for Application of the Method for Absorbing Probes. Addis Ababa, 2007.

Hecht J., ed. Irnee D'Haenens dies; assisted in making first laser. Laser Focus World, 2008.

Jet Propulsion Laboratory, California Institute of Technology. Available at: http://www.jpl.nasa.gov/index.cfm

Matthews S.J., ed. Good Fundamentals. In: Back to Basics: Semiconductor Lasers. Laser Focus World, 2002.

Production of fiber lasers in Russia. OptoIQ, 2010 Nov 17. Available at: http://www.optoiq.com

Pshenitsyna O. New laser equipment stops snoring and blindness. 2010, July 6. The Voice of Russia. Available at: http://english.ruvr.ru/2010/07/06/11612683.html

Sona A., ed. Lasers and their Applications. Gordon and Breach Science Publishers Ltd., London, 1976. 73-88656. ISBN 0 667 15030 X.

Wallace J. Gas-dynamic laser enters pulse-periodic mode. Quantum Electronics 33(9) 753. Available at: http://www.laserfocusworld.com.

Wallace J. High-beam switcher recognizes cars; CMOS images. Quantum Electronics 33(9) 753. Available at: http://www.laserfocusworld.com

http://www.polarization.com/rainbow/rainbow.html

http://polarization.com/index-net/index.html

Appendix 1

Letters of the Greek alphabet

Α α	альфа	['ælfə]	Ν ν	ню (ни)	[ni:]
Β β	бета (вита)	['bi:tə]	Ξ ξ	кси	[ksi:]
Γ γ	гамма	['gæmə]	Ο ο	омикрон	[ou'maikrən]
Δ δ	дельта	['deltə]	Π π	пи	[pi:]
Ε ε	эпсилон	['epsilən]	Ρ ρ	ро	[rou]
Ζ ζ	дзета	['zi:tə]	Σ σ ς	сигма	['sigmə]
Η η	эта	['i:tə]	Τ τ	тау	[tau]
θ Θ	тета	['θi:tə]	Υ υ	ипсилон	['ipsilən]
Ι ι	йота	[ai'outə]	Φ ϕ	фи	[fi:]
Κ κ	каппа	['kæpə]	Χ χ	хи	[hi:]
Λ λ	ламбда	['læmbdə]	Ψ ψ	пси	[psi:]
Μ μ	мю (ми)	[mi:]	Ω ω	омега	['oumegə]

Appendix 2

Vocabulary

A

a few [əˈfjuː] — несколько, незначительное количество
a number of [əˈnʌmbərəv] — несколько, ряд
a variety of [əˌvəˈraɪətɪəv] — ряд, целый ряд, различные
aberration [ˌæbəˈreɪʃ(ə)n] — аберрация света
absolute standard [ˌæbsəˈluːt ˈstændəd] — эталон, воспроизводящий единицу физической величины абсолютным методом ‖ эталонный
absorb [əbˈzɔːb] — поглощать, впитывать
absorption [əbˈzɔːpʃ(ə)n] — поглощение
absorption coefficient [əbˈzɔːpʃ(ə)nˌkəuɪˈfɪʃ(ə)nt] — коэффициент поглощения
absorption curve [əbˈzɔːpʃ(ə)nˈkɜːv] — кривая поглощения
absorption spectrum [əbˈzɔːpʃ(ə)n ˈspektrəm] — спектр поглощения
accelerator [əkˈseləreɪtə] — ускоритель, ускоритель заряженных частиц
accept [əkˈsept] — принимать, признавать, допускать, брать
acceptance [əkˈseptəns] — аксептанс (*ускорителя*); принятие, признание
access [ˈækses] — доступ; обращение ‖ предоставлять доступ, допускать
accident rate [ˈæksɪdentˌreɪt] — коэффициент аварийности, уровень травматизма, травматизм
accidental exposure [ˌæksɪˈdent(ə)l ɪkˈspəuʒə] — случайное воздействие, случайное облучение
accompanied by [əˈkʌmpənɪdbaɪ] — в сочетании с, сопровождаемый, с последующим
account [əˈkaunt] — считать, рассматривать ‖ счет
account for [əˈkauntfə] — объяснять
accuracy [ˈækjərəsɪ] — точность, правильность
accurate [ˈækjərət] — верный, правильный, точный; скрупулёзный, тщательный
accurate measurement [ˌækjərət ˈmeʒəmənt] — точное измерение
acoustical [əˈkuːstɪkəl] — акустический
acoustical holography [əˈkuːstɪkəlˌhɔˈlɔgrəfɪ] — акустическая голография
acousto-optic [əˌkuːstəuˈɔptɪk] — опто-акустический
acousto-optic Q-switch [əˌkuːstəuˈɔptɪkˈkjuːswɪʧ]— акустооптический модулятор добротности
acousto-optic Q-switched pulse duration [əˌkuːstəuˈɔptɪkˈkjuːswɪʧtˌpʌlsdjuəˈreɪʃ(ə)n] — длительность импульса лазера с акустооптической модуляцией добротности

action at a distance ['ækʃənətə'dɪstəns]– воздействие на расстоянии, дистанционное действие
active center [ˌæktɪv'sentə] – активный центр
active medium [ˌæktɪv'miːdɪəm] – активная среда
active region [ˌæktɪv'riːʤən] – активная область, действующая область
active species [ˌæktɪv'spiːʃiːz] – активная среда, активатор, активная частица
active volume [ˌæktɪv'vɔljuːm] – активный объём, чувствительный объём
actually ['æktʃuəlɪ] – действительно, в самом деле
actuator ['ækttʃueɪtə] – возбудитель, привод, соленоид
adapt to [ə'dæpt] – приспосабливать, приспосабливаться
adaptable [ə'dæptəbl] – адаптивный, адаптируемый, совместимый
adaptable system [əˌdæptəbl'sɪstəm] – адаптируемая система, адаптивная система
adaptive optics [əˌdæptɪv 'ɔptɪks] – адаптивная оптика, самонастраивающаяся оптика
add to ['ædtə] – увеличивать, увеличивать; складывать, означать, иметь смысл
add to complexity ['ædtəˌkəm'pleksətɪ] – увеличивать сложность
adequate ['ædɪkwət] – адекватный, отвечающий требованиям, пригодный
adjust [ə'ʤʌst] – регулировать, настраивать, устанавливать, подстраивать, юстировать
advance [əd'vɑːns] – движение вперёд, успех, прогресс, достижение ‖ двигаться вперёд, продвигаться
advance toward [əd'vɑːnstəˌwɔːd] – продвижение вперёд к
advancement [əd'vɑːnsmənt] – продвижение вперёд, распространение, развитие
advantages over [əd'vɑːntɪʤɪzˌəuvə] – преимущество перед
affect ['æfekt] – действовать на, сказываться на, влиять, затрагивать, воздействовать
afford [ə'fɔːd] – быть в состоянии, иметь возможность, дать, представить
afforded [ə'fɔːdɪd] – предусмотренный
after all [ˌɑːftər'ɔːl] – в конце концов, в конечном счёте, все же
against the background of [əˌgenstðə'bækgraundəv] – на фоне
air traffic control ['eəˌtræfɪkkən'trəul] – управление воздушным движением, обеспечение безопасности полётов
air tube ['eəˌt(j)uːb] – пневмопровод, воздухопровод, воздушная трубка
airborne contaminant ['eəbɔːnkən'tæmɪnənt] – загрязняющее вещество в атмосфере; загрязняющее вещество, переносимое по воздуху
airfoil ['eəfɔɪl] – несущая поверхность, профиль крыла, аэродинамическая поверхность
align [ə'laɪn] – юстировать, настраивать, выравнивать, регулировать
all-optical transistor ['ɔːlˌɔptɪk(ə)ltræn'zɪstə] – чисто-оптический транзистор, полностью оптический транзистор
along with [ə'lɔŋwɪð] – наряду с, одновременно с, вместе с
allow [ə'lau] – позволять, допускать, разрешать
allow for – предусматривать, допускать
alteration [ˌɔːltə'reɪʃən] – изменение
alternate ['ɔːltəneɪt] – чередоваться, чередовать, сменять друг друга
alternating current [ˌɔːltəneɪtɪŋ'kʌrənt] – переменный ток
alternative to [ɔːl'tɜːnətɪvtə] – альтернатива чему-л) ‖ альтернативный

alternatively [æl'tɜːnətɪvlɪ] – и наоборот, в качестве альтернативы, или же
amorphous [ə'mɔːfəs] – аморфный, некристаллический
amorphous solid substance [ə'mɔːfəsˌsɔlɪd'sʌbstəns] – аморфное твёрдое тело
amplification [ˌæmplɪfɪ'keɪʃən] – увеличение (оптического прибора), усиление
amplified spontaneous emission (*ASE*) ['æmplɪfaɪd spɔn'teɪnɪəs ɪ'mɪʃən] – усиленная спонтанная эмиссия, усиленное спонтанное излучение
amplifier ['æmplɪfaɪə] – усилитель, усилитель на эффекте переноса электронов
amplitude transmittance [ˌæmplɪt(j)uːdtrænz'mɪtəns] – коэффициент пропускания
an order of magnitude [ənˌɔːdərəv'mægnɪt(j)uːd] – порядок величины
analyzer [æn(ə)'laɪzə] – анализатор, дисперсионная призма
anisotropic [əˌnaɪsə'trɔpɪk] – анизотропный, имеющий разные физические характеристики
angle ['æŋgl] – угол
angle of incidence [ˌæŋgləv'ɪnsɪdəns] – угол падения (*света, волны*)
angle of rotation [ˌæŋgləvrə'teɪʃ(ə)n] – угол поворота, угол поворота
angular ['æŋgjulə] – угловой
angular alignment [ˌæŋgjulərə'laɪnmənt] – угловое выравнивание
angular distribution ['æŋgjuləˌdɪstrɪ'bjuːʃən] – угловое распределение, угловое распределение фотоэлектронов
antisolar point – антисолнечная точка
apart [ə'pɑːt] – на расстоянии
apart from [ə'paːtˌfrəm] – не говоря (уже) о, кроме, не считая
aperture ['æpətjuə] – апертура
appear [ə'pɪə] – появляться, возникать; казаться, выглядеть
applicability [əˌplɪkə'bɪlɪtɪ] – применимость, пригодность; область применения
applications [ˌæplɪ'keɪʃənz] – методы применения, области применения, практическое применение
apply [ə'plaɪ] – применять; прикладывать, наносить
appreciable [ə'priːʃəbl] – заметный, ощутимый, значительный; измеряемый, наблюдаемый
approach [ə'prəutʃ] – подход, метод, способ
approach a problem (a challenge) [ə'prəutʃ ə 'prɔbləm] (['ʧælɪnʤ]) – рассматривать вопрос (сложную задачу), подойти к рассмотрению задачи
appropriate [ə'prəuprɪət] – надлежащий, соответствующий
appropriate to the task [ə'prəuprɪət tə ðə'tɑːsk] – отвечающий задаче, соответствующий задаче
approximate [ə'prɔksɪmət] – приближенный, приблизительный, ориентировочный
arbitrary ['ɑːbɪtrərɪ] – произвольный, произвольно выбранный
arc discharge [ˌɑːk dɪs'ʧɑːʤ] – дуговой разряд
arc lamp ['ɑːklæmp] – дуговая лампа, дуговая электролампа
arc-lamp pumping ['ɑːklæmp'pʌmpɪŋ] – накачка дуговой лампой
archival recording [ɑː'kaɪvəl rɪ'kɔːdɪŋ] – фондовая запись
arise from [ə'raɪz frəm] – происходить, проистекать, возникать в результате
as a matter of course – как нечто само собой разумеющееся, естественно
as a practical matter – на практике

as compared to [əzˌkəm'peədtə] – по сравнению с
as evidenced by [əz'evɪdənstbaɪ] – что подтверждено, о чем свидетельствует, что явствует из
as follows [əz'fɔləuz] – следующим образом, как указано ниже
as well as [ˌəz'weləz] – так же как, а так же, равно как и
assume [ə's(j)uːm] – предполагать, допускать
assumption [ə'sʌmpʃən] – предположение, допущение
at least [ət'liːst] – по крайней мере, как минимум, по меньшей мере
at length [ət'leŋθ] – подробно
at most [ət'məust] – самое большее, по большей части, главным образом
at rest [ət'rest] – в состоянии покоя, находящийся в состоянии покоя
at room temperature [ətˌruːm'tempərətʃə] – при комнатной температуре, при обычной температуре
atmospheric disturbance [ˌætməs'ferɪkdɪ'stɜːb(ə)ns] – атмосферное возмущение, атмосферные помехи
atomic theory [əˌtɔmɪk'θɪərɪ] – атомистическая теория, атомическая теория, атомистика
attain [ə'teɪn] – достигать, добиваться; приобретать (*напр., свойства*)
attenuate [ə'tenjuɪt] – ослаблять, ослабевать, затухать
attenuation [əˌtenju'eɪʃ(ə)n] – ослабление, затухание (*сигнала*)
auxiliary [ɔːg'zɪlɪərɪ] – второстепенный, подчинённый, вспомогательный
available [ə'veɪləbl] – доступный, имеющийся, имеющийся в наличии, имеющийся в распоряжении, наличный
average power [ˌæv(ə)rɪʤ 'pauə] – средняя мощность
axis ['æksɪs] (pl) axes ['æksiːz]) – ось

B

b. (*born*) – родившийся
back and forth [ˌbækən(d)'fɔːθ] – взад и вперёд, туда и сюда, в ту и в другую сторону
backward-traveling wave ['bækwədˌtræv(ə)lɪŋ'weɪv] – обратная (распространяющаяся, блуждающая) бегущая волна
ballpark ['bɔːlpɑːk] – сфера влияния, область действия ‖ приближенный, приблизительный, примерный;
be in the (right) ballpark – быть приблизительно верным
band [bænd] – полоса, зона (*уровней энергии*), полоса спектра
band-to-band absorption [ˌbændtə'bændəb'zɔːpʃ(ə)n] – межзонное поглощение, поглощение при оптических переходах зона – зона
band-to-band transition [ˌbændtə'bænd træn'zɪʃ(ə)n] – переход с уровня на уровень, междузонный энергетический переход, межзонный переход
bandgap ['bændˌgæp] – запрещенная зона, ширина запрещенной зоны
bandgap semiconductor ['bændˌgæpˌsemɪkən'dʌktə] – полупроводник с запрещенной зоной
bandwidth ['bændwɪdθ]] – ширина энергетической зоны
barium borate [ˌbeərɪəm'bɔːreɪt] – бората бария, борнокислый барий
be around [ˌbiː ə'raund] – быть популярным, быть известным

be due to [ˌbiːˈdjuːtə] – быть обусловленным, являться результатом, объясняться
be exposed to [ˌbiːɪkˈspəuzdtə] – подвергаться воздействию
be familiar with [ˌbiːfəˈmɪlɪəwɪð] – хорошо знать, быть знакомым с
be responsible for [ˌbiːrɪˈspɔnsəblfə] – быть причиной чего-либо, вызывать
be survived by [ˌbiːsəˈvaɪvdbaɪ] – оставить после себя
beam [biːm] – луч, пучок лучей
beam divergence [ˌbiːmdaɪˈvɜːʤəns] – расхождение пучка, расходимость пучка, уширение луча
beam power [ˌbiːmˈpauə] – мощность электронного пучка, мощность пучка
beam quality [ˌbiːmˈkwɔlətɪ] – качество пучка, структура пучка
because of [bɪˈkɔzəv] – вследствие, из-за, в результате, по причине
become available [bɪˌkʌm əˈveɪləbl] – появляться; освобождаться, быть полученным (*напр. о данных*)
bell-shaped [ˈbelʃeɪpt] – воронкообразный, колоколообразный
bend (bent – bent) **around obstacles** [ˈbendəˌraund ˈɔbstəklz] – огибать препятствия
benefit from [ˈbenɪfɪtfrəm] – извлекать выгоду из, выигрывать от, извлекать выгоду
benign [bɪˈnaɪn] – неопасный, слабого действия, не вредоносный, невредный, доброкачественный
bewilder [bɪˈwɪldə] – смущать, ставить в тупик, сбивать с толку, приводить в замешательство
bewildering [bɪˈwɪldərɪŋ] – сбивающий с толку, приводящий в замешательство
beyond [bɪˈjɔnd] – за пределами, вне чего-либо
bias [ˈbaɪəs] – смещение, отклонение уклон ‖ смещать
bind [baɪnd] (bound – bound) – связывать, привязывать
biological analysis [ˌbaɪəuˈlɔʤɪk(ə)ləˈnæləsɪs] – биологический анализ
birefringence [ˌbaɪrɪˈfrɪndʒəns] – двулучепреломление
birefringent crystal [ˌbaɪrɪˈfrɪndʒənt ˈkrɪst(ə)l] – кристалл с двойным лучепреломлением, двулучепреломляющий кристалл
bisect [baɪˈsekt] – делить пополам, разрезать
bistable device [baɪˌsteɪbl dɪˈvaɪs] – бистабильный прибор
bit-error rate – вероятность ошибки в двоичном разряде, коэффициент однобитовых ошибок
bit-error rate test – проверка достоверности (*сообщений*) по частоте битовых ошибок
bizarre [bɪˈzɑː] – странный, причудливый
bleaching [ˈbliːtʃɪŋ] – отбеливание, обесцвечивание ‖ отбеливающий, обесцвечивающий
blindness [ˈblaɪn(d)nəs] – слепота
blurred boundaries [ˌblɜːd ˈbaund(ə)rɪz] – расплывчатые (неясные) границы (очертания)
boost [buːst] – повышение, подъём (*напр. давления, напряжения*); усиление; добавочное напряжение; подъём частотной характеристики ‖ повышать (*напр. давление, напряжение*); усиливать, форсировать; поднимать частотную характеристику

bore sighting (*harmonization*) ['bɔːsaɪtɪŋ] ([ˌhɑːmənaɪ'zeɪʃ(ə)n]) – установка направления, юстировка
borosilicate [ˌbɔːrəu'sɪlɪkɪt, -ˌkeɪt] – боросиликат
bound electrons [ˌbaundɪ'lektrɔnz] – связанные электроны
boundary ['baundərɪ] – граница, предел, линия раздела ‖ граничный, пограничный
break down into ['breɪk'dauníntə] – раскладывать на (*составляющие*)
break into categories ['breɪkintə'kætəg(ə)rɪz] – разделять на категории
breakthrough ['breɪkθruː] – крупное научное (техническое) достижение, прорыв (*в науке*)
Brewster angle ['bruːstər'æŋgl] (*Brewster's angle*) – угол Брюстера, угол полной поляризации
brief review [ˌbriːfrɪ'vjuː] – краткий обзор
bright star ['braɪtˌstɑː] – яркая звезда
brightness ['braɪtnəs] – яркость, освещенность
Brilluin zone – зона Бриллюэна
bring about ['brɪŋə'baut] – осуществлять, вызывать, влечь за собой, приводить к
bring to life – воплотить в жизнь, выявлять, обнаружить, раскрыть
bring to light – обнаружить, выявить, выяснить, раскрыть
broadband measurements ['brɔːdbænd'meʒəmənts] – широкополосные измерения
broadband pump [ˌbrɔːdbænd'pʌmp] – широкополосная накачка
broadcast ['brɔːdkɑːst] – трансляция, телевизионное вещание ‖ передавать по телевидению, транслировать
broaden ['brɔːdn] – расширять, расширяться
brown dwarf [ˌbraun 'dwɔːf] – коричневый карлик
build up ['bɪld'ʌp] – постепенно создавать, наращивать, накоплять
build up an image ['bɪld'ʌpən'ɪmɪʤ] – создавать изображение, формировать изображение
build up oscillations ['bɪld'ʌpˌɔsɪ'leɪʃ(ə)nz] – раскачивать колебания
bulk damage [ˌbʌlk 'dæmɪʤ] – разрушение (*кристалла*), объёмное разрушение, объёмное повреждение
burn [bɜːn] (burnt–burnt; burned–burned) – выжигание, ожог, прожигание ‖ выжигать
burst [bɜːst] – импульс, всплеск (*излучения*), пачка импульсов
by a factor of ten – в десять раз, на порядок
by extension [baɪ ɪk'stenʃ(ə)n] – в расширительном смысле, соответственно
by means of – посредством, с помощью

C

ca. (*circa*) ['sɜːkə] – примерно
CA (*California*) – штат Калифорния
CATV (*cable television*) – кабельное телевидение
cable ['keɪbl] – кабель, провод
calculus ['kælkjuləs] – исчисление, дифференциальное и интегральное исчисление

calibrated ['kælıbreıtıd] – градуированный, калиброванный
calipers ['kælıpəz] – толщиномер, кронциркуль, штангенциркуль
cancel ['kæns(ə)l] – уничтожать, сводить на нет, подавлять
candela (candelae) (Cd) [kən'delə, -'diːlə] – свеча, кандела (кд) (*единица силы света*)
candidate ['kændıdət] – кандидат, (возможный) вариант (*напр. решения*)
capabilities [ˌkeıpə'bılətız] – возможности, характеристики
capability [ˌkeıpə'bılətı] – способность; мощность, производительность; соответствие (*характеристик техническим требованиям*)
capacitance [kə'pæsıt(ə)ns] – ёмкостное сопротивление, ёмкость конденсатора, конденсаторная ёмкость
capacity [kə'pæsətı] – мощность, емкость, способность, возможность, пропускная способность, объем, производительность, производственная мощность
capsule ['kæpsjuːl] – капсула
carbon-dioxide laser [ˌkɑːb(ə)n daı'ɔksaıdˌleızə] – лазер на диоксиде углерода, лазер на двуокиси углерода, CO_2-лазер
carrier ['kærıə] – носитель заряда, электрон проводимости
carry out ['kærı'aut] – выполнять, проводить в жизнь, осуществлять
carry out research ['kærı'aut rı'sɜːʧ] – проводить научные исследования
cast (cast–cast) [kɑːst] – отливка, литьё || придавать форму; разливать, отливать || литой, отлитый
cast a shadow [ˌkɑːstə'ʃædəu] – отбрасывать тень
casually ['kæʒjuəlı] – мимоходом, попутно, случайно; небрежно, непреднамеренно
cause problems [ˌkɔːz 'prɔbləmz] – создавать проблемы
cautiously ['kɔːʃəslı] – осторожно, с предосторожностями, тщательно
cavity ['kævətı] – резонатор, полость
cavity dumping ['kævətıˌdʌmpıŋ] – затухающие колебания, модуляция добротности (*связанных резонаторов*)
cell [sel] – ячейка
chelate laser ['kiːleıtˌleızə] – лазер на хелатах
challenge ['ʧælınʤ] – сложная задача, проблема
challenging ['ʧælınʤıŋ] – сложный, требующий напряжения (*сил*), испытывающий (*способности, стойкость*)
channel ['ʧæn(ə)l] – канал
checkerboard pattern ['ʧekəbɔːdˌpæt(ə)n] – шахматная конфигурация, настроечная таблица
chemical reaction [ˌkemık(ə)l rı'ækʃ(ə)n] – химическая реакция
chemically stable [ˌkemık(ə)lı 'steıbl] – химически стойкий, химически стабильный
chop [ʧɔp] – изменяться, прерывать
chopped [ʧɔpt] – прерывистый
chromium (Cr) ['krəumıəm] – хром
circular polarization ['sɜːkjələˌpəul(ə)raı'zeıʃ(ə)n] – круговая поляризация
clarification [ˌklærıfı'keıʃ(ə)n] – разъяснение, уточнение, пояснение
clarifier ['klærıfaıə] – осветлитель, осветляющее средство; отстойник

clarity [ˈklærɪtɪ] – ясность, прозрачность, понятность
classical approach [ˌklæsɪk(ə)l əˈprəutʃ] – классический метод
cleavage [ˈkliːvɪʤ] – расщепление, расхождение, разложение
clock frequency [ˌklɔk ˈfriːkwənsɪ] – тактовая частота, частота синхронизации, частота тактовых импульсов
closely woven material [ˈkləuslɪˌwəuv(ə)n məˈtɪərɪəl] – плотная ткань
closure rate [ˈkləuʒəˌreɪt] – скорость сближения
coated surface [ˌkəutɪd ˈsɜːfɪs] – поверхность с нанесённым покрытием
coating failure [ˌkəutɪŋ ˈfeɪljə] – повреждение покрытия
coefficient [ˌkəuɪˈfɪʃ(ə)nt] – коэффициент, показатель
coercive voltage [kəuˌɜːsɪv ˈvəultɪʤ] – коэрцитивная сила сегнетоэлектрика
coherence [kəuˈhɪər(ə)ns] – когерентность
coherence length [kəuˌhɪər(ə)nsˈleŋθ] – длина когерентности
coherent emission [kəuˌhɪər(ə)nt ɪˈmɪʃ(ə)n] – когерентное излучение
coherent light [kəuˌhɪər(ə)ntˈlaɪt] – когерентное излучение
coherent light source [kəuˌhɪər(ə)ntˈlaɪtˌsɔːs] – источник когерентного света
coherently [kəuˈhɪər(ə)ntlɪ] – когерентно
coil [kɔɪl] – катушка, виток, спираль, змеевик, обмотка
coincide with [ˌkəuɪnˈsaɪdwɪð] – совпадать с
coincident [kəuˈɪnsɪd(ə)nt] – совпадающий, совмещённый, соответствующий
collect samples [kəˈlekt ˈsɑːmplz] – отбирать пробы, брать пробы
collimated beam [ˈkɔlɪˌmeɪtɪdˈbiːm] – коллимированный пучок, коллимированный луч
colloidal silver [kəˌlɔɪd(ə)l ˈsɪlvə] – стирол, коллоидное серебро
color center [ˈkʌləˌsentə] – центр окраски, цветовой центр, центр окрашивания
color center laser [ˈkʌləˌsentə ˈleɪzə] – лазер с окрашенными центрами, лазер на центрах окраски
comb [kəum] – гребенка, гребенчатая структура
come from – быть результатом
come up with – предложить, придумать
commercial applications [kəˈmɜːʃ(ə)lˌæplɪˈkeɪʃ(ə)nz] – коммерческое применение, промышленное применение
commercialize [kəˈmɜːʃ(ə)laɪz] – коммерциализировать, извлекать прибыль; осуществлять промышленное внедрение
commercially available [kəˌmɜːʃ(ə)li əˈveɪləbl] – имеющийся в продаже, имеющийся на рынке
common [ˈkɔmən] – общий; обычный, обыкновенный
common source [ˌkɔmənˈsɔːs] – общий источник
commonsense – [ˌkɔmənˈsens] здравый смысл ‖ [ˈkɔmənsens] отвечающий здравому смыслу
communication [kəˌmjuːnɪˈkeɪʃ(ə)n] – связь, сообщение, коммуникация
communication system [kəˌmjuːnɪˈkeɪʃ(ə)n ˈsɪstəm] – система связи
compared with [kəmˈpeədwɪð] – по сравнению с
complementary [ˌkɔmplɪˈment(ə)rɪ] – взаимодополняющий, дополнительный
complementary metal oxide semiconductor (*CMOS*) [ˌkɔmplɪˈment(ə)rɪ ˌmet(ə)l ˈɔksaɪdˌsemɪkənˈdʌktə] – комплементарный металло-оксидный полупроводник, КМОП-технология

complex [ˈkɔmpleks] – комплекс ‖ [ˈkɔmpleks]/[kɔmˈpleks] комплексный, сложный
component wave [kəmˌpəunəntˈweɪv] – составляющая волна
compose [kəmˈpəuz] – составлять, компоновать, формировать
composition [ˌkɔmpəˈzɪʃ(ə)n] – состав, компоновка, составные части, смесь, химический состав
comprise [kəmˈpraɪz] – включать, заключать в себе, содержать
concave [kɔŋˈkeɪv]/[ˈkɔnkeɪv] – вогнутая поверхность, вогнутая линза ‖ образовывать вогнутую поверхность, углублять ‖ вогнутый, сферический
concave grating [ˌkɔnkeɪvˈgreɪtɪŋ] – вогнутая дифракционная решётка
concave mirror [ˌkɔnkeɪvˈmɪrə] – вогнутое зеркало
concerning [kənˈsɜːnɪŋ] – относительно, в отношении
conduction [kənˈdʌkʃ(ə)n] – проводимость, конвективный теплообмен
conduction band [kənˌdʌkʃ(ə)nˈbænd] – зона проводимости, электрическая зона проводимости
conductivity [ˌkɔndʌkˈtɪvətɪ] – электропроводность, удельная электрическая проводимость
configuration [kənˌfɪgjuˈreɪʃ(ə)n] – компоновка, конфигурирование
confine [kənˈfaɪn] – граница, предел, ограничение ‖ ограничивать, заключать
confined volume [kənˌfaɪnd ˈvɔljuːm] – замкнутый объём, замкнутое пространство
confinement [kənˈfaɪnmənt] – ограничение; локализация; удержание; герметизация; ограждение данных
confocal laser cavity [kɔnˌfəuk(ə)l ˈleɪzəˌkævətɪ] – конфокальный лазерный резонатор
consequence [ˈkɔnsɪkwəns] – последствие, следствие, вывод, значение
consequences [ˈkɔnsikwənsɪz] – последствия
conservation [ˌkɔnsəˈveɪʃ(ə)n] – сохранение, охрана, консервация, хранение
conserve momentum [kənˈsɜːv məˈmentəm] – сохранять количество движения
conserved momentum [kənˌsɜːvd məˈmentəm] – сохраняющийся импульс
consideration [kənˌsɪdəˈreɪʃn] – рассмотрение, анализ, принятие во внимание; соображение; обсуждение, рассмотрение
consistent [kənˈsɪst(ə)nt] – последовательный, согласующийся, непротиворечивый, совместимый
conspicuous [kənˈspɪkjuəs] – видный, заметный, очевидный, привлекающий внимание
conspire [kənˈspaɪə] – объединять усилия, сговариваться, действовать сообща
constrain [kənˈstreɪn] – сдерживать, связывать, ограничивать
constraint [kənˈstreɪnt] – ограничение, ограничивающее условие; ‖
with a minimum of constraints – с минимальными ограничениями
consume [kənˈsjuːm] – потреблять, расходовать, поглощать
consumption [kənˈsʌm(p)ʃ(ə)n] – потребление, поглощение, расходование
contaminant [kənˈtæmɪnənt] – загрязняющее вещество, примесь, загрязнитель
contaminants [kənˈtæmɪnənts] – загрязняющие примеси
continued [kənˈtɪnjuːd] – продолжающийся, продолженный, непрерывный
continuous wave [kənˈtɪnjuəsˌweɪv] – непрерывное излучение качание

continuous-wave power [kən'tɪnjuəsˌweɪv 'pauə] — мощность непрерывного излучения
continuously operating laser [kən'tɪnjuəslɪˌɔpəreɪtɪŋ'leɪzə] — лазер непрерывного излучения; лазер, генерирующий в непрерывном режиме
contradict [ˌkɔntrə'dɪkt] — противоречить, опровергать
contrary to popular belief ['kɔntr(ə)rɪ təˌpɔpjələ bɪ'liːf] — вопреки расхожему мнению
control system [kən'trəulˌsɪstəm] — система контроля, система регулирования, система управления
convection [kən'vekʃ(ə)n] — конвекция
convective flow [kənˌvekʃ(ə)n'fləu] — конвективный поток
conveniently [kən'viːnɪəntlɪ] — удобно; легко, просто, без труда
conventional [kən'venʃn(ə)l] — обычный, традиционный, принятый
converge [kən'vɜːʤ] — сближаться, сужаться
convergence [kən'vɜːʤ(ə)ns] — схождение в одной точке, схождение, сближение, конвергенция
convergent [kən'vɜːʤ(ə)nt] — сходящийся в одной точке, собирающий
converging lens [kənˌvɜːʤɪŋ'lenz] — сходящаяся линза, собирающая линза, положительная линза
conversely [kɔn'vɜːslɪ] — наоборот, и наоборот, в противоположность чему-либо
conversion efficiency [kən'vɜːʃ(ə)n ɪ'fɪʃ(ə)nsɪ] — эффективность преобразования частоты (*лазерного излучения*)
conversion process [kən'vɜːʃ(ə)n'prəuses] — процесс преобразования
convincing [kən'vɪnsɪŋ] — убедительный, веский
cool [kuːl] — прохладный, холодный ‖ охлаждаться, охлаждать, остывать
cooling fluid [ˌkuːlɪŋ'fluːɪd] — охлаждающая жидкость
cooperative target [kəuˌɔp(ə)rətɪv'tɑːgɪt] — взаимодействующая цель, цель с ответчиком
core [kɔː] — остов (*напр., иона*), жила, активная зона (*ядерного реактора*), керн, кор, сердечник, сердцевина (*напр., волоконного световода*), ядро
corner cube ['kɔːnəˌkjuːb] — уголковый отражатель
corpuscular theory of light [kɔː'pʌskjələˌθɪərɪ əv'laɪt] — корпускулярная теория света
correlation [ˌkɔrə'leɪʃ(ə)n] — корреляция, соотношение, взаимосвязь, взаимоотношение
correspond [ˌkɔrɪ'spɔnd] — соответствовать, согласовываться
correspond to [ˌkɔrɪ'spɔndtə] — соответствовать с, согласовываться с
correspondence principle [ˌkɔrɪ'spɔndəns 'prɪnsəpl] — принцип соответствия
correspondingly [ˌkɔrɪ'spɔndɪŋli] — соответственно, соответствующим образом
cost model ['kɔstˌmɔd(ə)l] — модель затрат
cost of ownership [ˌkɔstəv'əunəʃɪp] — стоимость владения, стоимость покупки и эксплуатации
couple ['kʌpl] — пара, пара сил ‖ образовывать пару, объединять(ся) в пару; соединять, сцеплять
coupler ['kʌplə] — выходной элемент связи
coupling ['kʌplɪŋ] — взаимодействие, соединение, связь (*между элементами в электронике, в атоме*), спаривание

cover ['kʌvə] – крышка, покрытие ‖ покрывать, охватывать
cover a wide domain ['kʌvərəˌwaɪd dəu'meɪn] – охватывать широкую область
cps (*cycle per second*) – герц (Гц)
crest [krest] – гребень волны
criterion (pl) criteria) [kraɪ'tɪərɪən] ([kraɪ'tɪərɪə]) – критерий, признак, мера оценки
cross section [ˌkrɔs 'sekʃ(ə)n] – поперечное сечение
cross talk (*crosstalk*) ['krɔsˌtɔːk] – взаимные помехи, перекрёстные помехи
cryogen ['kraɪədʒən] – криогенное вещество
cryogenic fluid [ˌkraɪə'dʒenɪk 'fluːɪd] – криогенная жидкость
crystalline lattice [ˌkrɪst(ə)laɪn'lætɪs] – кристаллическая решётка
crystalline material [ˌkrɪst(ə)laɪn mə'tɪərɪəl] – кристаллический материал, кристаллическое вещество
curiously enough [ˌkjuərɪəslɪ ɪ'nʌf] – любопытно, как ни странно
current ['kʌr(ə)nt] – (*электрический*) ток, поток, течение ‖ токовый; текущий, протекающий; действующий
currently ['kʌr(ə)ntlɪ] – на данный момент, в настоящее время
curve [kɜːv] – кривая, кривая линия
customary ['kʌstəm(ə)rɪ] – обычный, сложившийся;
it is customary to distinguish – традиционно различают
cutting edge [ˌkʌtɪŋ'eʤ] – самый современный, передовой ‖ передний край
cw (*continuous wave*) – непрерывное излучение, выходная мощность
cw oscillator – генератор незатухающих колебаний
cw power output – выходящая мощность непрерывной длины волны

D

damage ['dæmɪʤ] – повреждение, дефект, разрушение
damage threshold [ˌdæmɪʤ'θreʃ(h)əuld] – предел повреждения, лучевая стойкость, порог лучевой стойкости
darkening ['dɑːk(ə)nɪŋ] – потемнение (*эмульсионного слоя*); воронение, чернение; насыщенность (*краски*)
data highway system ['deɪtə'haɪweɪˌsɪstəm] – система передачи данных, магистраль данных
data integrity['deɪtə ɪn'tegrətɪ] – достоверность данных, целостность данных, сохранность данных
data path ['deɪtəˌpɑːθ] – канал передачи данных, информационный канал
data rate ['deɪtəˌreɪt] – скорость обработки данных, скорость передачи данных
data transmission system [ˌdeɪtə trænz'mɪʃ(ə)nˌsɪstəm] – система передачи данных
dB (*decibel*) ['desɪbel] – децибел (дБ)
dBm (*decibels per milliwatt*) – децибелл на миливатт, (*логарифмическая единица измерения мощности сигнала по отношению к 1 милливатту*)
dc (*direct current*) **discharge** [dɪs'ʧɑːʤ] – накачка разрядом постоянного тока
DC voltage – напряжение постоянного тока
deal with ['diːlwɪð] – иметь дело с, рассматривать
decay [dɪ'keɪ] – спад, затухание, ослабление ‖ спадать, затухать, ослабляться
decay time [dɪ'keɪˌtaɪm] – время спада импульса, время затухания

decibel (*dB*) ['desɪbel] – децибел (дБ) (*стандартная единица измерения относительной мощности или амплитуды сигнала*)
dedicate ['dedɪkeɪt] – посвящать, открывать (*в торжественной обстановке*)
dedicatee [ˌdedɪkə'tiː] – лицо, которому что-л., посвящено
dedication [ˌdedɪ'keɪʃ(ə)n] – посвящение; приверженность, преданность (кому-л., чему-л.)
dedicator ['dedɪkeɪtə] – тот, кто посвящает (*напр. книгу*)
deep-ultraviolet source ['diːpˌʌltrə'vaɪələt 'sɔːs] – источник дальнего ультрафиолетового излучения
deflect [dɪ'flekt] – отклонять, отклоняться, преломляться
deflected beam [dɪˌflektɪd 'biːm] – отклонённый луч
deflected light beam [dɪˌflektɪd 'laɪtˌbiːm] – отклонённый луч, отклонённый пучок
deflection [dɪ'flekʃ(ə)n] – преломление, отклонение
deformable mirror [dɪˌfɔːməbl 'mɪrə] – деформируемое зеркало
defy [dɪ'faɪ] – бросать вызов, игнорировать, препятствовать, нарушать, не поддаваться
degradation [ˌdegrə'deɪʃ(ə)n] – снижение работоспособности, деградация, снижение эффективности, потеря энергии
degrade [dɪ'greɪd] – ухудшать(ся), снижать(ся), понижать, ослабляться
degree [dɪ'griː] – ступень, степень, уровень, предел; градус (*мера угла, температуры*)
deleterious [ˌdelɪ'tɪərɪəs] – вредный, вредоносный
demanding [dɪ'mɑːndɪŋ] – требовательный, трудный, трудоёмкий, ответственный
demonstrate convincingly ['demənstreɪt kən'vɪnsɪŋlɪ] – ярко продемонстрировать, убедительно показать
density ['densɪtɪ] – плотность, концентрация, интенсивность
density modulation ['densɪtɪˌmɔdjə'leɪʃ(ə)n] – модуляция по плотности, плотностная модуляция (*пучка*)
depart [dɪ'pɑːt] – отступать, отклоняться
departure [dɪ'pɑːʧə] – уход, отступление, отклонение (*параметра от заданного значения*);
departure from the law – отступление от закона
depend (*on*) [dɪ'pend] – зависеть (от)
dependent (*on*) [dɪ'pendənt] – зависящий (от), обусловленный
deplete [dɪ'pliːt] – обеднять, истощать, исчерпывать, уменьшать
deposition [ˌdepə'zɪʃ(ə)n] – осаждение, выделение (*металла на аноде или катоде при электролизе*), выпадение, депонирование, нанесение (*покрытий, плёнок и т.п.*), напыление, отложение
depth dimension [ˌdepθdaɪ'menʃ(ə)n] – вертикальные размеры
desirable [dɪ'zaɪərəbl] – желательный
desired [dɪ'zaɪəd] – искомый, требуемый
detail ['diːteɪl] – деталь, подробность ‖ детализировать, подробно освящать
detect [dɪ'tekt] – обнаруживать, определять, детектировать
detectable [dɪ'tektəbl] – обнаружимый, обнаруживаемый
detected [dɪ'tektɪd] – обнаруженный, замеченный

detecting [dɪˈtektɪŋ] – обнаружение ‖ обнаруживающий
detection [dɪˈtekʃ(ə)n] – обнаружение, детектирование, выявление, регистрация, открытие
detector [dɪˈtektə] – детектор, датчик, индикатор, регистратор, чувствительный элемент
detector output [dɪˌtektərˈautput] – выход детектора, выходной сигнал детектора
development [dɪˈveləpmənt] – разработка, проектирование, конструирование; развитие, совершенствование, доводка; проявление, проявка
deviate [ˈdiːvɪeɪt] – отклоняться, отступать
diaphragm [ˈdaɪəfræm] – диафрагма, мембрана (*чувствительный элемент*) ‖ диафрагмировать
dielectric [ˌdaɪɪˈlektrɪk] – диэлектрик ‖ диэлектрический
dielectric insulator [ˌdaɪɪˈlektrɪk ˈɪnsjəleɪtə] – диэлектрический изолятор
difference of potentials [ˈdɪf(ə)r(ə)ns əv pəˈtenʃ(ə)lz] – разность потенциалов
differentiate (*from, between*) [ˌdɪf(ə)ˈrenʃɪeɪt] – различать, разграничивать, отличать
diffracted beam [dɪˌfræktɪdˈbiːm] – отражённый луч, отражённый пучок, дифрагированный луч
diffuse [dɪˈfjuːz] – рассеивать;
diffuse the light from a source – рассеивать свет от источника
diffused hologram [dɪˌfjuːzd ˈhɔləgræm] – голограмма, полученная при диффузном освещении; голограмма, полученная при освещении диффузным когерентным светом
diffusive [dɪˈfjuːsɪv] – диффузионный, рассеивающий
digital modulation [ˈdɪʤɪt(ə)lˌmɔdjəˈleɪʃ(ə)n] – цифровая модуляция
dilute electron beam [daɪˈluːt ɪˈlektrɔnˌbiːm] – низкоэнергетический электронный пучок
dim [dɪm] – тусклый, неяркий, слабый (*о светящихся объектах*)
direct bandgap semiconductor [dɪˌrekt ˈbændˌgæpˌsemɪkənˈdʌktə] – собственный, беспримесный полупроводник
direct imaging [dɪˌrektˈɪmɪʤɪŋ] – прямое изображение
directed energy weapons [dɪˈrektɪdˌenəʤɪ ˈwepənz] – энергетическое оружие направленного действия, лазерное оружие
discern [dɪˈsɜːn] – различать, разглядеть, распознавать
discharge [dɪsˈʧɑːʤ] – разряд, электрический разряд
discharge lamp [dɪsˈʧɑːʤˌlæmp] – газоразрядная лампа
discontinuous [ˌdɪskənˈtɪnjuəs] – прерываемый, дискретный
discrete [dɪˈskriːt] – дискретный, прерывистый
dispense with [dɪˈspenswɪð] – обходиться без
dispersion [dɪˈspɜːʃ(ə)n] – диспергирование, дисперсия, дисперсность, рассеяние ‖ дисперсионный
dissociated molecule [dɪˌsəuʃɪeɪtɪd ˈmɔlɪkjuːl] – диссоциированная молекула
distant [ˈdɪst(ə)nt] – дистанционный, удалённый, дальний, далёкий, отдалённый
distant point source [ˌdɪst(ə)nt ˈpɔɪntˌsɔːs] – удалённый точечный источник
distinct [dɪˈstɪŋkt] – различный, особый, явный, отдельный, особый, ясный, отчетливый

distinctive property [dɪˌstɪŋktɪv 'prɔpətɪ] – характерная особенность
distinguish [dɪ'stɪŋgwɪʃ] – отличать, различать, выделять, отмечать, распознавать
distinguish cause from effect – различать причину и следствие
distinguishable [dɪ'stɪŋgwɪʃəbl] – различимый, видимый, заметный
distort [dɪ'stɔːt] – искажать, деформировать, искривлять
distorting medium [dɪˌstɔːtɪŋ 'miːdɪəm] – деформирующая среда, искажающая среда
distortion [dɪ'stɔːʃ(ə)n] – искажение, деформация, искривление, дисторсия
distributed Raman amplifier (*DRA*) – распределённый Рамановский усилитель
disturbance [dɪ'stɜːb(ə)ns] – распределение поля возмущения
diverge [daɪ'vɜːʤ] – расходиться, отходить, отклоняться
divergence [daɪ'vɜːʤəns] – расхождение, отклонение
diverging beam [daɪˌvɜːʤɪŋ'biːm] – расходящийся пучок
diverging lens [daɪˌvɜːʤɪŋ'lenz] – рассеивающая линза, отрицательная линза
diversity [daɪ'vɜːsɪtɪ] – разнообразие, многообразие, разнородность
docking maneuver [ˌdɔkɪŋmə'nuːvə] – манёвр стыковки с включением двигателя, манёвр стыковки
doctoral fellowship [ˌdɔkt(ə)r(ə)l 'feləuʃɪp] – докторантская стипендия
domain period [dəu'meɪnˌpɪərɪəd] – период доменной структуры, шаг доменной структуры
domain wall [dəu'meɪnˌwɔːl] – доменная граница, стенка домена
domestic production [dəˌmestɪk prə'dʌkʃ(ə)n] – отечественное производство, продукция отечественного производства
dope [dəup] – активировать (*о лазерных материалах*), легировать (*полупроводник*) ‖ легирующая добавка, добавка, легирующая примесь
Doppler method – доплеровский метод
double-pulse hologram ['dʌblˌpʌls 'hɔləgræm] – двухэкспозиционная голограмма
double refraction [ˌdʌbl rɪ'frækʃ(ə)n] – двулучепреломление
doubling of an image [ˌdʌblɪŋ əv ən 'ɪmɪʤ] – удвоение, сдваивание изображения
download ['daunləud] – загружать (*дистанционно по каналу связи*), скачивать (файл) ‖ скачиваемый файл
dramatic [drə'mætɪk] – исключительно сильный, резкий, существенный (*об изменениях*)
drawback ['drɔːbæk] – недостаток, погрешность, изъян, отрицательная сторона
drift [drɪft] – дрейф, смещение, уход, сдвиг, медленное изменение параметров ‖ уходить, смещать
duct [dʌkt] – труба, канал, проток, волновод, короб
due [djuː] – соответствующий, надлежащий
DWDM (*Dense Wavelength Division Multiplexing*) ([ˌdens'weɪvleŋθ dɪˌvɪʒ(ə)n 'mʌltɪpleksɪŋ]) – спектральное уплотнение, мультиплексирование с разделением по спектральной плотности
dye cell ['daɪˌsel] – ячейка с красителем, кювета с красителем (*для лазера*)
dye-cell Q-switch ['daɪˌsel 'kjuːswɪʧ] – модуляция добротности на ячейке с красителем
dye laser ['daɪleɪzə] – лазер на красителе, оптический квантовый генератор на пигментах

dye solution [ˈdaɪˌsəˈluːʃ(ə)n] – раствор красителя
dynamic response [daɪˌnæmɪk rɪˈspɔns] – динамическая характеристика, частотная характеристика

E

earn a master's degree [ˈɜːnə ˌmɑːstəz dɪˈgriː] – получить степень магистра
earn PhD [ˈɜːnəˌpiːeɪtʃˈdiː] – получить степень доктора философии
effective focal length [ɪˌfektɪv ˈfəuk(ə)lˌleŋθ] – полезное (*эквивалентное*) фокусное расстояние
effective path length [ɪˌfektɪv ˈpɑːθˌleŋθ] – эффективная длина луча, эффективная длина пути
efficiency [ɪˈfɪʃəntsɪ] – эффективность, кпд, производительность, коэффициент полезного действия
efficiency factor [ɪˈfɪʃəntsɪˌfæktə] – коэффициент эффективности, показатель эффективности
elaborate [ɪˈlæb(ə)rɪt] – тщательно разработанный, продуманный, сложный, замысловатый ‖ [ɪˈlæb(ə)reɪt] – детально разрабатывать (*тему, вопрос*); конкретизировать, развивать, уточнять; придавать законченный вид (*теории, изобретению*)
electric field intensity [ɪˈlektrɪkˌfiːld ɪnˈtensətɪ] – напряжённость электрического поля
electric insulator [ɪˌlektrɪk ˈɪnsjəleɪtə] – диэлектрик, электрический изолятор
electric power cable [ɪˌlektrɪk ˈpauəˌkeɪbl] – электрический кабель, кабель дальней связи
electric vector [ɪˌlektrɪk ˈvektə] – электрический вектор, вектор напряжённости электрического поля
electrical discharge [ɪˌlektrɪk(ə)l dɪsˈtʃɑːʤ] – электроразряд, электрический разряд
electrical hazard [ɪˌlektrɪk(ə)l ˈhæzəd] – опасность поражения электрическим током
electricity grid [ˌelekˈtrɪsətɪˌgrɪd] – электрическая сеть
electrocute [ɪˈlektrəkjuːt] – убивать электрическим током, оглушать электрическим током
electromagnetic theory of light [ɪˌlektrə(u)mægˈnetɪkˌθɪərɪəvˈlaɪt] – электромагнитная теория света
electron beam [ɪˌlektrɔnˈbiːm] – пучок электронов
electron beam excitation [ɪˌlektrɔnˈbiːmˌeksɪˈteɪʃ(ə)n]/[-ˈsaɪ-] – возбуждение электронным пучком, электронное возбуждение
electron-beam-pumped laser [ɪˌlektrɔnˈbiːmˌpʌmptˈleɪzə] – оптический квантовый генератор с электронной накачкой, лазер с накачкой электронным пучком
electron velocity [ɪˌlektrɔn vɪˈlɔsətɪ] – скорость электронов, скорость движения электрона
electronic circuitry [ˌelekˈtrɔnɪk ˈsɜːkɪtrɪ] – электронные схемы, электронная схематика
electronic energy levels [ˌelekˈtrɔnɪk ˈenəʤɪˌlev(ə)lz] – электронные уровни энергии
electronic gaming [ˌelekˈtrɔnɪk ˈgeɪmɪŋ] – электронные игры

electronic supplies [ˌelek'trɔnɪk sə'plaɪz] – источники питания электронного оборудования
electronic transition [ˌelek'trɔnɪk træn'zɪʃ(ə)n] – электронный переход
electro-optic Q-switch [ɪˌlektrəu'ɔptɪk 'kjuːswɪʧ] – электрооптический модулятор добротности
eliminate the need (*for*) [ɪ'lɪmɪneɪt ðə'niːd fə] – устранить необходимость
eliminate the problem [ɪ'lɪmɪneɪt ðə 'prɔbləm] – устранить проблему, устранять затруднение
elsewhere [ˌels'weə] – в других местах, в других источниках, где-либо ещё
embody [ɪm'bɔdɪ] – воплощать в жизнь, олицетворять, заключать в себе, содержать, олицетворять, осуществлять, реализовывать, осуществлять (*идею*)
emerge [ɪ'mɜːʤ] – появляться, возникать; выясняться, всплывать, обнаруживаться
emerge from [ɪ'mɜːʤ frəm] – появляться, выходить из
emission [ɪ'mɪʃ(ə)n] – излучение, эмиссия электронов
emission spectrum [ɪˌmɪʃ(ə)n 'spektrəm] – спектр излучения, спектр испускания, эмиссионный спектр
emit [ɪ'mɪt] – излучать, испускать, выделять; эмитировать
emitter [ɪ'mɪtə] – излучатель, источник излучения, эмитирующий электрод, эмиттер, излучатель, генератор, источник излучения
emphasize ['emfəsaɪz] – подчеркивать, выделять, акцентировать
enable [ɪ'neɪbl] – делать возможным, давать возможность, облегчать; запускать, задействовать; подключать, включать
encounter obstacles [ɪn'kauntər'ɔbstəklz] – наталкиваться на препятствия
energy density ['enəʤɪˌdensɪtɪ] – плотность энергии, интенсивность энергии
energy gap ['enəʤɪˌgæp] – энергетическая зона, запрещённая зона, ширина запрещённой зоны
energy levels ['enəʤɪˌlev(ə)lz] – энергетические уровни
energy states ['enəʤɪˌsteɪts] – энергетические состояния
energy storage ['enəʤɪˌstɔːrɪʤ] – накопление и хранение энергии
energy threshold ['enəʤɪˌθreʃ(h)əuld] – энергетический порог
engage in [ɪn'geɪʤ ɪn] – заниматься, заняться, приступить
enhance [ɪn'hɑːns] – повышать, улучшать, усиливать, увеличивать, усугублять
enjoy rebirth [ɪn'ʤɔɪˌriː'bɜːθ] – возрождаться, появляться вновь
ensue [ɪn'sjuː] – следовать, получаться в результате
ensuing decades [ɪnˌsjuːɪŋ'dekeɪdz] – следующие десятилетия
ensure [ɪn'ʃuə] – обеспечивать, гарантировать;
ensure data quality – обеспечивать качество данных
entangled light [ɪnˌtæŋgld'laɪt] – запутанный свет
enunciate an idea [ɪ'nʌnsɪeɪt ən aɪ'dɪə] – сформулировать идею, изложить идею
equal ['iːkwəl] – равный, одинаковый ‖ быть равным, равняться
equidistant planes [ˌiːkwɪ'dɪst(ə)nt 'pleɪnz] – равноотстоящие плоскости
erbium (Er) ['ɜːbɪəm] – эрбий
erbium-doped ['ɜːbɪəmˌdəupt] – легированный эрбием
erbium-doped fiber amplifier (*EDFA*) ['ɜːbɪəmˌdəuptˌfaɪbər 'æmplɪfaɪə] – волоконный усилитель с добавкой эрбия; волоконный усилитель, легированный эрбием

error margin [ˈerəˌmɑːʤɪn] – предел погрешности, допустимая погрешность, предельно допустимая ошибка
essential [ɪˈsenʃəl] – необходимый, неотъемлемый, существенный
essentially [ɪˈsenʃ(ə)lɪ] – по существу, существенно, главным образом
et al. (*Lat.*) [etˈæl] – и другие
evidence [ˈevɪd(ə)ns] – основание, доказательство, свидетельство
exact [ɪgˈzækt] – точный, строгий, верный
exceed [ɪkˈsiːd] – превышать, превосходить
exceed a threshold [ɪkˌsiːdəˈθreʃ(h)əuld] – превышать порог
exceed the threshold value [ɪkˌsiːd ðə ˈθreʃ(h)əuldˌvæljuː] – превышать пороговые значения
exceptional [ɪkˈsepʃ(ə)n(ə)l] – исключительный, необычайный, выдающийся
excess carrier [ɪkˌses ˈkærɪə] – возбужденный электрон проводимости, электрон с избыточной энергией, избыточный носитель заряда
excess energy [ɪkˌsesˈenəʤɪ] – избыточная энергия
exchange [ɪksˈʧeɪnʤ] – коммутационная станция; обмен; передача; смена, замена ‖ обменивать(ся), заменять
excimer laser [ˈeksəməˌleɪzə] – эксимерный лазер
excitation energy [ˌeksɪˈteɪʃ(ə)n ˈenəʤɪ] – энергия возмущения, энергия вынужденных колебаний, энергия возбуждения
excitation method [ˌeksɪˈteɪʃ(ə)n ˈmeθəd] – метод накачки, метод возбуждения
excitation parameter [ˌeksɪˈteɪʃ(ə)n pəˈræmɪtə] – эффективность возбуждения
excitation technique [ˌeksɪˈteɪʃ(ə)n tekˈniːk] – способ, метод возбуждения
excite [ɪkˈsaɪt] – возбуждать (*колебания*), вызывать, стимулировать
excited state [ɪkˌsaɪtɪd ˈsteɪt] – возбужденное состояние
exclude [ɪksˈkluːd] – исключать
exclusive [ɪksˈkluːsɪv] – исключительный, особый
exclusively [ɪksˈkluːsɪvlɪ] – исключительно
exhibit [ɪgˈzɪbɪt] – проявлять, обнаруживать
existence proof [ɪgˈzɪst(ə)ns ˈpruːf] – доказательство существования
exoplanet [ˈeksəuˌplænɪt] – экзопланета, экстрасолнечная планета
expectation [ˌekspekˈteɪʃən] – ожидание, надежда, предположение
experience [ɪkˈspɪərɪəns] – (*жизненный*) опыт, переживание ‖ испытывать, чувствовать
exploration [ˌekspləˈreɪʃ(ə)n] – исследование, изыскательская работа
explore [ɪkˈsplɔː] – исследовать, изучать, обследовать
explorer [ɪkˈsplɔːrə] – исследователь
explosive mixture [ɪkˌspləusɪvˈmɪksʧə] – взрывчатая смесь, взрывоопасная смесь
exponentially [ˌekspəˈnenʃlɪ] – экспоненциально, по экспоненте, по экспоненциальному закону
exposure [ɪkˈspəuʒə] – облучение, воздействие, экспозиция
exposure curve [ɪkˈspəuʒəˌkɜːv] – характеристическая кривая, кривая почернения
exposure limit [ɪkˈspəuʒəˌlɪmɪt] – предел облучения, предельно допустимый уровень воздействия, предел экспозиции
extend to infinity [ɪkˈstend tə ɪnˈfɪnətɪ] – уходить в бесконечность
extended source [ɪkˌstendɪdˈsɔːs] – протяжённый источник, неточечный источник

extender mirror [ɪk'stendəˌmɪrə] – зеркало для увеличения оптического пути
extensive [ɪk'stensɪv] – обширный, подробный, пространный, широкий
exterior surface [ɪkˌstɪərɪə 'sɜːfɪs] – внешняя поверхность, наружная поверхность
external [ɪk'stɜːn(ə)l] – внешний, наружный, выносной
extract [ɪk'strækt] – извлекать, удалять
extraordinary ray [ɪkˌstrɔːd(ə)n(ə)rɪ'reɪ] – необыкновенный луч, X-составляющая радиоизлучения при его распространении через ионосферу
extrapolation [ɪkˌstræpə'leɪʃ(ə)n] – экстраполяция, экстраполирование, распространение
extreme [ɪks'triːm] – край, предел, экстремум ‖ крайний, предельный, экстремальный
extremum (*pl*) extrema) [ɪk'striːməm] ([ɪk'striːmə]) – экстремальное значение
eye injury [ˌaɪ 'ɪnʤ(ə)rɪ] – травма глаз

F

fabricate ['fæbrɪkeɪt] – производить, изготовлять
fabrication [ˌfæbrɪ'keɪʃ(ə)n] – производство, изготовление
factor ['fæktə] – фактор, коэффициент, показатель
faint object [ˌfeɪnt'ɔbʤɪkt] – слабый объект, объект с небольшой интенсивностью излучения
false alarm [ˌfɔːlsə'lɑːm] – ложная тревога, сигнал ложной тревоги
familiar [fə'mɪlɪə] – знакомый, привычный, хорошо известный, близкий
fan out ['fæn'aut] – развёртываться веером, рассеиваться
far infrared spectral region [ˌfɑːrˌɪnfrə'redˌspektr(ə)l'riːʤ(ə)n] – дальняя инфракрасная область спектра
feature ['fiːʧə] – характеристика, параметр; особенность, (*отличительный*) признак, свойство
feed (fed – fed) [fiːd] – подавать, питать, снабжать, возбуждать, вводить
feel uneasy [ˌfiːl ʌn'iːzɪ] – терзаться, беспокоиться
ferroelectric crystal [ˌferəuɪ'lektrɪk 'krɪst(ə)l] – сегнетоэлектрический кристалл, ферроэлектрик
fiber bundle ['faɪbəˌbʌndl] – оптический кабель, волоконно-оптический жгут, волоконно-оптический кабель
fiber core ['faɪbəˌkɔː] – сердцевина волокна, световодная жила, центральная жила оптического волокна
fiber laser ['faɪbəˌleɪzə] – волоконный лазер
fiber losses ['faɪbəˌlɔsɪz] – потери в световоде, потери в волокне
field of view [ˌfiːldəv'vjuː] – зона обзора, зона видимости, поле обзора
figure of merit [ˌfɪgərəv'merɪt] – показатель качества, показатель добротности, качественный показатель
film [fɪlm] – плёнка
find one's way into – пробивать себе путь в, с трудом пробиваться, прокладывать себе дорогу
find out ['faɪnd'aut] – узнать, разузнать, выяснить; понять

fine-grain emulsion [ˈfaɪnˌgreɪn ɪˈmʌlʃ(ə)n] – мелкозернистая фотографическая эмульсия, мелкозернистая эмульсия
finish [ˈfɪnɪʃ] – производить финишную обработку, отделывать начисто, обрабатывать начисто
finite [ˈfaɪnaɪt] – конечный, ограниченный, имеющий предел
first light [ˌfɜːst ˈlaɪt] – рассвет
first priority [ˌfɜːst praɪˈɔrətɪ] – первоочерёдная задача
first pulse mode [ˈfɜːstˌpʌls ˈməud] – измерение дальности по первому импульсу
flashlamp [ˈflæʃlæmp] – импульсная лампа, лампа накачки
flashlight [ˈflæʃlaɪt] – карманный электрический фонарь
flat white paint – матовые белила, краска матового белого цвета
flaw [flɔː] – изъян, дефект, слабое место, недостаток
flexibility [ˌfleksɪˈbɪlətɪ] – гибкость, податливость
flicker [ˈflɪkə] – короткая вспышка, мерцание, мелькание, фликкер-шум ‖ мерцать, мелькать
flight time [ˈflaɪtˌtaɪm] – время пролета, продолжительность полёта
flint glass [ˈflɪntˌglɑːs] – оптическое стекло
flow [fləu] – течение, поток
fluence [ˈfluːəns] – флюенс, интенсивность потока, поток энергии
fluorescence [flɔːˈresəns]/[fluə-] – люминесценция, свечение, флуоресценция
fluorescent [flɔːˈresnt]/[fluə-] – флуоресцентный, флуоресцирующий, люминесцентный
fluorine (*F*) [ˈflɔːriːn]/[ˈfluə-] – фтор
flux [flʌks] – течение, интенсивность потока, поток (*излучения*)
focal plane [ˈfəuk(ə)lˌpleɪn]] – фокальная плоскость
focus [ˈfəukəs] – фокус ‖ фокусировать
focus on [ˈfəukəs ən] – обращать особое внимание на, делать упор
focused radiation [ˈfəukəstˌreɪdɪˈeɪʃ(ə)n] – сфокусированное излучение
follow precautions [ˈfɔləu prɪˈkɔːʃ(ə)nz] – соблюдать меры предосторожности
for economic reasons [fərˌiːkəˈnɔmɪk ˈriːz(ə)nz] – по экономическим соображениям
for our purpose [fərˌauəˈpɜːpəs] – условно, для данных целей
for simplicity [fə sɪmˈplɪsətɪ] – для простоты, для упрощения
for this reason [fə ðɪs ˈriːz(ə)n] – по этой причине, поэтому, на основании этого
formidable problem [ˌfɔːmɪdəbl ˈprɔbləm] – серьезная проблема, труднопреодолимая проблема
fortunately [ˈfɔːʧ(ə)nətlɪ] – к счастью, по счастью
Fourier analysis [ˈfurrɪeɪ əˌnælɪsiːz] – гармонический анализ, анализ Фурье
four-wave mixing [ˈfɔːˌweɪv ˈmɪksɪŋ] – четырехволновое взаимодействие, четырехволновое смешение
fraction [ˈfrækʃ(ə)n] – частица, доля, часть
Fraunhofer diffraction – дифракция Фраунгофера
free of – не содержащий, без
free-electron laser (*FEL*) [ˌfriːɪˈlektrɔnˌleɪzə] – лазер на свободных электронах
free-free transition [ˈfriːˌfriː trænˈzɪʃ(ə)n] – свободно-свободный переход

frequency [ˈfriːkwənsɪ] – частота
frequency conversion [ˈfriːkwənsɪ kənˈvɜːʃ(ə)n] – преобразование частоты
frequency doubling [ˈfriːkwənsɪˌdʌblɪŋ] – удвоение частоты
frequency doubling laser device [ˈfriːkwənsɪˌdʌblɪŋ ˈleɪzədɪˌvaɪs] – устройство удвоения частоты генерации лазера
frequency down-conversion [ˌfriːkwənsɪˈdaun kənˌvɜːʃ(ə)n] – преобразование с понижением частоты, понижающее преобразование
frequency range [ˈfriːkwənsɪˌreɪnʤ] – полоса частот, частотный диапазон
frequency up-conversion [ˌfriːkwənsɪˈʌp kənˌvɜːʃ(ə)n] – преобразование с повышением частоты
frequency-doubled [ˈfriːkwənsɪˌdʌbld] – с удвоенной частотой, с удвоением частоты
Fresnel diffraction [freɪˈnel dɪˈfrækʃ(ə)n] – дифракция Френеля, френелевская дифракция
fringe [frɪnʤ] – полоса, граничная зона, граница
fundamental measurement [ˌfʌndəˈment(ə)l ˈmeʒəmənt] – основное измерение, первичное измерение
fundamental mode [ˌfʌndəˈment(ə)lˈməud] – мода низшего порядка, основная мода колебаний
fundamentals [ˌfʌndəˈmentlz] – основные принципы, основы
furnish information about [ˈfɜːnɪʃ ˌɪnfəˈmeɪʃ(ə)n əˌbaut] – предоставить информацию о
further [ˈfɜːðə] – затем, далее
furthermore [ˌfɜːðəˈmɔː] – к тому же, кроме того, более того
fused quartz [ˌfjuːzdˈkwɔːts] – плавленный кварц
fuzzy [ˈfʌzɪ] – неопределённый, запутанный, расплывчатый, размытый, нечёткий

G

gain [geɪn] – усиление, коэффициент усиления
gain bandwidth [ˌgeɪnˈbandwɪdθ] – ширина полосы усиления, добротность, произведение коэффициента усиления на ширину полосы пропускания
gain curve [ˈgeɪnˌkɜːv] – контур усиления, кривая усиления, амплитудная характеристика
gain depletion [ˌgeɪn dɪˈpliːʃ(ə)n] – затухание усиления
gain medium [ˌgeɪnˈmiːdɪəm] – усиливающая среда, активная среда
gallium arsenide (GaAs) [ˌgælɪəmˈɑːsəˌnaɪd] – арсенид галлия
gap [gæp] – запрещённая (*энергетическая*) зона, зона нечувствительности; зазор, промежуток, интервал
gasdynamic expansion [ˌgæsdaɪˈnæmɪk ɪkˈspænʃ(ə)n] – газодинамическое расширение
gasdynamic laser [ˌgæsdaɪˈnæmɪkˈleɪzə] – газодинамический лазер
Gaussian [ˈgausɪən] – гауссиан
Gaussian curve [ˌgausɪənˈkɜːv] – колоколообразная кривая, гауссова кривая, кривая Гаусса
Gaussian function [ˌgausɪən ˈfʌŋkʃ(ə)n] – функция Гаусса, гауссова функция
Gbit [ˈgɪgəbɪt] – гигабит

general purpose laser [ˌʤen(ə)r(ə)l'pɜːpəs'leɪzə] – лазер общего назначения
generalize ['ʤen(ə)r(ə)laɪz] – обобщать, делать общие выводы
generate harmonics ['ʤen(ə)reɪt hɑː'mɔnɪks] – генерировать гармоники
generically [ʤɪ'nerɪkəlɪ] – в общем
geometrical optics [ˌʤɪə'metrɪk(ə)l) 'ɔptɪks] – геометрическая оптика
germanium (Ge) [ʤɜː'meɪnɪəm] – германий
get rid of [ˌget 'rɪdəv] – избавиться
get right [ˌget 'raɪt] – правильно, прекрасно понять, быть совершенно ясным
giant planets [ˌʤaɪənt 'plænɪts] – планеты – гиганты, большие планеты (*Юпитер, Сатурн, Уран, Нептун*)
gigahertz (GHz) ['gɪgəˌhɜːts]/ ['dʒɪg-] – гигагерц (ГГц)
Gillette [dʒɪ'let] – «жиллетт»
give off light ['gɪv'ɔf 'laɪt] – излучать свет, испускать свет
given [gɪv(ə)n] – при наличии; при условии, если; учитывая, что
glass laser ['glɑːsˌleɪzə] – лазер на стекле
glass plate ['glɑːsˌpleɪt] – стеклянная пластинка, стеклянная плитка
glimpse [glɪmps] – некоторое представление, беглое знакомство
glow discharge ['gləu dɪsˌʧɑːʤ] – тлеющий разряд
goal [gəul] – задача, цель
good-quality [ˌgud 'kwɔlətɪ] – добротный, хорошего качества
gradation [grə'deɪʃ(ə)n] – градация,оттенок, постепенный переход; ступенчатость, постепенность; гранулометрический состав
gradual ['grædjuəl] – градуальный, постепенный, последовательный
gradually ['grædjuəlɪ] – постепенно, мало-помалу, понемногу
graininess ['greɪnɪnəs] – зернистость, зернистая структура
grating ['greɪtɪŋ] – дифракционная решётка, решётка, сетка (*в интерференционных методах*)
ground level ['graundˌlev(ə)l] – основной энергетический уровень, основной уровень (*колебательный*)
ground potential ['graundpəˌtenʃ(ə)l] – электрический потенциал Земли
ground state ['graundˌsteɪt] – основное состояние (*в многоуровневой системе*), основное (*квантовое*) состояние
ground-based laser ['graundˌbeɪst 'leɪzə] – лазер наземного базирования, наземный лазер
grow exponentially ['grəuˌekspə'nenʃlɪ] – расти экспоненциально, расти по экспоненте
grow in importance ['grəu ɪn ɪm'pɔːt(ə)ns] – становиться более значительным, становиться всё более важным
GW (*gigawatt*) ['gigəˌwɔt] – ГВт (*гигаватт*)

H

handle ['hændl] – обрабатывать, управлять, обращаться, работать, оперировать
harm [hɑːm] – вред, ущерб, зло ‖ причинять вред, вредить, наносить вред
harmful ['hɑːmf(ə)l] – вредный, вредоносный
harmful environment [ˌhɑːmf(ə)l ɪn'vaɪər(ə)nmənt] – неблагоприятная среда

harmonics [hɑː'mɔnɪks] – гармоники, пульсации, гармоника
harmonics generation [hɑː'mɔnɪks ˌʤenə'reɪʃ(ə)n] – генерация гармоник
harsh light [ˌhɑːʃ'laɪt] – резкий свет
have to do with – иметь отношение к
haze [heɪz] – дымка, лёгкий туман, мгла, атмосферная дымка
head amplifier [ˌhed 'æmplɪfaɪə] – предусилитель, выносной усилитель
health and safety [ˌhelθ ən(d) 'seɪftɪ] – гигиена труда и техника безопасности, безопасность жизнедеятельности, здоровье и безопасность
health hazards ['helθˌhæzədz] – вредные условия производства, угроза для здоровья, вред для здоровья, угроза для здоровья
heat capacity ['hiːt kəˌpæsətɪ] – теплоёмкость
heat-absorbing ['hiːtəbˌzɔːbɪŋ] – теплопоглощающий, эндотермический
heterodyne detection ['het(ə)rəudaɪn dɪˌtekʃ(ə)n] – гетеродинный прием, гетеродинное детектирование
heterojunction ['het(ə)rə(u)ˌʤʌŋkʃ(ə)n] – гетеропереход, неоднородный переход в полупроводниковом приборе
high accuracy [ˌhaɪ 'ækjərəsɪ] – высокая точность, малая погрешность
high brightness [ˌhaɪ 'braɪtnəs] – с повышенной яркостью
high density [ˌhaɪ 'densɪtɪ] – высокоплотный, с высокой плотностью
high energy electron [ˌhaɪ'enəʤɪ ɪ'lektrɔn] – электрон высокой энергии
high energy level [ˌhaɪ'enəʤɪ 'lev(ə)l] – высокий энергетический уровень
high voltage electric power cable [ˌhaɪ'vəultɪʤ ɪ'ˌlektrɪk 'pauəˌkeɪbl] – высоковольтный электрический кабель
high-end [ˌhaɪ'end] – высококачественный, удовлетворяющий самым высоким требованиям
high-performance [ˌhaɪ pə'fɔːməns] – с высокими характеристиками, высокоэффективный
high-power laser [ˌhaɪ'pauə 'leɪzə] – мощный лазер, лазер большой мощности
high-speed counter [ˌhaɪ'spiːd 'kauntə] – высокоскоростной счётчик, быстродействующий счётчик
high-speed network [ˌhaɪ'spiːd 'netwɜːk] – высокоскоростная сеть
high-technology [ˌhaɪtek'nɔləʤɪ] – высокотехнологичный, наукоёмкий
high-threshold [ˌhaɪ 'θreʃ(h)əuld] – высокопороговый, с высоким пороговым уровнем
higher-order [ˌhaɪər'ɔːdə] – высокого порядка, более высокого порядка
higher-order harmonics [ˌhaɪər'ɔːdə hɑː'mɔnɪks] – гармоники более высокого порядка
higher-order modes [ˌhaɪər'ɔːdəˌməud] – моды высшего порядка
hinder ['hɪndə] – затруднять, замедлять, задерживать, препятствовать, мешать, быть помехой, тормозить
hole-electron pair [ˌhəul ɪ'lektrɔnˌpeə] – пара дырка-электрон
holmium (*Ho*) ['həulmɪəm]/['hɔl-] – гольмий
hologram reconstruction ['hɔləgræmˌriːk(ə)n'strʌkʃ(ə)n] – воспроизведение голограммы, восстановление голограммы
hologram recording ['hɔləgræm rɪ'kɔːdɪŋ] – регистрация голограммы
hologram interferometry ['hɔləgræmˌɪntəfə'rɔmɪtrɪ] – голографическая интерферометрия

holographic information storage [hɔlə'græfɪkˌɪnfə'meɪʃ(ə)n 'stɔːrɪʤ] – голографическое ЗУ

holographic interferometry [ˌhɔlə'græfɪk ˌɪntəfə'rɔmɪtrɪ] – голографическая интерферометрия

holographic motion pictures [hɔlə'græfɪk ˌməuʃ(ə)n 'pɪkʧəz] – голографический кинематограф

holography [hɔ'lɔgrəfɪ] – голография, получение голограмм

homogeneity [ˌhəuməʤɪ'nɪːɪtɪ]/[ˌhəuməuʤə'neɪətɪ] – гомогенность, однородность (*по составу*)

homogeneous [ˌhɔmə'ʤiːnɪəs] – однородный, гомогенный

host crystal ['həustˌkrɪst(ə)l] – основа, матрица, основной кристалл, кристалл-хозяин

however [hau'evə] – однако, тем не менее, несмотря на то, впрочем

humble ['hʌmbl] – простой, скромный;
humble pair of spectacles – простые очки (скромная пара очков)

Huygens' principle ['hɔɪgənzˌprɪnsəpl] – принцип Гюйгенса

I

ideal coding [aɪ'dɪəl 'kəudɪŋ] – идеальное кодирование

identical [aɪ'dentɪk(ə)l] – одинаковый, тождественный, однозначный, аналогичный

identification [aɪˌdentɪfɪ'keɪʃ(ə)n] – отождествление, распознавание, идентификация

identify [aɪ'dentɪfaɪ] – определить, идентифицировать, выявить, устанавливать

illuminate [ɪ'l(j)uːmɪneɪt] – освещать, облучать

illuminate uniformly [ɪ'l(j)uːmɪneɪt 'juːnɪfɔːmlɪ] – равномерно освещать

illuminated [ɪ'l(j)uːmɪneɪtɪd] – освещенный, светящийся, облучаемый

image ['ɪmɪʤ] – изображение ‖ изображать, формировать изображение

image enhancement [ˌɪmɪʤ ɪn'hɑːnsmənt] – улучшение изображения, повышение чёткости изображения, усиление изображения

image processing [ˌɪmɪʤ 'prəusesɪŋ] – обработка изображений

imager ['ɪmɪdʒə] – устройство формирования изображения, формирователь изображения

imaging ['ɪmɪʤɪŋ] – формирование изображения, отображение, получение изображения, визуализация

imaging sensor [ˌɪmɪʤɪŋ 'sensə] – датчик изображения, прибор обнаружения, датчик системы формирования изображений

immunity [ɪ'mjuːnɪtɪ] – иммунитет, невосприимчивость, устойчивость, защищённость

impediment [ɪm'pedɪmənt] – препятствие, помеха, затруднение, задержка, препона

imply [ɪm'plaɪ] – заключать в себе, значить, подразумевать, предполагать, иметь следствием

impose limitations on [ɪm'pəuz ˌlɪmɪ'teɪʃənz ɔn] – налагать ограничения на

improbable [ɪm'prɔbəbl] – невероятный, неправдоподобный, маловероятный, практически невозможный

impurity [ɪm'pjuərɪtɪ] – примесь (*нежелательная*), включение (*посторонее*)
impurity-doped [ɪm'pjuərətɪˌdəupt] – легированный, легированный примесью
impurity-doped crystal [ɪm'pjuərətɪˌdəupt 'krɪst(ə)l] – кристалл о примесями
in a stepwise fashion [inə'stepwaɪzˌfæʃ(ə)n] – ступенями, постепенно, шаг за шагом
in addition [ɪnə'dɪʃ(ə)n] – в добавление, к тому же, сверх, кроме того
in any case [ɪn'enɪˌkeɪs] – так или иначе, в любом случае, при любых обстоятельствах
in broad terms [ɪnˌbrɔːd 'tɜːmz] – в целом, в общих чертах
in certain cases [ɪnˌsɜːt(ə)n 'keɪsɪz] – в отдельных случаях, в ряде случаев
in concert with [ɪn'kɔnsət wɪð] – во взаимодействии с, согласованно с, вместе с
in contrast to [ɪn'kɔntrɑːst tə] – в отличие от, в противоположность, наоборот, напротив
in doing so [ɪn'duːɪŋ səu] – при этом, с этой целью
in either case [ɪn 'aɪðəˌkeɪs] – в обоих случаях
in fact [ɪn'fækt] – фактически, в действительности, на самом деле
in general [ɪn'ʤen(ə)r(ə)l] – вообще, обычно, в большинстве случаев, как правило
in general terms [ɪnˌʤen(ə)r(ə)l 'tɜːmz] – в общих чертах, вообще говоря, вообще
in more detail [ɪnˌmɔː 'diːteɪl] – более детально, более подробно
in operation [ɪnˌɔp(ə)'reɪʃ(ə)n] – в действии, в эксплуатации, находящийся в эксплуатации, использующийся
in order to [ɪn'ɔːdə tə] – чтобы; с целью; затем чтобы; для того, чтобы
in particular [ɪnpə'tɪkjələ] – в частности, в особенности
in principle [ɪn'prɪnsəpl] – в принципе, в основном, по существу
in series [ɪn'sɪəriːz] – соединённый последовательно (*об элементах*)
in terms of [ɪn'tɜːmzəv] – с учётом, в плане, в смысле, с точки зрения, на основании
in turn [ɪn'tɜːn] – в свою очередь, поочерёдно
in use [ɪn'juːs] – используемый, находящийся в употреблении
in volume [ɪn'vɔljuːm] – в массовом количестве, в большом количестве
inauguration [ɪˌnɔːgjə'reɪʃ(ə)n] – торжественное открытие, вступление в должность, ознаменование начала
incandescent lamp [ˌɪnkæn'des(ə)nt 'læmp] – лампа накаливания
incident ['ɪnsɪd(ə)nt] – падающий (*напр.*, *о луче*)
incident light [ˌɪnsɪd(ə)nt 'laɪt] – падающий свет
incident radiation [ˌɪnsɪd(ə)ntˌreɪdɪ'eɪʃ(ə)n] – падающее излучение
incident wave [ˌɪnsɪd(ə)nt'weɪv] – падающая волна, прямая волна
incoherent light [ˌɪnkəu'hɪər(ə)nt 'laɪt] – некогерентный свет
incoherent source [ˌɪnkəu'hɪər(ə)nt 'sɔːs] – некогерентный источник
incoming beam ['ɪnˌkʌmɪŋ 'biːm] – падающий луч, падающий пучок
incoming ray ['ɪnˌkʌmɪŋ'reɪ] – входящий луч
increase ['ɪnkriːs] – возрастание, увеличение ‖ [ɪn'kriːs] возрастать, увеличивать(ся)
independent of [ˌɪndɪ'pendəntəv] – независящий от, независимо от
index of refraction ['ɪndeks əv rɪ'frækʃ(ə)n] – индекс преломления, коэффициент рефракции, показатель лучепреломления

indicate ['ɪndɪkeɪt] – указывать, показывать, обозначать, означать, свидетельствовать

indigo ['ɪndɪgəu] – цвет индиго (*сине-фиолетовый*), тёмно-синий цвет

indirect bandgap (= *indirect band gap*) – запрещенная зона с непрямыми переходами

indirect bandgap semiconductor [ˌɪndɪ'rekt 'bændˌgæpˌsemɪkən'dʌktə] – примесный проводник, несобственный проводник

induce [ɪn'djuːs] – индуцировать, наводить, возбуждать

industrial laser [ɪnˌdʌstrɪəl'leɪzə] – промышленный лазер, технологический лазер

industrial television (*ITT*) [ɪnˌdʌstrɪəl 'telɪˌvɪʒ(ə)n] – промышленное телевидение

inefficient [ˌɪnɪ'fɪʃənt] – малопродуктивный, неэффективный; недостаточный, слабый

inertial fusion [ɪˌnɜːʃ(ə)l 'fjuːʒ(ə)n] – ядерный синтез с инерционным удержанием плазмы, инерциально-термоядерный синтез

inexpensive [ˌɪnɪk'spensɪv] – недорогой, дешевый

infinite ['ɪnfɪnət] – бесконечный, неопределённый, бесчисленный

infinitesimal [ˌɪnfɪnɪ'tesɪm(ə)l] – чрезвычайно малый, бесконечно малый

information density [ˌɪnfə'meɪʃ(ə)n 'densɪtɪ] – плотность потока информации, плотность информации

information technology [ˌɪnfə'meɪʃ(ə)n tek'nɔləʤɪ] – информационная технология, информатика

infrared light [ˌɪnfrə'red 'laɪt] – инфракрасное излучение, инфракрасный свет

infrared photon [ˌɪnfrə'red 'fəutɔn] – инфракрасный фотон

ingenious [ɪn'ʤiːnɪəs] – изобретательный, искусный, оригинальный, неординарный

inherently [ɪn'her(ə)ntlɪ] – неотъемлемо, по сути, по своему существу, в своей основе

inhibit [ɪn'hɪbɪt] – препятствовать, подавлять, тормозить, задерживать, замедлять

inhomogeneous [ɪnˌhəumə'dʒiːnɪəs] – неоднородный, неравномерный, гетерогенный

initial [ɪ'nɪʃ(ə)l] – начальный, исходный

initiate [ɪ'nɪʃɪeɪt] – начинать, инициировать, приступать, положить начало; стимулировать

injection [ɪn'ʤekʃ(ə)n] – инжекция, впрыск, введение

injection laser [ɪn'ʤekʃ(ə)nˌleɪzə] – инжекционный лазер, оптический инжекционный квантовый генератор

inorganic solvent [ˌɪnɔː'gænɪk 'sɔlvənt] – неорганический растворитель

input power ['ɪnputˌpauə] – мощность на входе

inquire into [ɪn'kwaɪərɪntə] – исследовать, расследовать

insensitive to [ɪn'sensətɪv tə] – нечувствительный к, невосприимчивый к, инертный

insert [ɪn'sɜːt] – вставлять, включать, помещать

insignificant [ˌɪnsɪg'nɪfɪk(ə)nt] – малосущественный, незначительный, ничтожно малый

install [ɪn'stɔːl] – устанавливать, монтировать, собирать
installable [ɪn'stɔːləbl] – устанавливаемый, требующий установки, разрешённый к установке
installation [ˌɪnstə'leɪʃ(ə)n] – установка, монтаж, сборка
installer [ɪn'stɔːlə] – монтажник, сборщик, сборочное приспособление
instantaneous [ˌɪnstən'teɪnɪəs] – мгновенный, моментальный, немедленный
instantaneous disturbance [ˌɪnstən'teɪnɪəs dɪ'stɜːb(ə)ns] – мгновенное возмущение
instantaneous rate [ˌɪnstən'teɪnɪəs 'reɪt] – моментный показатель (*характеризующий явление на данный момент*), текущий показатель
instead of [ɪn'stedəv] – взамен, вместо
instrument ['ɪnstrəmənt] – аппарат, прибор, измерительный прибор
insulating crystal [ˌɪnsjəleɪtɪŋ 'krɪst(ə)l] – кристалл диэлектрика, кристалл изолятора
insulator ['ɪnsjəleɪtə] – изолятор, изолирующее вещество, диэлектрик, изоляция
intense [ɪn'tens] – интенсивный, сильный, напряженный
intense light [ɪnˌtens 'laɪt] – интенсивное излучение, сильный свет
intensity [ɪn'tensətɪ] – интенсивность, напряжённость, яркость, плотность, сила света, фоновая интенсивность
intensity-dependent light transmission – управляемое светоиспускание
inter-city [ˌɪntə'sɪtɪ] – межгородской, междугородний
interact [ˌɪntər'ækt] – взаимодействовать
interaction length [ˌɪntər'ækʃ(ə)nˌleŋθ] – длина взаимодействия (*частиц*)
interconnection [ˌɪntəkə'nekʃ(ə)n] – взаимосвязь, межсоединение, соединение
interestingly ['ɪntrəstɪŋlɪ] – что интересно; примечательно, что; интересно то, что
interfere [ˌɪntə'fɪə] – интерферировать, препятствовать, быть помехой
interference [ˌɪntə'fɪər(ə)ns] – интерференция, взаимодействие
interference band [ˌɪntə'fɪər(ə)ns 'bænd] – интерференционная полоса
interfering beam [ˌɪntə'fɪərɪŋ 'biːm] – интерферирующий пучок
intermediate state [ˌɪntə'miːdɪət 'steɪt] – переходное состояние, промежуточное состояние
internal quantum efficiency [ɪn'tɜːn(ə)lˌkwɔntəm ɪ'fɪʃ(ə)nsɪ] – внутренний квантовый выход, внутренняя квантовая эффективность
internal reflection [ɪnˌtɜːn(ə)l rɪ'flekʃ(ə)n] – внутреннее отражение, полное внутреннее отражение
intersect a plane [ˌɪntə'sekt ə'pleɪn] – пересекать плоскость
intra-city network [ˌɪntrə'sɪtɪ 'netwɜːk] – внутригородская сеть
intracavity [ˌɪntrə'kævətɪ] – кювет, внутренний резонатор, внутрирезонаторное устройство (*напр.*, *модулятор добротности*) ‖ внутрирезонаторный
intracavity reflection losses [ˌɪntrə'kævətɪ rɪ'flekʃ(ə)nˌlɔsɪz] – внутрирезонаторные потери на отражение
intracavity shutter [ˌɪntrə'kævətɪ 'ʃʌtə] – внутрирезонаторный (*внутриполостной*) затвор
intrinsic [ɪn'trɪnzɪk] – внутренний, собственный, присущий, свойственный, действительный
intuitive [ɪn'tjuːɪtɪv] – наглядный, интуитивный, подсознательный

inverse [ˈɪnvəːs, ɪnˈvəːs] – противоположность, противоположное условие или состояние, обратный эффект; обратная последовательность, обратный порядок ‖ заменять на противоположное или обратное, обращать ‖ противоположный, обратный, обращённый

inverse relation [ˌɪnvзːs rɪˈleɪʃ(ə)n] – обратная зависимость

investigate [ɪnˈvestɪgeɪt] – исследовать, расследовать, изучать, обследовать

investigation [ɪnˌvestɪˈgeɪʃ(ə)n] – исследование, анализ, оценка

investigative [ɪnˈvestɪgətɪv]/[-geɪtɪv] – исследовательский, пытливый, любознательный

investigator [ɪnˈvestɪgeɪtə] – следователь; исследователь, испытатель

invisible radiation [ɪnˈvɪzəblˌreɪdɪˈeɪʃ(ə)n] – невидимая радиация, невидимое излучение

involve [ɪnˈvɔlv] – касаться, затрагивать; включать в себя, содержать; подразумевать

ion concentration [ˈaɪənˌkɔns(ə)nˈtreɪʃ(ə)n] – ионная концентрация, концентрация ионов

ion laser [ˈaɪənˌleɪzə] – оптический квантовый ионный генератор, лазер на ионизированном газе, ионный лазер, ионный газовый лазер

ionic [aɪˈɔnɪk] – ионный

ionized gas [ˌaɪənaɪzdˈgæs] – ионизованный газ

irradiance [ɪˈreɪdɪəns] – излучение, энергетическая освещённость, облучение, интенсивность излучения

irradiant [ɪˈreɪdɪənt] – светящийся, излучающий

irradiate [ɪˈreɪdɪeɪt] – облучать, излучать, испускать лучи

irradiation [ɪˌreɪdɪˈeɪʃ(ə)n] – иррадиация, лучеиспускание, излучение

irradiator [ɪˈreɪdɪeɪtə] – облучатель, излучатель

irrelevant [ɪˈreləv(ə)nt] – неуместный, не относящийся к делу, не имеющий отношения, несущественный

isoelectronic [ˌaɪsəuɪləkˈtrɔnɪk] – изоэлектронный, с равным числом электронов

isotropic [ˌaɪsəuˈtrɔpɪk] – изотропный, обладающий одинаковыми свойствами во всех направлениях, однородный

isotropic media [ˌaɪsəuˈtrɔpɪk ˈmiːdɪə] – изотропные среды

issue [ˈɪʃuː] (*Am.*), [ˈɪsjuː] (*Br.*) – предмет обсуждения, спорный вопрос, вопрос, проблема, задача

J

Jet Propulsion Laboratory – лаборатория реактивных двигателей (*США*)

jet stream [ˈʤetˌstriːm] – струйное течение, реактивная струя

joule [ʤuːl] – джоуль (Дж) (*единица измерения работы, энергии, количества теплоты*)

junction [ˈʤʌŋkʃ(ə)n] – переход, соединение

junction region [ˈʤʌŋkʃ(ə)nˌriːʤ(ə)n] – область перехода

K

keep to [ˈkiːptə] – придерживаться, не отклоняться

Kerr cell – ячейка Керра, керровская ячейка, элемент Керра, оптический затвор

Kerr-cell Q-switching – модуляция добротности с помощью ячейки Керра
key concept [ˌkiːˈkɔnsept] – ключевое понятие, ключевая концепция
key factor [ˌkiːˈfæktə] – главный критерий, ключевой фактор
kilohertz (kHz) [ˈkɪləuhɜːts] – килогерц (кГц)
krypton (Kr) [ˈkrɪptɔn] – криптон
KTP (*potassium titanyl phosphate*, $KTiOPO_4$) – калий-титанил-фосфат (*КТП*)

L

lantern [ˈlæntən] – фонарь
large-scale [ˌlɑːʤˈskeɪl] – крупномасштабный, широкий, массовый
largely [ˈlɑːʤlɪ] – в значительной степени, в большей мере, главным образом
laser beam [ˈleɪzəˌbiːm] – лазерный пучок, лазерный луч
laser beam deflector [ˈleɪzəˌbiːm dɪˈflektə] – лазерный дефлектор
laser cavity [ˈleɪzəˌkævətɪ] – лазерный резонатор
laser cavity configuration [ˈleɪzəˌkævətɪ kənˌfɪgjuˈreɪʃ(ə)n] – схема лазерного резонатора
laser cutting [ˈleɪzəˌkʌtɪŋ] – лазерная резка
laser deposition [ˈleɪzəˌdepəˈzɪʃ(ə)n], [ˌdiːpə-] – лазерное нанесение, лазерное напыление, лазерное осаждение
laser diode [ˈleɪzəˌdaɪəud] – лазерный диод, инжекционный лазер, диодный лазер
laser efficiency [ˈleɪzərɪˈfɪʃ(ə)nsɪ] – кпд лазера, эффективность лазера, коэффициент полезного действия лазера
laser engraving [ˈleɪzərɪnˈgreɪvɪŋ] – лазерное гравирование
laser frequency [ˈleɪzə ˈfriːkwənsɪ] – частота генерации лазера, частота лазерного излучения
laser frequency shifter [ˈleɪzəˌfriːkwənsɪ ˈʃɪftə] – устройство сдвига лазерной частоты
laser gain [ˈleɪzəˌgeɪn] – коэффициент усиления лазера, усиление лазера
laser imaging [ˈleɪzər ˈɪmɪʤɪŋ] – лазерное формирование изображений, лазерное экспонирование
laser levels [ˈleɪzəˌlev(ə)lz] – энергетические уровни лазера
laser medium [ˈleɪzəˌmiːdɪəm] – активное вещество лазера, лазерная активная среда
laser oscillation [ˈleɪzərˌɔsɪˈleɪʃ(ə)n] – генерирование лазерного излучения
laser output [ˈleɪzərˌautput] – выходная мощность лазера, выходной сигнал лазера
laser pulse [ˈleɪzəˌpʌls] – лазерный импульс
laser pulse intensity [ˈleɪzəˌpʌls ɪnˈtensətɪ] – интенсивность лазерного импульса
laser rangefinder [ˈleɪzə ˈreɪndʒˌfaɪndə] – лазерный дальномер
laser rod [ˈleɪzəˌrɔd] – стержень активного вещества лазера, стержень лазера
laser safety [ˌleɪzəˈseɪftɪ] – меры безопасности при работе с лазерами, безопасность при работе с лазерами, лазерная безопасность
laser setup [ˌleɪzə ˈsetʌp] – лазерная установка

laser source [ˈleɪzəˌsɔːs] – оптический квантовый генератор, лазер, лазерный источник
laser transition [ˈleɪzə trænˈzɪʃ(ə)n] – лазерный переход, генерационный переход в лазере
laser welding [ˌleɪzə ˈweldɪŋ] – лазерная сварка, сварка лазерным лучом
laser-diode array [ˈleɪzəˌdaɪəud əˈreɪ] – линейка лазерных диодов
laser-propelled spacecraft [ˈleɪzəprəˌpeldˈspeɪskrɑːft] – космический аппарат с лазерным двигателем
lasing [ˈleɪzɪŋ] – генерация когерентного оптического излучения, генерация лазерного излучения
last pulse mode – измерение дальности по последнему импульсу
lattice [ˈlætɪs] – решётка, пространственная решётка, кристаллическая решётка
lattice defect [ˈlætɪsˌdiːfekt]/[dɪˈfekt] – дефект в решётке, дефект решётки
lattice structure [ˈlætɪsˌstrʌktʃə] – структура кристаллической решётки, структура решётки
launch [lɔːntʃ] – пуск; возбуждение (*волны*) ‖ запускать, производить запуск; возбуждать (*волну*)
law of rectilinear propagation of light [ˈlɔːəvˌrektɪˈlɪnɪəˌprɔpəˈgeɪʃ(ə)nəvˈlaɪt] – закон прямолинейного распространения света
lay optical fibre cable [ˈleɪ ˈɔptɪk(ə)lˌfaɪbə ˈkeɪbl] – прокладывать волоконно-оптический кабель
lead (Pb) [led] – свинец
lead molybdate ($PbMoO_4$) [ˌled mɔˈlɪbdeɪt] – молибдат свинца
leading edge [ˈliːdɪŋˌedʒ] – передний фронт волны (*импульса*)
leading edge of research [ˈliːdɪŋˌedʒ rɪˈsɜːtʃ] – передний фронт исследований, передовые исследования
learned [ˈlɜːnɪd] – учёный, эрудированный, знающий
lengthen [ˈleŋθən] – удлиняться, удлинять
lidar (*light detection and ranging*) [ˈlaɪdɑː] – лидар, метеорологический лазерный локатор ИК-диапазона
life sciences [ˈlaɪfˌsaɪənsɪz] – медико-биологические науки
lifetime [ˈlaɪftaɪm] – время жизни
light amplification by stimulated emission of radiation [ˈlaɪtˌæmplɪfɪˈkeɪʃ(ə)n baɪ ˈstɪmjəleɪtɪd ɪˈmɪʃ(ə)n əvˌreɪdɪˈeɪʃ(ə)n] – усиление света с помощью индуцированного излучения, лазер
light bulb [ˈlaɪtbʌlb] – электрическая лампа;
a distant light bulb – удалённая электрическая лампа
light spot [ˈlaɪtˌspɔt] – световое пятно
light streak [ˈlaɪtˌstriːk] – полоса света
light-carrying fiber [ˈlaɪtˌkærɪŋ ˈfaɪbə] – оптическое волокно, световод, светопровод
light-emitting diode [ˈlaɪt ɪˌmɪtɪŋ ˈdaɪəud] – светодиод, светоизлучающий диод
likewise [ˈlaɪkwaɪz] – подобно, подобным образом, также
limit [ˈlɪmɪt] – предел, граница ‖ устанавливать предел, ограничивать
limitations [ˌlɪmɪˈteɪʃ(ə)nz] – ограничения, недостатки
linear absorption [ˈlɪnɪə əbˈzɔːpʃ(ə)n] – линейное поглощение
linear function [ˈlɪnɪə ˈfʌŋkʃ(ə)n] – линейная функция, прямолинейная функция

linear polarization ['lɪnɪəˌpəul(ə)raɪ'zeɪʃ(ə)n] – линейная поляризация
linearly polarized ['lɪnɪəlɪ 'pəul(ə)raɪzd] – линейно поляризованный
linearly polarized beam ['lɪnɪəlɪ 'pəul(ə)raɪzdˌbiːm] – линейно-поляризованный луч
linewidth ['laɪnwɪdθ] – ширина линии, ширина спектральной линии
liquid ['lɪkwɪd] – жидкий, жидкостный ‖ жидкость
list [lɪst] – список, перечень ‖ составлять список, перечислять, заносить в список
listed company [ˌlɪstɪd'kʌmpənɪ] – официально зарегистрированная компания, листинговая компания, зарегистрированная на бирже компания
living tissue [ˌlɪvɪŋ'tɪʃuː/-sjuː] – живая ткань
locate [ləu'keɪt] – располагать, размещать, обнаруживать, устанавливать местонахождение
location [ləu'keɪʃ(ə)n] – место, расположение, местонахождение, положение, ячейка
locator [ləu'keɪtə] – локатор, устройство обнаружения
long reach [ˌlɔŋ'riːtʃ] – глубокой досягаемости, дальней досягаемости
long-distance communication system [ˌlɔŋ'dɪst(ə)ns kəˌmjuːnɪ'keɪʃ(ə)n 'sɪstəm] – система связи на большие расстояния, система дальней связи
long-distance transmission [ˌlɔŋ'dɪst(ə)ns trænz'mɪʃ(ə)n] – передача на дальние расстояния
long-haul network [ˌlɔŋ'hɔːl 'netwɜːk] – сеть дальней связи, сеть широкого охвата
long-haul transmission [ˌlɔŋ'hɔːl trænz'mɪʃ(ə)n] – передача на дальние расстояния
long-sightedness [ˌlɔŋ'saɪtɪdnəs] – дальнозоркость
look into ['luk ɪntə] – исследовать (*напр. вопрос*), изучать, рассматривать
losses ['lɔsɪz] – потери
lossy ['lɔsɪ] – допускающий потери, с большим затуханием, рассеивающий энергию
low bit rate [ˌləu'bɪtreɪt] – низкая скорость передачи информации
low cost [ˌləu'kɔst] – низкая стоимость
low-impedance output [ˌləu ɪm'piːd(ə)ns 'autput] – низкое выходное сопротивление
lower laser level [ˌləuə 'leɪzəˌlev(ə)l] – нижний лазерный уровень
lumen (lm) ['luːmən] – люмен (лм) (***единица светового потока в СИ***)
luminosity curve [ˌluːmɪ'nɔsətɪˌkɜːv] – кривая видности, кривая относительной спектральной световой эффективности
luminous ['luːmɪnəs] – светящийся, освещённый
lunar ranging ['luːnə 'reɪnʤɪŋ] – локация луны, измерение дальности до Луны

M

made of ['meɪdəv] – сделанный из
made up of ['meɪd'ʌpəv] – состоящий из, в составе
magical ['mæʤɪk(ə)l] – колдовской, сверхъестественный, волшебный, магический

magnetic field [mæg'netɪk 'fiːld] – магнитное поле
magnification [ˌmægnɪfɪ'keɪʃ(ə)n] – увеличение (*изображения*)
magnification of the transmitter telescope [ˌmægnɪfɪ'keɪʃ(ə)n əvðə trænz'mɪtə 'telɪskəup] – увеличение телескопа передатчика
main highway loop [ˌmeɪn'haɪweɪˌluːp] – основная коммуникационная сеть компьютера
maintain [meɪn'teɪn] – поддерживать, сохранять
maintenance ['meɪnt(ə)nəns] – содержание и техническое обслуживание, уход; текущий ремонт
major drawback [ˌmeɪʤə 'drɔːbæk] – основной недостаток
major factor [ˌmeɪʤə 'fæktə] – ведущий фактор, основной фактор
make a big leap forward ['meɪkəˌbɪg'liːpˌfɔːwəd] – сделать большой шаг вперёд
make an appearance ['meɪkə'pɪər(ə)ns] – появляться
make an assumption ['meɪkən ə'sʌmpʃ(ə)n] – сделать предположение, допускать
make an attempt ['meɪkən ə'tempt] – сделать попытку
make appeal to ['meɪk ə'piːltə] – обращаться, прибегать к
make distinction between ['meɪk dɪ'stɪŋkʃ(ə)n bɪ'twiːn] – проводить различие между, делать различия между
make measurements ['meɪk 'meʒəmənts] – выполнять измерения, производить измерения
make possible ['meɪk'pɔsəbl] – давать возможность, обеспечивать возможность, делать возможным, способствовать
make sense ['meɪk 'sens] – иметь смысл, быть разумным
make use of ['meɪk 'juːsəv] – использовать, применять, употреблять
manifest itself ['mænɪfest ɪtˌself] – выражаться, выразиться, обнаруживаться, проявляться
manifestation [ˌmænɪfes'teɪʃ(ə)n] – проявление
manifold ['mænɪfəuld] – многообразие, множество, совокупность ‖ многообразный, разнообразный, разнородный
manufacture [ˌmænjə'fæktʃə] – изготовление, производство
manufacturer [ˌmænjə'fæktʃərə] – производитель, изготовитель, предприятие-изготовитель
manufacturing [ˌmænjə'fæktʃ(ə)rɪŋ] – производство, изготовление ‖ производственный, промышленный, технологический
march in lockstep ['mɑːtʃɪn'lɔkstep] – шагать в ногу тесным строем
margin for error ['mɑːʤɪn fər'erə] – предел погрешности, допустимая погрешность
market penetration ['mɑːkɪtˌpenɪ'treɪʃ(ə)n] – проникновение на рынок, выход на рынок сбыта
market presence ['mɑːkɪt 'prez(ə)ns] – присутствие на рынке
mass range ['mæsˌreɪnʤ] – диапазон массовых чисел
master ['mɑːstə] – эталон, образец, модель
master oscillator power amplifier (*MOPA*) ['mɑːstərˌɔsɪleɪtə 'pauərˌæmplɪfaɪə] – усилитель мощности задающего генератора
match [mætʃ] – сопряжение, сочетание, соответствие, согласование ‖ сопрягать, сочетать, согласовывать, соответствовать
material selection [mə'tɪərɪəl sɪ'lekʃ(ə)n] – выбор материалов

mature [məˈtʃuə] – назревший, зрелый ‖ совершенствовать(ся), становиться зрелым

maximum (pl) maxima) [ˈmæksɪməm] ([ˈmæksɪmə]) – максимальное значение, максимум, верхний предел

meanwhile [ˌmiːnˈwaɪl] – между тем, в то же время

measure [ˈmeʒə] – мера, критерий; единица измерения ‖ мерить, измерять

measurement [ˈmeʒəmənt] – замер, измерение (*определение значения величины*)

mechanical strength [mɪˈkænɪk(ə)lˌstreŋθ] – механическая прочность, прочность

mechanically [mɪˈkænɪkəlɪ] – механически

mechanically induced strain waves [mɪˈkænɪkəlɪ ɪnˈdjuːst ˈstreɪnˌweɪvz] – волны упругости, наводимые механическим путем

medium (pl) media) [ˈmiːdɪəm] ([ˈmiːdɪə]) – среда

megawatt (*MW*) [ˈmegəwɔt] – мегаватт (МВт)

mercury [ˈmɜːkj(ə)rɪ]/[ˈmɜːkjurɪ] – ртуть

merge into [ˈmɜːʤˌɪntə] – стать частью

metal-wire communication system [ˈmet(ə)lˌwaɪə kəˌmjuːnɪˈkeɪʃ(ə)n ˈsɪstəm] – кабельная система связи

metrology [meˈtrɔləʤɪ] – метрология, система мер и весов

microphotography [ˌmaɪkrə(u)fəˈtɔgrəfɪ] – микрокопирование, микрофотографирование, микрофотография

microresonator [ˌmaɪkrə(u)ˈrez(ə)neɪtə] – микрорезонатор

microwave holography [ˈmaɪkrə(u)weɪv hɔˈlɔgrəfɪ] – СВЧ-голография, сверхвысокочастотная голография

microwave technology [ˈmaɪkrə(u)weɪv tekˈnɔləʤɪ] – СВЧ-техника

middle infrared [ˈmɪdlˌɪnfrəˈred] – средневолновая ИК-область спектра

milliwatt (mW) [ˈmɪlɪwɔt] – милливатт (мВт)

miniature [ˈmɪnətʃə] – миниатюра, уменьшенная копия ‖ миниатюрный, маленький

miniaturize [ˈmɪnətʃ(ə)raɪz] – уменьшать размеры, миниатюризировать

minimum (pl) minima) [ˈmɪnɪməm] ([ˈmɪnɪmə]) – минимальная величина, минимум, низший предел

minimum quantity [ˈmɪnɪməm ˈkwɔntətɪ] – минимальная величина

minute [maɪˈn(j)uːt] – мелкий, мельчайший, незначительный, крошечный, несущественный

mirror-folded cavity design [ˈmɪrəˌfəuldɪd ˈkævətɪ dɪˌzaɪn] – зеркальная конструкция с изломом оси

mixed crystal [ˌmɪkstˈkrɪst(ə)l] – кристалл твёрдого раствора, смешанный кристалл

mixing [ˈmɪksɪŋ] – смешение, смешивание, перемешивание

mode [məud] – мода, тип колебаний

mode of operation [ˈməudəvˌɔp(ə)ˈreɪʃ(ə)n] – режим работы, режим действия

mode-locked laser [ˈməudlɔktˌleɪzə] – лазер с синхронизацией мод; лазер, работающий в режиме синхронизации мод

mode-locked laser system [ˈməudlɔkt ˈleɪzəˌsɪstəm] – лазерная система с синхронизацией мод

mode-locker [ˈməudlɔkə] – синхронизатор мод, устройство синхронизации мод
mode-locking [ˈməudlɔkɪŋ] – синхронизация мод
modulated beam [ˈmɔdjuleɪtɪdˌbiːm] – модулированный пучок, модулированный луч
modulated beam rangefinder [ˈmɔdjuleɪtɪdˌbiːm ˈreɪndʒˌfaɪndə] – фазовый дальномер
modulated continuous wave [ˈmɔdjuleɪtɪd kənˈtɪnjuəsˌweɪv] – модулированная волна, незатухающая гармоническая волна
modulated continuous wave rangefinder [ˈmɔdjuleɪtɪd kənˈtɪnjuəsˌweɪv ˈreɪndʒˌfaɪndə] – фазовый дальномер
moisture [ˈmɔɪstʃə] – влажность, влага
molecular ion [məˌlekjulərˈaɪən] – молекулярный ион
molecule [ˈmɔlɪkjuːl] – молекула
momentum [məˈmentəm] – импульс, количество движения, импульсная сила ‖ импульсный
moonwalk [ˈmuːnˌwɔːk] – выход человека на поверхность луны, «лунная прогулка»
mother spacecraft [ˌmʌðə ˈspeɪskrɑːft] – космический аппарат-носитель
mount [maunt] – устанавливать, монтировать, закреплять на плоской поверхности, собирать
multiphoton [ˌmʌltɪˈfəutɔn] – многофотонный, с участием нескольких фотонов
multiphoton absorption [ˌmʌltɪˈfəutɔn əbˈzɔːpʃ(ə)n] – многофотонное поглощение
multiple-beam interference [ˌmʌltɪˈbiːmˌɪntəˈfɪər(ə)ns] – многолучевая интерференция
multiplexer [ˈmʌltɪˌpleksə] – мультиплексор, устройство уплотнения каналов, коммутатор
multiply by [ˈmʌltɪplaɪ baɪ] – умножать на
multiwatt – мощный, многоваттный
mutually perpendicular [ˈmjuːtʃuəlɪ ˌpɜːp(ə)nˈdɪkjulə] – взаимно перпендикулярный

N

nanosecond pulse [ˈnænə(u)ˌsekənd ˈpʌls] – наносекундный импульс
Nd (*neodymium*) [ˌniːəuˈdɪmɪəm] – неодим, неодимий
Nd:glass laser – лазер на неодимовом стекле
Nd:YAG laser – лазер на алюмоиттриевом гранате, активированный неодимом
near infrared [ˌnɪərˌɪnfrəˈred] – ближняя инфракрасная область
nearby [ˌnɪəˈbaɪ] – ближайший, близлежащий, соседний
negligible [ˈneglɪʤəbl] – незначительный, ничтожный, пренебрежимо малый, несущественный
neodymium (Nd) [ˌniːəuˈdɪmɪəm] – неодимий, неодим
neon gas (Ne) [ˈniːɔnˌgæs] – неон
neon-helium laser [ˌniːɔnˈhiːlɪəmˌleɪzə] – гелий – неоновый лазер
neutral gas [ˈnjuːtr(ə)lˌgæs] – инертный газ, нейтральный газ, неионизированный газ

neutral molecule ['njuːtr(ə)lˌmɔlɪkjuːl] – нейтральная молекула
nit [nɪt] – нит (*единица яркости*)
nitrobenzene [ˌnaɪtrəu'benziːn] – нитробензол
nm (*nanometer*) ['nænə(u)ˌmiːtər] – нанометр (*1 billionth of a meter*), нм
no longer – более не, больше не, уже не
Nobel prize [nou'belˌpraɪz] – Нобелевская премия
noise performance ['nɔɪz pəˌfɔːməns] – шумовая характеристика
noise pickup ['nɔɪzˌpɪkʌp] – шумовая перекрёстная помеха, помехи
nonconducting [ˌnɔnkən'dʌktɪŋ] – непроводящий, не проводящий электрического тока
non-cooperative target [ˌnɔnkəu'ɔp(ə)rətɪv 'tɑːgɪt] – цель, не ожидающая встречи
nonlinear [nɔn'lɪnɪə] – нелинейный
nonlinear absorption [nɔn'lɪnɪə əb'zɔːpʃ(ə)n] – нелинейное поглощение
nonlinear coefficient [nɔn'lɪnɪəˌkəuɪ'fɪʃ(ə)nt] – нелинейный коэффициент
nonlinear frequency conversion [nɔnˌlɪnɪə 'friːkwənsɪ kənˌvɜːʃ(ə)n] – нелинейное преобразование частоты
nonlinear material [nɔn'lɪnɪə mə'tɪərɪəl] – материал с нелинейными свойствами, нелинейный материал
nonlinear optics (*NLO*) [nɔn'lɪnɪə 'ɔptɪks] – нелинейная оптика
nonlinear problem [nɔn'lɪnɪə 'prɔbləm] – нелинейная задача
nonlinear scattering [nɔn'lɪnɪə 'skæt(ə)rɪŋ] – нелинейное рассеяние
nonlinearity [ˌnɔnlɪnɪ'ærɪtɪ] – нелинейность, нелинейная характеристика
nonnuclear [ˌnɔn'njuːklɪə] – неядерный, не связанный с ядерной энергией
nonradiative process – безызлучательный процесс
nonradiative recombination – безызлучательная рекомбинация
non-optical – неоптический
ns (*nanosecond*) ['nænəuˌsekənd] – наносекунда (*one thousand-millionth of a second*), нс
nuclear decay [ˌnjuːklɪə dɪ'keɪ] – ядерный распад

O

obey a law [ə'beɪə'lɔː] – подчиняться закону
object beam ['ɔbʤɪkt 'biːm] – объектный луч, объектный пучок, предметный пучок
obscure [əb'skjuə] – неясный, смутный, нечёткий, скрытый
obscurely [əb'skjuəlɪ] – неясно, неотчётливо, смутно
observation [ˌɔbzə'veɪʃ(ə)n] – наблюдение, результаты наблюдений, исследование
observe [əb'zɜːv] – наблюдать, замечать, осуществлять наблюдение
obstacle ['ɔbstəkl] – препятствие, помеха, преграда
obtainable [əb'teɪnəbl] – достижимый, доступный
obvious ['ɔbvɪəs] – явный, очевидный, заметный
occur [ə'kɜː] – случаться, происходить
ocular ['ɔkjələ] – глазной, окулярный ‖ глаз
of practical interest [əv'præktɪk(ə)l 'ɪnt(ə)rəst] – представляющий практический интерес

on the one hand – с одной стороны
on the other hand – с другой стороны, в то же время, напротив, наоборот
on-board radar [ˌɔnbɔːd 'reɪdɑː] – автономная радарная установка, бортовая радиолокационная станция
once [wʌns] – как только, поскольку, однажды
opacity [ə(u)'pæsətɪ] – непрозрачность, непроницаемость, светонепроницаемость
opaque obstacles [ə(u)ˌpeɪk'ɔbstəklz] – непрозрачные предметы
operating principle [ˌɔpəreɪtɪŋ'prɪnsəpl] – принцип работы, принцип действия
operating wavelength [ˌɔpəreɪtɪŋ'weɪvleŋθ] – рабочая длина волны
ophthalmic surgery [ɔfˌθælmɪk'sɜːʤ(ə)rɪ] – глазная хирургия
optic ['ɔptɪk] – линза (*оптического прибора*), объектив, окуляр
optical absorption ['ɔptɪk(ə)l əb'zɔːpʃ(ə)n] – поглощение света, оптическое поглощение
optical amplifier ['ɔptɪk(ə)l 'æmplɪfaɪə] – усилитель оптического диапазона, оптический усилитель
optical bistability ['ɔptɪk(ə)lˌbaɪstə'bɪlətɪ] – оптическая бистабильность
optical coating ['ɔptɪk(ə)l 'kəutɪŋ] – оптическое покрытие, защитное оптическое покрытие
optical computer ['ɔptɪk(ə)l kəm'pjuːtə] – фотонный компьютер, оптический компьютер
optical damage ['ɔptɪk(ə)l 'dæmɪʤ] – разрушение оптическим излучением, оптическое разрушение
optical device ['ɔptɪk(ə)l dɪ'vaɪs] – оптический прибор, оптическое устройство
optical disturbance ['ɔptɪk(ə)l dɪ'stɜːb(ə)ns] – распределение оптического поля
optical element ['ɔptɪk(ə)l 'elɪmənt] – оптический элемент
optical engineering ['ɔptɪk(ə)l ˌenʤɪ'nɪərɪŋ] – техническая оптика, техническая оптика, оптическое производство
optical feedback ['ɔptɪk(ə)l 'fiːdbæk] – оптическая обратная связь
optical fibre ['ɔptɪk(ə)l 'faɪbə] – оптическое волокно, оптоволокно
optical fibre cable [ˌɔptɪk(ə)l 'faɪbə 'keɪbl] – волоконно-оптический кабель
optical fibre communication system [ˌɔptɪk(ə)l 'faɪbə kəˌmjuːnɪ'keɪʃ(ə)n 'sɪstəm] – волоконно-оптическая система связи (*ВОЛС*)
optical fiber core [ˌɔptɪk(ə)l 'faɪbəˌkɔː] – сердцевина оптического стекловолокна, световедущая жила оптического волокна
optical gain [ˌɔptɪk(ə)l 'geɪn] – оптическое усиление, усиление в оптическом диапазоне
optical hologram [ˌɔptɪk(ə)l 'hɔləgræm] – оптическая голограмма
optical homogeneity ['ɔptɪk(ə)lˌhəuməuʤə'neɪətɪ] – оптическая однородность
optical multiplexer [ˌɔptɪk(ə)l 'mʌltɪˌpleksə] – оптический мультиплексор
optical networking [ˌɔptɪk(ə)l 'netwɜːkɪŋ] – оптоволоконные сети, волоконно-оптические сети
optical noise [ˌɔptɪk(ə)l 'nɔɪz] – оптический шум
optical parametric oscillation (*OPO*) ['ɔptɪk(ə)lˌpærə'metrik ˌɔsɪ'leɪʃ(ə)n] – параметрическая генерация, параметрические колебания
optical phase conjugation (*OPC*) [ˌɔptɪk(ə)l 'feɪzˌkɔnʤu'geɪʃ(ə)n] – обращение волнового фронта, сопряжение фаз оптических сигналов

optical pumping [ˌɔptɪk(ə)l 'pʌmpɪŋ] – оптическая накачка
optical resonator [ˌɔptɪk(ə)l 'rez(ə)neɪtə] – оптический резонатор
optical scene [ˌɔptɪk(ə)l 'siːn] – оптический объект, картина
optical signal processor ['ɔptɪk(ə)l 'sɪgn(ə)l 'prəusesə] – устройство оптической обработки сигнала
optical train [ˌɔptɪk(ə)l 'treɪn] – оптическая система, оптическая схема
optical transparency [ˌɔptɪk(ə)l træn'spær(ə)nsɪ] – оптический транспарант, оптическая прозрачность
optical vector [ˌɔptɪk(ə)l 'vektə] – электрический вектор
optically-pumped laser ['ɔptɪk(ə)lɪˌpʌmpt'leɪzə] – лазер с оптической накачкой
optoelectronic measurements [ˌɔptəuˌelek'trɔnɪk 'meʒəmənts] – оптоэлектронные измерения
order ['ɔːdə] – порядок, упорядоченность, упорядочение; степень, порядок, кратность ‖ упорядочивать
order of magnitude [ˌɔːdərəv'mægnɪt(j)uːd] – порядок величины, порядок возрастания
organic compound [ɔːˌgænɪk 'kɔmpaund] – органическое соединение
organic dye [ɔːˌgænɪk'daɪ] – органический краситель
organic dye laser [ɔːˌgænɪk'daɪleɪzə] – лазер на органическом красителе
organic molecule [ɔːˌgænɪk 'mɔlɪkjuːl] – молекула органического соединения, органическая молекула
organic solvent [ɔːˌgænɪk 'sɔlvənt] – органический растворитель
oscillate ['ɔsɪleɪt] – колебаться, вибрировать
oscillating function ['ɔsɪleɪtɪŋ 'fʌŋkʃ(ə)n] – функция колебаний
oscillation [ˌɔsɪ'leɪʃ(ə)n] – колебание, качание
oscillator ['ɔsɪleɪtə] – излучатель, генератор колебаний
other than ['ʌðəˌðən] – а не, исключая, кроме, помимо
otherwise ['ʌðəwaɪz] – иначе, в противном случае, в других отношениях, или же
output ['autput] – выход, результат, выходной сигнал ‖ выходной
output characteristics ['autput ˌkærəktə'rɪstɪks] – выходные характеристики
output mirror [ˌautput 'mɪrə] – выходное зеркало
output power [ˌautput 'pauə] – мощность на выходе, генерируемая мощность
output power density [ˌautput 'pauə 'densɪtɪ] – плотность мощности на выходе
output pulse [ˌautput'pʌls] – импульс на выходе, выходной импульс
output waveform [ˌautput 'weɪvˌfɔːm] – волновой фронт, фронт волнового излучения, выходной сигнал
over a wide range – в широком диапазоне
over the past years – на протяжении последних лет
overcome [ˌəuvə'kʌm] – преодолеть, овладевать, побороть
overlap [ˌəuvə'læp] – частично совпадать
overly ['əuvəlɪ] – чрезмерно, излишне, избыточно, слишком
oxidize ['ɔksɪdaɪz] – оксидировать, окисляться

P

p-n junction – p-n переход, электронно-дырочный переход
paramagnetic ion [ˌpærəmæg'netɪk 'aɪən] – парамагнитный ион

parasitic transition [ˌpærə'sɪtɪk træn'zɪʃ(ə)n] – пассивный переход
partial coherence ['pɑːʃ(ə)l kə(u)'hɪər(ə)ns] – частичная когерентность
partially reflecting surface ['pɑːʃ(ə)lɪ rɪˌflektɪŋ 'sɜːfɪs] – частично отражающая поверхность
particularly [pə'tɪkjələlɪ] – в особенности, в частности
particularly important [pə'tɪkjələlɪ ɪm'pɔːt(ə)nt] – особо важный, особенно важный
pass filter [ˌpɑːs'fɪltə] – полосовой фильтр
pave the way for [ˌpeɪvðə'weɪ fə] – подготовить почву для, создавать условия для
payload bay ['peɪləudˌbeɪ] – грузовой отсек
peak [piːk] – максимум (*нагрузки*), пиковое значение
peak level [ˌpiːk'lev(ə)l] – максимальный уровень, пиковый уровень
peak output power [ˌpiːk 'autputˌpauə] – максимальная выходная мощность
peak power [ˌpiːk'pauə] – пиковая мощность, импульсная мощность
peak power density ['piːkˌpauə 'densɪtɪ] – плотность пиковой (*импульсной*) мощности, пиковое значение плотности мощности
peak power output ['piːkˌpauər 'autput] – максимальная выходная мощность
peculiarity [pɪˌkjuːlɪ'ærətɪ] – особенность, свойство
pendulum clock ['pendj(ə)ləmˌklɔk] – маятниковые часы
penetrate ['penɪtreɪt] – проникать, пронизывать, проникать внутрь, внедряться
pentaphosphate [ˌpentə'fɔsfeɪt] – пентафосфат
per unit volume [pəˌjuːnɪt'vɔljuːm] – на единицу объёма
perceive [pə'siːv] – воспринимать, различать
perceptible to the eye [pə'septəbl tə ðɪ 'aɪ] – видимый глазом, различимый глазом
perform an experiment [pə'fɔːmən ɪk'sperɪmənt] – проводить опыт, проводить эксперимент
performance [pə'fɔːməns] – работа, интенсивность работы, рабочие характеристики
periodic structure [ˌpɪərɪ'ɔdɪk 'strʌktʃə] – периодическая структура, регулярная структура
periodicity [ˌpɪərɪə'dɪsətɪ] – периодичность, принцип периодичности
perpendicular to [ˌpɜːp(ə)n'dɪkjulətə] – перпендикулярный к
phase difference ['feɪz ˌdɪf(ə)r(ə)ns] – разность фаз
phase match ['feɪzˌmætʃ] – совпадение по фазе
phase matching ['feɪzˌmætʃɪŋ] – условие фазового синхронизма, совпадение по фазе, фазовое сопряжение
phase-conjugate mirror (*PCM*) ['feɪzˌkɔnʤugət 'mɪrə] – фазово-сопряжённое зеркало
phenomenon (*pl. phenomena*) [fɪ'nɔmɪnən] ([fɪ'nɔmɪnə]) – явление, феномен, необыкновенное явление
phonon-assisted transition ['fəunɔn əˌsɪstɪd træn'zɪʃ(ə)n] – переход с наличием фонона, переход с участием фононов
photographic emulsion [ˌfəutə'græfɪk ɪ'mʌlʃ(ə)n] – фотоэмульсия
photographic plate [ˌfəutə'græfɪkˌpleɪt] – фотографическая пластинка, фотопластинка
photographic technique [ˌfəutə'græfɪk tek'niːk] – фотографическая техника, фототехника

photometry [ˌfəu'tɔmɪtrɪ] – фотометрия, световое измерение
photomultiplier [ˌfəutəu'mʌltɪˌplaɪə] – фотоумножитель, фотоэлектрический умножитель
photomultiplier tube [ˌfəutəu'mʌltɪˌplaɪə 't(j)uːb] – фотоумножитель, фотоэлектрический умножитель
photon absorption [ˌfəutɔn əb'zɔːpʃ(ə)n] – фотонное поглощение
photon emission [ˌfəutɔn ɪ'mɪʃ(ə)n] – излучение фотонов, испускание фотонов
physiological optics [ˌfɪzɪə'lɔʤɪk(ə)l 'ɔptɪks] – физиологическая оптика
piece of evidence [ˌpiːsəv'evɪd(ə)ns] – доказательство
piezoelectric crystal [paɪˌiːzouɪ'lektrɪk 'krɪst(ə)l] – пьезокристалл, пьезоэлектрический кристалл, пьезоэлектрик
pinhole ['pɪnhəul] – пиксель (*элемент разложения*), точечная диафрагма, отверстие
place constraints on ['pleɪs kən'streɪnts ɔn] – накладывать ограничения на
plague [pleɪg] – чума, бедствие ‖ досаждать, изводить, мучить, надоедать, не давать покоя
plane grating ['pleɪnˌgreɪtɪŋ] – двумерная дифракционная решётка, плоская дифракционная решётка
plane polarization ['pleɪnˌpəul(ə)raɪ'zeɪʃ(ə)n] – плоская или линейная поляризация
plane-parallel plate [ˌpleɪn'pærəlel ˌpleɪt] – плоскопараллельная пластинка
plane-polarized light [ˌpleɪn'pəul(ə)raɪzdˌlaɪt] – свет с линейной поляризацией, плоскополяризованный свет
plasma ['plæzmə] – плазма
play back ['pleɪ'bæk] – воспроизводить ‖ воспроизведение
Pockels cell – ячейка Поккельса
point source ['pɔɪntˌsɔːs] – точечный источник
point out ['pɔɪnt 'aut] – выделять, подчёркивать
polarization [ˌpəul(ə)raɪ'zeɪʃ(ə)n] – поляризация
polarization angle [ˌpəul(ə)raɪ'zeɪʃ(ə)n 'æŋgl] – угол Брюстера, угол полной поляризации
polarizing filter ['pəul(ə)raɪzɪŋ 'fɪltə] – поляризационный фильтр, поляризатор
polarizing microscope ['pəul(ə)raɪzɪŋ 'maɪkrəskəup] – поляризационный микроскоп
poling process ['pəulɪŋ ˌprəuses] – процесс поляризации
polynomial [ˌpɔlɪ'nəumɪəl] – многочлен, полином
population inversion [ˌpɔpjə'leɪʃ(ə)n ɪn'vɜːʃ(ə)n] – инверсная населенность
population inversion density [ˌpɔpjə'leɪʃ(ə)n ɪn'vɜːʃ(ə)n 'densɪtɪ] – плотность инверсии населённостей
potassium dihydrogen phosphate (*PDP*) [pə'tæsɪəm daɪ'haɪdrəʤən 'fɔsfeɪt] – дигидрофосфат калия
potassium titanyl phosphate (*PTP*) – калий-титанил-фосфат, фосфат калия-титанила
power amplifier [ˌpauər'æmplɪfaɪə] – усилитель мощности, генератор с посторонним возбуждением
power density [ˌpauə'densɪtɪ] – плотность энергии, энергонапряжённость

power fluctuations [ˈpauəˌflʌktʃuˈeɪʃ(ə)nz]/[-tju-] – колебания мощности
power scalability [ˈpauəˌskeɪləˈbɪlɪtɪ] – диапазон значений (*уровень*) выходной мощности
precedence (*over*) [ˈpresɪd(ə)ns]/[prɪˈsiː-] – превосходство, предпочтение
precipitate [prɪˈsɪpɪteɪt] – осадок ‖ выпадать в осадок, выкристаллизовываться, осаждать
precise lunar or satellite ranging – точное измерение расстояния до Луны и спутников
precisely [prɪˈsaɪslɪ] – ровно, точно, определенно
precision requirements [prɪˈsɪʒ(ə)n rɪˈkwaɪəmənts] – требуемая точность
preclude [prɪˈkluːd] – исключать, препятствовать, мешать, предотвращать, устранять
predictable [prɪˈdɪktəbl] – предсказуемый, прогнозируемый, поддающийся оценке
preferred direction [prɪˈfɜːd dɪˈrekʃ(ə)n]/[daɪ-] – выделенное направление, преимущественное направление
presently [ˈprez(ə)ntlɪ] – вскоре; теперь, сейчас, в настоящий момент, в настоящее время
preserve [prɪˈzɜːv] – сохранять, хранить
prevent [prɪˈvent] – предотвращать
primarily [praɪˈmer(ə)lɪ] – первоначально; в основном, прежде всего, главным образом
primary [ˈpraɪmerɪ] – первичный, основной, начальный
primary rainbow [ˌpraɪmerɪˈreɪnbəu] – основная радуга, первичная радуга, радуга первого порядка
primary wave [ˌpraɪmerɪˈweɪv] – первичная волна
prime [praɪm] – лучший, отличный, превосходный
principle of Huygens–Fresnel [ˈprɪnsəpləv ˈhɔɪgənz freɪˈnel] – принцип Гюйгенса–Френеля
product [ˈprɔdʌkt] – произведение
professional career [prəˈfeʃ(ə)n(ə)l kəˈrɪə] – профессиональная карьера, служебная карьера
progressively [prəˈgresɪvlɪ] – прогрессивно, все больше, постепенно
project [prəˈʤekt] – проектировать, планировать, предполагать, прогнозировать
promising [ˈprɔmɪsɪŋ] – перспективный, многообещающий
prone to [ˈprəuntə] – склонный к, подверженый
propagate [ˈprɔpəgeɪt] – распространяться, проходить
propagation [ˌprɔpəˈgeɪʃ(ə)n] – распространение
propagation loss [ˌprɔpəˈgeɪʃ(ə)nˌlɔs] – потери при распространении
properties of gain medium [ˈprɔpətɪzəv ˈgeɪnˌmiːdɪəm] – свойства усиливающей среды
proponent [prəˈpəunənt] – защитник, поборник, сторонник
proprietary [prəˈpraɪət(ə)rɪ] – специальный, индивидуально изготовленный (*фирмой*), патентованный, запатентованный, фирменный
prospect [ˈprɔspekt] – перспектива, надежда, планы на будущее
protein [ˈprəutiːn] – протеин, белок ‖ протеиновый

proven [ˈpruːv(ə)n] – доказавший свою пригодность, подтверждённый, проверенный
provide [prəˈvaɪd] – обеспечивать, предусматривать, снабжать, давать
provided [prəˈvaɪdɪd] – при условии
ps (*picosecond*) [ˈpiːkəuˌsekənd]/[ˈpaɪkəu-] – пикосекунда
public telecommunication system [ˈpʌblɪkˌtelɪkəˌmjuːnɪˈkeɪʃ(ə)n ˈsɪstəm] – связь общего пользования
pulse duration [ˌpʌlsdjuəˈreɪʃ(ə)n] – длительность лазерного выстрела, длительность импульсов, продолжительность импульса
pulse energy [ˌpʌlsˈenəʤɪ] – энергия в импульсе
pulse length [ˌpʌls ˈleŋθ] – длительность импульса, продолжительность импульса
pulse shape [ˌpʌls ˈʃeɪp] – профиль импульса, форма импульса
pulsed discharge [ˌpʌlst dɪsˈʧɑːʤ] – импульсный разряд
pulsed laser [ˌpʌlst ˈleɪzə] – лазер, работающий в импульсном режиме; импульсный лазер
pulsed laser rangefinding system [ˌpʌlst ˈleɪzə ˈreɪndʒˌfaɪndɪŋ ˈsɪstəm] – импульсный дальномер
pulsed output [ˌpʌlst ˈautput] – импульсный выход, импульсная излучаемая мощность
pulsed ruby laser [ˌpʌlst ˈruːbɪˌleɪzə] – импульсный рубиновый лазер
pulsed source [ˌpʌlst ˈsɔːs] – импульсный источник
pulse-periodic laser [ˈpʌls ˌpɪərɪˈɔdɪkˌleɪzə] – импульсно-периодический лазер
pulse-pumped laser [ˈpʌlsˌpʌmpt ˈleɪzə] – лазер с импульсной накачкой
pulse-repetition frequency [ˈpʌls ˌrepɪˈtɪʃ(ə)n ˈfriːkwənsɪ] – частота повторения импульсов
pulsewidth [ˈpʌlswɪdθ] – длительность импульса
pump [pʌmp] – накачивать, возбуждать; накачивать лазер || накачка
pump energy [ˌpʌmpˈenəʤɪ] – энергия накачки, энергия импульса накачки лазера
pump laser [ˌpʌmpˈleɪzə] – лазер с накачкой, лазер накачки
pump level [ˌpʌmpˈlev(ə)l] – уровень накачки, уровень сигнала накачки
pump power [ˌpʌmpˈpauə] – мощность накачки
pump source [ˌpʌmpˈsɔːs] – источник накачки, генератор накачки
pump wave [ˌpʌmpˈweɪv] – волна накачки
pumped [pʌmpt] – с накачкой
pumping [ˈpʌmpɪŋ] – накачка, возбуждение
pumping source [ˌpʌmpɪŋ ˈsɔːs] – источник накачки, генератор накачки
pursue a subject [pəˈsjuː əˈsʌbʤekt] – продолжать обсуждение вопроса
push [puʃ] – толкать, проталкивать, продвигать
pyroelectric detector [ˌpaɪrəuɪˈlektrɪk dɪˈtektə] – пироприёмник, пироэлектрический детектор
pyroelectric effect [ˌpaɪrəuɪˈlektrɪk ɪˈfekt] – пироэлектрический эффект, пироэлектричество, пироэффект

Q

Q-switch [ˈkjuːswɪʧ] – модулятор добротности
Q-switching [ˈkjuːswɪʧɪŋ] – модуляция добротности, переключение добротности

Quality factor (*Q*) ['kwɔlətɪˌfæktə] – коэффициент добротности
quantify ['kwɔntɪfaɪ] – определять количество, квантифицировать
quantity ['kwɔntətɪ] – величина, физическая величина
quartz [kwɔːts] – кварцевый кристалл, кварцевый резонатор, кварц
quartz-controlled oscillator [ˌkwɔːts kən'trəuld 'ɔsɪleɪtə] – кварцованный генератор
quasi continuum ['kwɑːzɪ kən'tɪnjuəm] – квази-непрерывный ‖ квазиконтинуум
quasirandom ['kweɪzaɪ-]/['kwɑːzɪ-] ['rændəm] – псевдослучайный, квазислучайный
question ['kwestʃən] – подвергать сомнению, сомневаться
quiescent point [kwɪ'es(ə)ntˌpɔɪnt] – рабочая (неподвижная) точка, точка устойчивой работы

R

radian ['reɪdɪən] – рад, радиан (*единица плоского угла*)
radiative lifetime ['reɪdɪətɪv 'laɪftaɪm] – излучательное время жизни энергетического уровня
radiative process ['reɪdɪətɪv 'prəuses] – излучательный процесс
radioactive decay [ˌreɪdɪəu'æktɪv dɪ'keɪ] – радиоактивный распад
radiometric unit [ˌreɪdɪəu'metrɪk 'juːnɪt] – радиометрическая единица
radiometry [ˌreɪdɪ'ɔmetrɪ] – радиометрия, техника измерения лучистой энергии
Raman amplification – комбинационное (*рамановское*) усиление
Raman amplifier – ВКР-усилитель
Raman effect [ɪ'fekt] – рамановское рассеяние света, эффект комбинационного рассеяния света
Raman transition – комбинационный переход, переход в комбинационном спектре, рамановский переход
Raman shifting – романовское (комбинационное) смещение
random background [ˌrændəm 'bækgraund] – случайный фон
random process [ˌrændəm 'prəuses] – случайный процесс, стохастический процесс
random variable [ˌrændəm 'veərɪəbl] – случайная переменная
random-number generator ['rændəm ˌnʌmbə 'ʤen(ə)reɪtə] – генератор случайных чисел, генератор псевдослучайных чисел
range [reɪnʤ] – диапазон, расстояние, дальность
range from ... to – колебаться в пределах от ... до
range resolution ['reɪnʤˌrez(ə)'luːʃ(ə)n] – разрешение по дальности, разрешающая способность по дальности
rangefinder ['reɪndʒˌfaɪndə] – дальномер
ranging ['reɪndʒɪŋ] – измерение расстояния, определение дальности, изменение дальности
rapidity [rə'pɪdətɪ] – скорость, быстрота
rapidly ['ræpɪdlɪ] – быстро
rare earth chelate laser [ˌreərɜːθ'kiːleɪtˌleɪzə] – лазер на редкоземельных хелатах, лазер на хелатах редкоземельных элементов
rare earth ion [ˌreərɜːθ'aɪən] – ион редкоземельного элемента, редкоземельный ион

rate equation [ˌreɪt ɪ'kweɪʒ(ə)n] – уравнение скорости реакции
rather than ['rɑːðə ðən] – а не, скорее чем, вместо того, чтобы
ratio ['reɪʃɪəu] – отношение, соотношение, коэффициент, пропорция; степень
ray optics ['reɪˌɔptɪks] – геометрическая оптика, лучевая оптика
razor blade ['reɪzəˌbleɪd] – лезвие бритвы
reach equilibrium ['riːʧˌiːkwɪ'lɪbrɪə] – устанавливать в положение равновесия, устанавливать равновесие
readily ['redɪlɪ] – без труда, легко, быстро
real image [ˌrɪəl 'ɪmɪʤ] – действительное изображение, реальное изображение
real-time interferometry ['rɪəltaɪmˌɪntəfɪə'rɔmɪtrɪ] – интерферометрия в реальном масштабе времени
real-world [ˌrɪəl 'wɜːld] – реальный, практический, физический
realm [relm] – область, сфера
rear mirror [ˌrɪə 'mɪrə] – непрозрачное зеркало
reasonable approach ['riːz(ə)nəbl ə'prəuʧ] – разумный подход
reasonable prices ['riːz(ə)nəbl 'praɪsɪz] – приемлемые цены
receiver end [rɪˌsiːvər'end] – приёмный конец
receiver optical train [rɪ'siːvərˌɔptɪk(ə)l 'treɪn] – система оптических элементов приемника
recently ['riːs(ə)ntlɪ] – недавно, в последнее время, за последнее время
recombination rate [ˌriːkɔmbɪ'neɪʃənˌreɪt] – скорость рекомбинации
recombine [ˌriːkəm'baɪn] – воссоединяться, перекомпоновываться
reconfigurable [ˌriːkən'fɪgərəbl] – с переменной конфигурацией, реконфигурируемый, переналаживаемый, перестраиваемый
reconstruction [ˌriːk(ə)n'strʌkʃ(ə)n] – восстановление, реконструкция
reconstruction beam [ˌriːk(ə)n'strʌkʃ(ə)n 'biːm] – восстанавливающий луч, восстанавливающий луч (*в голографии*)
record a hologram [rɪ'kɔːd ə'hɔləgræm] – записывать голограмму
rectangular resonator [rek'tæŋgjələ 'rez(ə)neɪtə] – прямоугольный резонатор
rectilinear propagation of light [ˌrektɪ'lɪnɪə ˌprɔpə'geɪʃ(ə)n əv'laɪt] – прямолинейное распространение света
reduce [rɪ'djuːs] – уменьшать, снижать, понижать, сокращать
reduce losses [rɪ'djuːs 'lɔsɪz] – снижать (уменьшать, сокращать) потери
refer to [rɪ'fɜːˌtə] – относить к, ссылаться на
reference ['ref(ə)r(ə)ns] – ссылка, отношение, упоминание
reference beam ['ref(ə)r(ə)nsˌbiːm] – опорный луч, эталонный луч
reference fiber ['ref(ə)r(ə)nsˌfaɪbə] – эталонное волокно
reference pattern ['ref(ə)r(ə)nsˌpæt(ə)n] – исходная (опорная) диаграмма направленности; эталонный образ (*в распознавании образов*)
refit ['riːfɪt] – переоборудовать, реконструировать, восстанавливать
reflected wave [rɪˌflektɪd'weɪv] – отражённая волна
reflecting hologram [rɪˌflektɪŋ 'hɔləgræm] – отражательная голограмма
reflecting surface [rɪˌflektɪŋ'sɜːfɪs] – отражающая поверхность, поверхность отражения
reflection [rɪ'flekʃ(ə)n] – отражение

reflection grating [rɪˌflekʃ(ə)n'greɪtɪŋ] – отражательная дифракционная решётка, отражающая дифракционная решётка
refraction [rɪ'frækʃ(ə)n] – преломление, рефракция
refractive index [rɪˌfræktɪv'ɪndeks] – коэффициент преломления, показатель преломления
refresh [rɪ'freʃ] – обновлять, освежать, подкреплять ‖ регенерация
regardless of [rɪ'gɑːdləs əv] – независимо от, не принимая во внимание, вне зависимости от
regeneration [rɪˌʤenə'reɪʃən] – восстановление, регенерация
regenerative-amplifier gas-dynamic laser [rɪ'ʤen(ə)rətɪv 'æmplɪfaɪə ˌgæsdaɪ'næmɪk ˌleɪzə] – газодинамический лазер с регенеративным усилителем
reinforce [ˌriːɪn'fɔːs] – укреплять, усиливать
rejuvenate [rɪ'ʤuːv(ə)neɪt] – восстанавливать силы, омолаживать
relate to [rɪ'leɪt tə] – устанавливать связь между, определять соотношение между, сопоставлять с
relationships [rɪ'leɪʃənʃɪps] – отношения, закономерности
relative to ['relətɪv tə] – отосительно, по отношению к
relatively ['relətɪvlɪ] – относительно, сравнительно
relatively speaking ['relətɪvlɪ 'spiːkɪŋ] – в общем, собственно говоря, относительно
relativity [ˌrelə'tɪvətɪ] – теория относительности, относительность
relaxation time [ˌriːlæk'seɪʃ(ə)nˌtaɪm] – время релаксации, продолжительность релаксации
release energy [rɪ'liːs 'enəʤɪ] – выделять энергию, высвобождать энергию
relevant ['reləvənt] – относящийся к делу, уместный, соответственный, существенный
rely on [rɪ'laɪ ɔn] – полагаться на, надеяться на, основываться на, опираться на
remote [rɪ'məut] – удаленный, дистанционный, отдаленный, далекий, дальний, маловероятный
remote control [rɪˌməut kən'trəul] – дистанционное управление
remote possibility [rɪˌməut ˌpɔsə'bɪlətɪ] – маловероятная возможность, незначительная вероятность
removal [rɪ'muːv(ə)l] – удаление, устранение, отвод
remove [rɪ'muːv] – удалять, снимать, убирать, устранять
render ['rendə] – приводить в какое-либо состояние
rendezvous and docking maneuvers ['rɔndɪvuː ən(d) 'dɔkɪŋ mə'nuːvəz] – сближение и стыковка
repeatability [rɪˌpiːtə'bɪlətɪ] – повторяемость, воспроизводимость
repeater [rɪ'piːtə] – ретранслятор, промежуточный усилитель
repeater spacing [rɪˌpiːtə 'speɪsɪŋ] – ретрансляционный интервал, размещение ретрансляторов
replace [rɪ'pleɪs] – заменять, возвращать, восстанавливать
represent [ˌreprɪ'zent] – представлять, означать, представлять собой
reproduce [ˌriːprə'djuːs] – воспроизводить, размножать, повторять, восстанавливать, репродуцировать
reproducible – воспроизводимый, повторимый

rescue ['reskjuː] – спасение, избавление, освобождение, высвобождение *come to smb's rescue* – приходить кому-л) на помощь
research [rɪ'sɜːtʃ] – исследование, научные исследования, научно-исследовательская работа
researcher [rɪ'sɜːtʃə] – исследователь, научный работник
reshape [ˌriː'ʃeɪp] – переделывать, преобразовывать, трансформировать
resolution [ˌrez(ə)'luːʃ(ə)n] – разрешение, разрешающая способность
resonance ['rez(ə)nəns] – резонанс, резонансные колебания, резонансная вибрация ‖ резонансный
respectively [rɪ'spektɪvlɪ] – соответствующим образом, соответственно
restrict [rɪ'strɪkt] – ограничивать, сокращать
restricted [rɪ'strɪktɪd] – узкий, ограниченный
restricted area of applicability [rɪ'strɪktɪd 'eərɪə əv əˌplɪkə'bɪlɪtɪ] – ограниченное применение
result from [rɪ'zʌlt frəm] – быть результатом чего-либо
result in [rɪ'zʌlt ɪn] – приводить к чему-либо
resultant [rɪ'zʌlt(ə)nt] – возникший, образующийся (при этом)
retardation [ˌriːtɑː'deɪʃ(ə)n] – замедление, запаздывание, отставание, задержка
retire [rɪ'taɪə] – уходить в отставку, уходить на пенсию, оставлять должность
retrieve information [rɪ'triːvˌɪnfə'meɪʃ(ə)n] – осуществлять выборку, вести поиск данных, извлекать информацию
retroreflection [ˌretrəurɪ'flekʃ(ə)n] – отражение в обратном направлении, обратное отражение
retroreflective [ˌretrəurɪ'flektɪv] – с обратным отражением, отражённый
retroreflector [ˌretrəurɪ'flektə] – ретрорефлектор, уголковый отражатель
revolving mirror [rɪˌvɔlvɪŋ 'mɪrə] – вращающееся зеркало
rf (radio-frequency) **discharge** ['reɪdɪəu 'friːkwənsɪ 'dɪstʃɑːʤ] – СВЧ-накачка, радиочастотный разряд, высокочастотный разряд
r.f. drive power ['reɪdɪəu 'friːkwənsɪ 'draɪvˌpauə] – мощность радиочастотного (высокочастотного) сигнала, радиочастотный источник сигнала
rhodamine ['rəudəmiːn] – родамин
rhodamine dye [ˌrəudəmiːn'daɪ] – родаминовый краситель
ripple ['rɪpl] – рябь, зыбь
rms (*root-mean-square*) (['ruːt ˌmiːnˌskweə]) – среднеквадратичный ‖ среднеквадратичное значение
rms value – среднеквадратичная величина
roll off ['rəul'ɔf] – спадать, уменьшаться
rotating-element Q-switch [rəu'teɪtɪŋˌelɪmənt 'kjuːswɪtʃ] – модулятор добротности с помощью вращающегося элемента
rotational energy level [rə'teɪʃ(ə)n(ə)l 'enəʤɪ ˌlev(ə)l] – вращательный уровень, вращательный энергетический уровень
rotational transition [rə'teɪʃ(ə)n(ə)l træn'zɪʃ(ə)n] – вращательный переход
rough surface [ˌrʌf'sɜːfɪs] – неровная поверхность, необработанная поверхность, шероховатая поверхность
round trip [ˌraund'trɪp] – прохождение сигнала туда и обратно
round-trip travel time [ˌraund'trɪp 'træv(ə)ltaɪm] – время прохождения сигнала до цели и обратно

routine calibration [ruːˈtiːn ˌkælɪˈbreɪʃ(ə)n] – повседневная поверка, поверка с невысокой точностью
ruby crystal [ˈruːbɪˌkrɪst(ə)l] – кристалл рубина, рубиновый кристалл
ruby rod [ˈruːbɪˌrɔd] – рубиновый стержень
rudimentary precautions [ˌruːdɪˈment(ə)rɪ prɪˈkɔːʃ(ə)nz] – элементарные меры предосторожности
rule [ruːl] – гравировать, наносить, налиновывать
rule of thumb [ˌruːləvˈθʌm] – приближенный метод, метод «научного тыка», правило правой руки
ruling [ˈruːlɪŋ] – нанесение линий, растровая сетка

S

safely [ˈseɪflɪ] – безопасно, надежно, без риска
safety hazard [ˈseɪflɪˌhæzəd] – угроза безопасности, опасность травмирования, опасный производственные фактор, угроза безопасности (*на производстве*)
salient [ˈseɪlɪənt] – выдающийся, заметный, яркий, бросающийся в глаза
sample [ˈsɑːmpl] – образец, проба ‖ отбирать образцы, брать пробы
satellite ranging [ˈsæt(ə)laɪt ˈreɪnʤɪŋ] – определение координат спутника
saturable absorber [ˈsætʃərəbl əbˈzɔːb(ə)] – насыщающийся поглотитель
saturate [ˈsætʃ(ə)reɪt] – насыщать, пропитывать
saturation flux [ˌsætʃ(ə)ˈreɪʃ(ə)nˌflʌks] – поток насыщения
saving of time and space – выигрыш во времени и пространстве, экономия времени и пространства
scalar quantity [ˈskeɪləˌkwɔntətɪ] – скалярная величина
scale [skeɪl] – шкала, масштаб ‖ шкалировать, градуировать ‖ определять масштаб, масштабировать; изменять масштаб; сводить к определённому масштабу
scaling law [ˈskeɪlɪŋˌlɔː] – правило масштабирования, закон распределения уровней
scaling model [ˈskeɪlɪŋˌmɔd(ə)l] – масштабированная модель, шкальная модель
scanning probe microscopy (*SPM*) – сканирующая зондовая микроскопия (*СЗМ*)
scatter [ˈskætə] – разбрасывать, рассеивать
scattered wave [ˌskætədˈweɪv] – вторичная волна
scatterer [ˈskætərə] – рассеиватель, рассеивающий элемент, изотропный рассеиватель
scattering coefficient [ˈskæt(ə)rɪŋˌkəuɪˈfɪʃ(ə)nt] – коэффициент рассеяния, показатель рассеяния
scattering process [ˌskæt(ə)rɪŋˈprəuses] – процесс рассеяния
schedule [ˈʃedjuːl] *Br.* [ˈskeʤuːl] *Am.* – график, расписание, план ‖ составлять график или расписание, планировать
scheduling [ˈʃedjuːlɪŋ] *Br.* [ˈskeʤuːlɪŋ] *Am.* – планирование, составление календарного плана или графика
schematic [skiːˈmætɪk] – диаграмма, схема, схематическое изображение ‖ схематический

search for [ˈsɜːʧ fə] – вести поиск, искать
second-harmonic generation (*SHG*) [ˈsek(ə)nd hɑːˈmɔnɪkˌʤenəˈreɪʃ(ə)n] – генерация второй гармоники
secondary rainbow [ˌsek(ə)nd(ə)rɪ ˈreɪnbəu] – отражённая радуга, вторичная радуга, радуга второго порядка
secondary source [ˌsek(ə)nd(ə)rɪˈsɔːs] – вторичный источник
secondary waves [ˌsek(ə)nd(ə)rɪˈweɪvz] – вторичные волны
seek (sought – sought) [siːk] – искать, пытаться найти, добиваться
seemingly [ˈsiːmɪŋlɪ] – казалось бы, по-видимому
selective element [sɪˌlektɪv ˈelɪmənt] – избирательный мультиплексор
selective filter [sɪˌlektɪvˈfɪltə] – селективный светофильтр
selective loss [sɪˌlektɪvˈlɔs] – селективные потери
self-focusing [ˌselfˈfəukəsɪŋ] – самофокусировка ‖ самофокусирующийся
self-phase modulation [ˌselfˈfeɪz ˌmɔdjəˈleɪʃ(ə)n] – фазовая автомодуляция
self-terminated operation [ˌselfˈtɜːmɪneɪtɪd ˌɔp(ə)ˈreɪʃ(ə)n] – пичковый режим (*в отличие от стационарного*)
self-terminating laser [ˌself ˈtɜːmɪneɪtɪŋ ˈleɪzə] – лазер на самоограниченных переходах
semiconductor [ˌsemɪkənˈdʌktə] – полупроводник
semiconductor diode [ˌsemɪkənˈdʌktə ˈdaɪəud] – полупроводниковый диод
semiconductor light detector [ˌsemɪkənˈdʌktə ˈlaɪt dɪˌtektə] – полупроводниковый приемник света, полупроводниковый приёмник светового излучения
semiconductor light emitter [ˌsemɪkənˈdʌktə ˈlaɪt ɪˌmɪtə] – полупроводниковый излучатель света
send out light [ˈsendˈautˌlaɪt] – испускать свет, излучать свет
sensing system [ˈsensɪŋˌsɪstəm] – приёмник сигналов, система датчиков, система измерения
sensitivity [ˌsensɪˈtɪvətɪ] – чувствительность
sequentially [sɪˈkwenʃ(ə)lɪ] – последовательно, секвенциально
service station [ˈsɜːvɪsˌsteɪʃ(ə)n] – станция техобслуживания, заправочная станция
set a limit to – [ˌsetəˈlɪmɪt tə] устанавливать предел, ограничивать
set to... [ˈset tə] – устанавливать на...
severe electromagnetic interference [sɪˈvɪə ɪˌlektrə(u)mægˈnetɪk ˌɪntəˈfɪər(ə)ns] – сильные электромагнитные помехи (радиопомехи, кондуктивные электромагнитные помехи)
severely limited [sɪˌvɪəlɪ ˈlɪmɪtɪd] – весьма ограниченный, значительно ограниченный
sharp pulse [ˈʃɑːpˌpʌls] – скачущий пульс, толчкообразный пульс
sheet polarizer [ˌʃiːt ˈpəuləˌraɪzə] – пленочный (листовой) поляризатор
shock wave [ˈʃɔkweɪv] – ударная волна, волна возмущений
shoot (shot – shot) [ʃuːt] – стрелять, выстреливать, выбрасывать
short-pulse laser [ˈʃɔːtˌpʌls ˈleɪzə] – короткоимпульсный лазер
short-sightedness [ˌʃɔːtˈsaɪtɪdnəs] – близорукость; недальновидность
shrink (shrank – shrunk) [ʃrɪŋk] ([ʃræŋk] – [ʃrʌŋk]) – сжиматься, сокращаться, давать усадку
shutter [ˈʃʌtə] – затвор

SI unit (*International System unit*) – единица в системе СИ, единица международной системы единиц
side note [ˈsaɪdˌnəut] – ремарка, примечание
sighting channel [ˌsaɪtɪŋˈtʃænl] – визирный канал
sighting telescope [ˌsaɪtɪŋˈtelɪskəup] – визирная труба
signal leakage [ˌsɪgn(ə)lˈliːkɪʤ] – утечка сигналов, потеря сигнала
signal-to-noise ratio [ˈsɪgn(ə)l təˌnɔɪz ˈreɪʃɪəu] – соотношение сигнал-шум
significantly [sɪgˈnɪfɪkəntlɪ] – значительно, в значительной степени, существенно
silica [ˈsɪlɪkə] – кварц, двуокись кремния, оксид кремния
silica fiber [ˈsɪlɪkəˌfaɪbə] – кварцевое волокно, кварцевое волокно из плавленого кварца
silicon substrate [ˌsɪlɪkənˈsʌbstreɪt] – кремниевая подложка
silver bromide [ˌsɪlvəˈbrəumaɪd] – бромид серебра, бромистое серебро
silver grains [ˈsɪlvəˌgreɪnz] – микрокристаллы галогенидов серебра (*в фотоэмульсии*)
silver halide [ˌsɪlvəˈhælaɪd] – галоид серебра
similar to [ˈsɪmɪlə tə] – как и в случае с, подобно, аналогично
similarly [ˈsɪmɪləlɪ] – аналогично, подобно, подобным образом, точно так же ‖ сходный с, похожий на
simultaneously [ˌsɪm(ə)lˈteɪnɪəslɪ] – одновременно
single mode [ˌsɪŋglˈməud] – одиночный тип колебаний, одномодовый режим
single-mode laser [ˌsɪŋglˈməud ˈleɪzə] – лазер с одним видом колебаний, одномодовый лазер
single-pulse bulk-damage threshold intensity [ˌsɪŋglˈpʌlsˌbʌlk ˈdæmɪʤ ˈθreʃ(h)əuld ɪnˈtensətɪ] – пороговая мощность разрушения при моноимпульсном излучении
single pass [ˌsɪŋglˈpɑːs] – однократное прохождение (*сигнала*)
skewed [skjuːd] – асимметричный, скошенный, косой, отклонённый
slit [slɪt] – щель
slit diffraction [ˌslɪt dɪˈfrækʃ(ə)n] – дифракция на щели
slope [sləup] – скат (*кривой*), крутизна кривой, угол наклона, крутизна (*характеристики*), наклон (*кривой*), тангенс угла наклона
small signal gain [ˌsmɔːl ˈsɪgn(ə)lˌgeɪn] – усиление в режиме малых сигналов
small signal gain coefficient [ˌsmɔːl ˈsɪgn(ə)lˌgeɪn ˌkəuɪˈfɪʃ(ə)nt] – коэффициент усиления в режиме малого сигнала
smooth [smuːð] – сглаживание (*напр., функции*) ‖ гладкий, плавный, ровный ‖ сглаживать (*напр., функцию*), выравнивать
snoring [ˈsnɔːrɪŋ] – храп, храпение
so far [səuˈfɑː] – до сих пор, до настоящего времени, пока
so that [ˈsəuðæt] – с тем, чтобы; так, чтобы
so-called [ˌsəuˈkɔːld] – так называемый
soap bubble [ˈsəupˌbʌbl] – мыльный пузырь
sodium (*Na*) [ˈsəudɪəm] – натрий ‖ натриевый
sodium discharge lamp [ˈsəudɪəm ˈdɪsʧɑːʤˌlæmp] – натриевая газоразрядная лампа
solar battery [ˈsəuləˌbætərɪ] – батарея солнечных элементов, солнечная батарея

solid ['sɔlɪd] – твёрдое тело; объёмная фигура ‖ твёрдотельный, твёрдый; объёмный; сплошной (*о линии*); телесный (*об угле*)
solid state laser [ˌsɔlɪd'steɪtˌleɪzə] – твердотельный лазер, оптический квантовый твердотельный генератор
soliton ['sɔlɪtɔn] – солитон, уединённая волна, одиночная волна
solve a problem ['sɔlv ə 'prɔbləm] – разрешать проблему, решать проблему, решать задачу
solvent ['sɔlvənt] – растворитель, растворяющее средство
solute ['sɔljuːt] – раствор, растворённое вещество
solution [sə'luːʃ(ə)n] – решение; раствор, состав
sophisticated instrument [sə'fɪstɪkeɪtɪd 'ɪnstrəmənt] – современный прибор
spaceborne laser ['speɪsbɔːn 'leɪzə] – бортовой лазер космического летательного аппарата, лазер (на борту) КА
span [spæn] – охватывать, простираться, распространяться ‖ диапазон, интервал, промежуток
spatial ['speɪʃ(ə)l] – пространственный
spatial coherence [ˌspeɪʃ(ə)l kə(u)'hɪər(ə)ns] – пространственная когерентность
spatial filter [ˌspeɪʃ(ə)l 'fɪltə] – пространственный фильтр, фильтр пространственных частот
specialized application ['speʃəlaɪzd ˌæplɪ'keɪʃ(ə)n] – специальное применение
species (*sing. + pl.*) ['spiːʃiːz] – частица
specific [spə'sɪfɪk] – конкретный, характерный, определённый
specify ['spesɪfaɪ] – задавать, уточнять, определять, специфицировать
spectral content [ˌspektr(ə)l 'kɔntent] – спектральный состав
spectral gain bandwidth ['spektr(ə)lˌgeɪn 'bændˌwɪdθ] – ширина полосы усиления
spectral linewidth [ˌspektr(ə)l 'laɪnˌwɪdθ] – ширина спектральной линии
spectral peak [ˌspektr(ə)l'piːk] – амплитуда спектра, пик спектра
spectral region [ˌspektr(ə)l 'riːʤ(ə)n] – область спектра, спектральная область
spectral tunability – спектральная перестройка
spectral tuning range [ˌspektr(ə)l 't(j)uːnɪŋˌreɪnʤ] – спектральный диапазон перестройки
spectrograph ['spektrəˌgrɑːf] – спектрограф
spectroscopy [spek'trɔskəpɪ] – спектроскопия
spectrum ['spektrəm] (*pl. spectra* ['spektrə]) – спектр, спектральная функция
speed of light [ˌspiːdəv'laɪt] – скорость света
split [splɪt] – расщеплять, расщепляться
splitted ['splɪtɪd] – расщеплённый
splitter ['splɪtə] – расщепитель, распределитель, светоделитель
spontaneous emission [spɔn'teɪnɪəs ɪ'mɪʃ(ə)n] – спонтанное излучение, спонтанная эмиссия
spontaneously [spɔn'teɪnɪəslɪ] – спонтанно, самопроизвольно
spurious results ['spjuərɪəs rɪ'zʌlts] – ложные результаты, неточные результаты
spurious signal ['spjuərɪəs 'sɪgn(ə)l] – ложный сигнал, паразитный сигнал, побочный сигнал
squeezed light [ˌskwiːzd 'laɪt] – сжатый свет
stand side by side – стоять рядом (бок о бок)

standard candle [ˌstændəd ˈkændl] – стандартная свеча, эталонная свеча, эталонный источник света
standing wave [ˌstændɪŋˈweɪv] – стационарная волна, стоячая волна
startling effect [ˌstɑːtlɪŋ ɪˈfekt] – поразительный (потрясающий, удивительный) эффект
state of polarization [ˈsteɪtəvˌpəul(ə)raɪˈzeɪʃ(ə)n] – поляризация, состояние поляризации
state-of-the-art [ˌsteɪtəvðɪˈɑːt] – новейший, передовой, находящийся на уровне современного развития, соответствующий последнему слову техники
statement [ˈsteɪtmənt] – заявление, утверждение
statistical significance [stəˈtɪstɪk(ə)l sɪgˈnɪfɪkəns] – статистическая значимость
steady [ˈstedɪ] – делать устойчивым, делать равномерным, становиться устойчивым, равномерным, приводить в равновесие, укреплять ‖ устойчивый
steady state [ˌstedɪˈsteɪt] – стационарный режим
steady-state population inversion [ˌstedɪˈsteɪtˌpɔpjəˈleɪʃ(ə)n ɪnˈvɜːʃ(ə)n] – инверсная населенность в устойчивом состоянии
stem from [ˈstemfrəm] – корениться, происходить, вести начало, проистекать, возникать
still further [ˌstɪlˈfɜːðə] – ещё дальше, более того
stimulated Brillouin scattering – вынужденное рассеяние Мандельштама–Бриллюэна, вынужденное бриллюэновское рассеяние
stimulated emission cross-section [ˈstɪmjəleɪtɪd ɪˈmɪʃ(ə)n ˈkrɔssekʃ(ə)n] – сечение стимулированного излучения
stimulated Raman scattering (*SRS*) – вынужденное комбинационное рассеяние
stimulated recombination [ˈstɪmjəleɪtɪd ˌriːkɔmbɪˈneɪʃən] – вынужденная рекомбинация, индуцированная рекомбинация
stimulated scattering [ˈstɪmjəleɪtɪd ˈskæt(ə)rɪŋ] – вынужденное рассеяние, стимулированное рассеяние, индуцированное рассеяние
stoichiometric crystal [ˌstɔɪkɪəˈmetrɪkˌkrɪst(ə)l] – стехиометрический кристалл
stoichiometric laser [ˌstɔɪkɪəˈmetrɪkˌleɪzə] – стехиометрический лазер
stoichiometric material [ˌstɔɪkɪəˈmetrɪk məˌtɪərɪəl] – вещество стехиометрического состава
stoichiometry [ˌstɔɪkɪˈɔmɪtrɪ] – стехиометрия, стехиометрия реакции, стехиометрический состав
Stokes wave [ˈstəuksˌweɪv] – волна Стокса, стоксова волна
storage [ˈstɔːrɪʤ] – память, накопление
store [stɔː] – хранить, запасать, накапливать
store energy [ˌstɔːrˈenəʤɪ] – аккумулировать энергию, накапливать энергию
stored energy [ˌstɔːdˈenəʤɪ] – накопленная энергия
strain sensor [ˌstreɪnˈsensə] – датчик деформаций, тензочувствительный датчик
strain waves [ˌstreɪnˈweɪvz] – волны упругости, упругие волны
strict [strɪkt] – строгий, точный
stuff [stʌf] – материал, состав, вещество (*из чего что-л. состоит*)
subatomic particle [ˌsʌbəˈtɔmɪk ˈpɑːtɪkl] – субатомная частица, элементарная частица
submarine [ˌsʌbməˈriːn] – подводный ‖ подводная лодка

subscriber loop [səb'skraɪbəˌluːp] – абонентское ответвление, абонентская линия, абонентский контур
subsequent ['sʌbsɪkwənt] – последующий, следующий, дальнейший
subsequently ['sʌbsɪkwəntlɪ] – впоследствии, в дальнейшем, далее
substance ['sʌbst(ə)ns] – вещество, субстанция
substitute ['sʌbstɪtjuːt] – использовать вместо, заменить; подставлять (*into*)
subtend [səb'tend] – противолежать (*об угле*), стягивать (*угол*)
succeed in [sək'siːdˌɪn] – добиться успеха в, преуспеть в
succession [sək'seʃ(ə)n] – последовательность
suffer from ['sʌfəˌfrəm] – страдать от
sufficient [sə'fɪʃ(ə)nt] – достаточный
suitable ['s(j)uːtəbl] – подходящий, пригодный, соответствующий, годный, применимый
suite [swiːt] – комплект, набор, комплекс
sum frequency ['sʌmˌfriːkwənsɪ] – частота суммарного сигнала, частота сигнала, суммарная частота
sum up ['sʌm'ʌp] – подытоживать, суммировать, обобщать, подводить итог, складывать
summarize ['sʌm(ə)raɪz] – суммировать, подводить итог, резюмировать
summit ['sʌmɪt] – вершина
superimpose [ˌs(j)uːp(ə)rɪm'pəuz] – накладывать (*одну волну на другую*)
superior to [s(j)uː'pɪərɪəˌtə] – лучше, чем ‖ превосходящий (что-либо)
superposition [ˌs(j)uːpəpə'zɪʃ(ə)n] – наложение, суперпозиция
superposition principle [ˌs(j)uːpəpə'zɪʃ(ə)nˌprɪnsəpl] – принцип суперпозиции, принцип наложения
surround [sə'raund] – окружение ‖ окружать
surroundings [sə'raundɪŋz] – окрестности, обстановка, окружение, среда
sustain oscillation [sə'steɪnˌɔsɪ'leɪʃ(ə)n] – поддерживать генерацию, поддерживать колебания
switch between modes ['swɪʧ bɪˌtwiːn 'məudz] – переключать режимы работы
synchrotron ['sɪŋkrəutrən] – синхротрон ‖ синхротронный

T

take into account – принимать во внимание, учитывать
take pains [ˌteɪk 'peɪnz] – прилагать усилия, брать на себя труд, постараться
taken together ['teɪk(ə)n tə'geðə] – в своей совокупности, взятые вместе
tangential to [tæn'ʤenʃ(ə)l tə] – направленный по касательной к
tangentially [tæn'ʤenʃ(ə)lɪ] – относительно, по касательной
target ['tɑːgɪt] – цель, мишень ‖ нацеливать
Tbit (*terabit*) ['terəbɪt] – терабит (*один триллион бит*)
technical staff [ˌteknɪk(ə)l'stɑːf] – инженерно-технический персонал, технический персонал, штат специалистов
technique [tek'niːk] – метод, способ
techniques [tek'niːks] – техника, методы, способы, приёмы
telecom ['teləˌkəm] – телекоммуникация, дальняя связь
telecommunications [ˌtelɪkəˌmjuːnɪ'keɪʃnz] – средства дальней связи, техника связи

temperature reference ['temp(ə)rəʧə 'ref(ə)r(ə)ns] – эталон температуры
temperature stability ['temp(ə)rəʧə stə'bɪlətɪ] – термостабильность, термоустойчивость
tempering ['tempərɪŋ] – отпуск, закалка, термообработка
tend to ['tend tə] – иметь тенденцию к, стремиться, имеет обыкновение
terminal ['tɜːmɪn(ə)l] – терминал, конечный пункт
terminal node [ˌtɜːmɪn(ə)l 'nəud] – вывод терминала, концевая вершина, концевой узел
terminal state [ˌtɜːmɪn(ə)l'steɪt] – нижний рабочий уровень
the very – именно тот, как раз
theoretical performance [θɪə'retɪk(ə)l pə'fɔːməns] – теоретические характеристики, расчётные характеристики, теоретическая производительность
theoretical treatment [θɪə'retɪk(ə)l 'triːtmənt] – теоретическое рассмотрение, теоретическое исследование
theorist ['θɪərɪst] – теоретик
thereby [ˌðeə'baɪ] – тем самым, таким образом, посредством этого
therefore ['ðeəfɔː] – следовательно, поэтому, вследствие этого
thermal conductivity ['θɜːm(ə)l ˌkɔndʌk'tɪvətɪ] – теплопроводность, удельная теплопроводность, коэффициент теплопроводности
thermal detector ['θɜːm(ə)l dɪ'tektə] – индикатор теплового излучения, тепловой детектор
thermal excitation ['θɜːm(ə)l ˌeksɪ'teɪʃ(ə)n] – тепловое возбуждение, термическое возбуждение
thermal processing ['θɜːm(ə)l 'prəusesɪŋ] – термообработка, термическая обработка
thermopile ['θɜːməpaɪl] – термоэлектрическая батарея, термобатарея (*из термопар*), термостолбик, термопара
third harmonic generation [ˌθɜːd hɑː'mɔnɪkˌʤenə'reɪʃ(ə)n] – генерация третьей гармоники
this is not the case – дело обстоит не так
thorough understanding ['θʌrə ˌʌndə'stændɪŋ] – полное понимание
three-dimensional image [ˌθriːdaɪ'menʃ(ə)n(ə)l 'ɪmɪʤ] – трехмерное изображение, пространственное изображение
three-level laser system – лазер с трёхуровневой энергетической схемой, трёхуровневый лазер
three-level system – трёхуровневая система
threshold ['θreʃ(h)əuld] – порог, пороговая интенсивность, пороговый уровень ‖ пороговый
threshold comparator [ˌθreʃ(h)əuld kəm'pærətə] – пороговое устройство, компаратор
threshold current [ˌθreʃ(h)əuld 'kʌr(ə)nt] – пороговый ток, максимальный ток
threshold value [ˌθreʃ(h)əuld 'væljuː] – пороговое значение
through [θruː] – посредством, через
throughput ['θruːput] – производительность, выработка, пропускная способность
thumb drive ['θʌmˌdraɪv] – флеш-накопитель, флешка
thus [ðʌs] – так, таким образом, итак, соответственно

tight [taɪt] – крепкий, плотный, тугой, тесный, герметичный
time coherence [ˌtaɪm kə(u)'hɪər(ə)ns] – временная когерентность
time lag ['taɪmˌlæg] – отставание во времени, запаздывание, период ожидания
time-reversed reflection [ˌtaɪmrɪ'vɜːst rɪ'flekʃ(ə)n] – инвертированное (*обращённое*) во времени (*встречное*) отражение
timing accuracy [ˌtaɪmɪŋ 'ækjərəsɪ] – точность определения временных интервалов, точность синхронизации
tiny ['taɪnɪ] – очень маленький, крошечный
to a small extent – в незначительной степени
to be sure – несомненно, безусловно, конечно
to date – на сегодняшний день, до сих пор, до настоящего времени
to our knowledge – насколько нам известно
to some extent – до некоторой степени
to unprecedented accuracy [tə ʌn'presɪd(ə)ntɪd 'ækjərəsɪ] – с беспрецедентной (небывалой) точностью
trade-offs ['treɪdɔfs] – плюсы и минусы, баланс преимуществ и недостатков
trailing edge [ˌtreɪlɪŋ'eʤ] – задний фронт волны (*импульса*)
transient phenomenon [ˌtrænzɪənt fɪ'nɔmɪnən] – переходный процесс, явление при переходном процессе
transition [træn'zɪʃ(ə)n] – переход
transition probability [træn'zɪʃ(ə)n ˌprɔbə'bɪlətɪ] – вероятность перехода
transmission axis [trænzˌmɪʃ(ə)n 'æksɪs] – ось пропускания
transmission capacity [trænzˌmɪʃ(ə)n kə'pæsətɪ] – пропускная способность, передаваемая мощность
transmission length [trænzˌmɪʃ(ə)n 'leŋθ] – длина зоны передачи напряжений
transmission rate [trænzˌmɪʃ(ə)n 'reɪt] – производительность источника информации, темп передачи, скорость распространения, скорость передачи данных
transmitted intensity [trænzˌmɪtəd ɪn'ten(t)sətɪ] – интенсивность прошедшего излучения
transmitted light [trænzˌmɪtəd'laɪt] – пропущенный свет, преломлённый свет
transmitted light intensity [trænz'mɪtədˌlaɪt ɪn'ten(t)sətɪ] – интенсивность света, прошедшего через плёнку
transmitter optical train [trænz'mɪtəˌɔptɪk(ə)l 'treɪn] – система оптических элементов передатчика
transmitter power [trænzˌmɪtə 'pauə] – мощность передатчика
transparency [træn'spær(ə)nsɪ] – прозрачность; прозрачная плёнка, изображение на прозрачной подложке
transparent [træn'spær(ə)nt] – прозрачный, просвечивающий
transponder [træn'spɔndə] – повторитель сигналов, ретранслятор, транспондер, преобразователь непрерывных данных в цифровые
transverse [trænz'vɜːs] – поперечный
transverse direction [trænzˌvɜːs dɪ'rekʃ(ə)n/daɪ-] – поперечное направление
transverse electromagnetic mode (*TEM*) [trænz'vɜːs ɪˌlektrə(u)mæg'netɪkˌməud] – поперечный электромагнитный тип колебаний, волна типа *TEM*
traverse [trə'vɜːs] – пересекать
trivalent [traɪ'veɪlənt]/['trɪvələnt] – трёхвалентный

trough [trɔf] – подошва волны
trunk communication [ˌtrʌŋk kəˌmjuːnɪ'keɪʃ(ə)n] – междугородная связь, магистральная связь, дальняя связь
tunability [ˌtjuːnə'bɪlɪtɪ] – перестраиваемость
tunable ['tjuːnəbl] – перестраиваемый
tunable dye laser [ˌtjuːnəbl 'daɪleɪzə] – перестраиваемый лазер на красителе
tunable laser [ˌtjuːnəbl 'leɪzə] – перестраиваемый лазер, лазер с перестройкой частоты
tunable optical filter ['tjuːnəblˌɔptɪk(ə)l 'fɪltə] – перестраиваемый оптический фильтр
tune [t(j)uːn] – перестраивать (*лазер*)
tuning ['t(j)uːnɪŋ] – перестройка (*частоты*), подрегулировка, подстройка
two-beam interference ['tuːˌbiːmˌɪntə'fɪər(ə)ns] – двухлучевая интерференция
two-state saturation ['tuːˌsteɪtˌsætʃ(ə)'reɪʃ(ə)n] – двухуровневое насыщение
typically ['tɪpɪk(ə)lɪ] – как правило, часто, нередко, обычно

U

ubiquitous [juː'bɪkwɪtəs] – повсеместный, вездесущий, повсеместно распространённый
ultimately ['ʌltɪmətlɪ] – в конечном счёте, в конце концов, самое главное, прежде всего
ultrafast ['ʌltrəˌfaːst] – сверхбыстрый, сверхскоростной, быстродействующий
ultraviolet (UV) light [ˌʌltrə'vaɪələt'laɪt] – ультрафиолетовое излучение, УФ-излучение, ультрафиолетовый свет
ultraviolet spectral region [ˌʌltrə'vaɪələtˌspektr(ə)l 'riːʤ(ə)n] – ультрафиолетовая область спектра
uncertainty [ʌn'sɜːt(ə)ntɪ] – погрешность, недостоверность, неопределённость, неточность
under the project [ˌʌndəðə'prɔʤekt] – по проекту, в соответствии с проектом
underlie [ˌʌndə'laɪ] – лежать в основе
underlying [ˌʌndə'laɪɪŋ] – базовый (*напр., о технологии*), основополагающий, основной, лежащий в основе
undoubtedly [ʌn'dautɪdlɪ] – несомненно, без сомнения
unfortunate [ʌn'fɔːtʃ(ə)nət] – неуместный, несчастливый, неудачный
unfortunately [ʌn'fɔːtʃ(ə)nətlɪ] – к несчастью, к сожалению, жаль
uniform ['juːnɪfɔːm] – однородный, равномерный
uniformly distributed ['juːnɪfɔːmlɪ dɪ'strɪbjuːtɪd] – равномерно распределённый
unintended [ˌʌnɪn'tendɪd] – непредусмотренный, ненамеренный
unique [juː'niːk] – однозначный, однозначно определяемый; уникальный
uniquely [juː'niːklɪ] – однозначно, уникально, единственно, единственным образом
unit ['juːnɪt] – единица измерения
unit of length [ˌjuːnɪtəv'leŋθ] – единица длины
unity ['juːnɪtɪ] – единица (*число*)
unobstructed [ˌʌnəb'strʌktɪd] – беспрепятственный, свободный
unoccupied [ʌn'ɔkjəpaɪd] – свободный, незаполненный

unperturbed [ˌʌnpə'tɜːbd] – без изменений, невозмущённый, ненарушенный
unpolarized light – естественный свет, неполяризованный свет
until recently [ənˌtɪl 'riːs(ə)ntlɪ] – до недавнего времени
unwanted [ʌn'wɔntɪd] – нежелательный, нежеланный
upgrade [ˌʌp'greɪd] – модернизировать, совершенствовать
upper laser level – верхний лазерный уровень
user-friendly [ˌjuːzə'frendlɪ] – интуитивно понятный, практичный, удобный в употреблении, простой в эксплуатации
utilize ['juːtɪlaɪz] – использовать, применять

V

vacuum field ['vækjuːmˌfiːld] – вакуумное поле
vacuum fluctuations ['vækjuːmˌflʌkʧu'eɪʃ(ə)nz] – вакуумные флуктуации, флуктуации вакуума
vacuum ultraviolet ['vækjuːmˌʌltrə'vaɪələt] – вакуумный ультрафиолет, вакуумное УФ излучение
valence ['veɪl(ə)ns] – валентность
valence band ['veɪl(ə)nsˌbænd] – валентная зона
valid ['vælɪd] – обоснованный, действительный, имеющий силу
validity [və'lɪdətɪ] – действительность, обоснованность, точность; rigorous validity – абсолютная точность
vanish ['vænɪʃ] – исчезать, пропадать, стремиться к нулю
vaporize ['veɪp(ə)raɪz] – выпаривать, испарять, превращать в пар
variable ['veərɪəbl] – переменный, непостоянный ‖ переменная величина, переменная
variation [ˌveərɪ'eɪʃ(ə)n] – варьирование, изменение, неравномерность
vary ['veərɪ] – изменять, изменяться, менять, разнообразить
vector quantity ['vektəˌkwɔntətɪ] – векторная величина
velocity of light [ˌvektərəv'laɪt] – скорость света
velocity of propagation [vɪ'lɔsətɪ əvˌprɔpə'geɪʃ(ə)n] – скорость распространения
velocity distribution [vɪ'lɔsətɪ ˌdɪstrɪ'bjuːʃ(ə)n] – распределение скоростей, распределение по скорости, спектр скоростей
versatility [ˌvɜːsə'tɪlətɪ] – разнообразие, универсальность, многосторонность, разносторонность
version ['vɜːʃ(ə)n] – версия, вариант, модификация
versus ['vɜːsəs] – в сравнении с, против, в противовес
viability [ˌvaɪə'bɪlətɪ] – жизнеспособность, жизненность, жизнестойкость
viable ['vaɪəbl] – действующий, жизнеспособный, целесообразный
vibration plane [vaɪˌbreɪʃ(ə)n'pleɪn] – плоскость колебаний
vibration-free [vaɪˌbreɪʃ(ə)n'friː] – с малым уровнем вибраций
vibrational energy level [vaɪ'breɪʃ(ə)nəl 'enəʤɪˌlev(ə)l] – колебательный уровень, колебательный энергетический уровень
vibrational mode [vaɪˌbreɪʃ(ə)nəl'məud] – колебательная мода, тип колебаний, характер колебаний
vibrational transition [vaɪˌbreɪʃ(ə)nəl træn'zɪʃ(ə)n] – колебательный энергетический переход, колебательный переход

vibronic transition [vaɪˌbrɔnɪk træn'zɪʃ(ə)n] – вибронный переход, электронно-колебательный переход
video transmission system ['vɪdɪəutrænzˌmɪʃ(ə)n'sɪstəm] – система передачи телевизионных изображений, система передачи видеосигнала
violent disturbance [ˌvaɪəl(ə)nt dɪ'stɜːb(ə)ns] – сильное возмущение
virtual ['vɜːʧuəl] – виртуальный, созданный искусственно, смоделированный, мнимый, возможный; действующий, эффективный
virtual image [ˌvɜːʧuəl'ɪmɪʤ] – мнимое изображение, виртуальное изображение
visible laser ['vɪzəblˌleɪzə] – лазер видимого диапазона; лазер, работающий в видимой области спектра
visible laser rangefinder ['vɪzəblˌleɪzə 'reɪndʒˌfaɪndə] – лазерный дальномер видимого диапазона
visible portion of the electromagnetic spectrum [ˌvɪzəbl'pɔːʃ(ə)nəvðɪ ɪˌlektrə(u) mæg'netɪk 'spektrəm] – видимая часть электромагнитного спектра
visible region of the spectrum [ˌvɪzəbl 'riːʤ(ə)n əvðə 'spektrəm] – видимая область спектра
visible spectrum [ˌvɪzəbl 'spektrəm] – оптическая область спектра, видимая область спектра
vitreous material [ˌvɪtrɪəs mə'tɪərɪəl] – стекловидный материал
voltage ['vəultɪʤ] – напряжение, электрическое напряжение, разность потенциалов, вольтаж

W

walk-off ['wɔːkˌɔf] – снос (*пучка лазера*)
waste heat ['weɪstˌhiːt] – избыточное тепло, отходящая теплота, использованная теплота
watt (*W*) [wɔt] – ватт (*Вт*)
wave number ['weɪvˌnʌmbə] – частота формы волны, волновое число
wave optics ['weɪvˌɔptɪks] – волновая оптика, физическая оптика
wave surface ['weɪvˌsɜːfɪs] – фронт волны, волновая поверхность, волновой фронт
waveband ['weɪvbænd] – диапазон волн, полоса частот
wavefront ['weɪvˌfrʌnt] – фронт импульса, волновой фронт
waveform ['weɪvˌfɔːm] – колебание, сигнал, форма колебаний, форма сигнала
wavelength ['weɪvleŋθ] – длина волны
wavelength range ['weɪvleŋθˌreɪnʤ] – диапазоны длины волны, диапазон волн
wavelength-division multiplexing (WDM) ['weɪvleŋθ dɪˌvɪʒ(ə)n 'mʌltɪˌpleksɪŋ] – спектральное разделение, спектральное уплотнение, спектральное объединение по длинам волн
wavelet ['weɪvlət] – волна малой длительности, волна малой амплитуды, элементарная волна импульс
weak pulse [ˌwiːk 'pʌls] – слабый пульс
well-known (*for*) [ˌwel'nəun] – широко известный, общеизвестный
white light [ˌwaɪt'laɪt] – ахроматический свет, белый свет, дневной свет
wide angle lens [ˌwaɪd'æŋgl 'lenz] – широкоапертурная линза, широкоугольный объектив

widespread [ˈwaɪdspred] – широко распространённый, масштабный, распространённый
width [wɪdθ] – ширина (*импульса*), длительность (*импульса*)
Wiener's method [ˈwiːnəzˌmeθəd] – метод Винера
with respect to [wɪðrɪˈspektə] – что касается, относительно, принимая во внимание
with the aid of – с помощью
withdraw [wɪðˈdrɔː] – снимать, удалять, убирать, извлекать
withstand high irradiance [wɪðˈstændˌhaɪ ɪˈreɪdɪəns] – выдерживать излучение высокой интенсивности
work well [ˌwɜːkˈwel] – быть применимым (*о теориях*), оправдываться
workhorse [ˈwɜːkhɔːs] – рабочий орган, исполнительный механизм, рабочая лошадка
workstation [ˈwɜːkˌsteɪʃ(ə)n] – (автоматизированное) рабочее место

X

X-ray laser [ˌeksreɪˈleɪzə] – лазер рентгеновского излучения, рентгеновский лазер
X-ray source [ˌeksreɪˈsɔːs] – рентгеновский источник, источник рентгеновских лучей
X-ray region [ˌeksreɪˈriːʤ(ə)n] – диапазон рентгеновского излучения
X-ray spectral region [ˌeksreɪ ˈspektr(ə)lˌriːʤ(ə)n] – спектральный диапазон рентгеновского излучения
xenon flashlamp [ˌziːnɔn ˈflæʃlæmp] – ксеноновая импульсная лампа

Y

YAG (*yttrium-aluminum garnet*) [yag] ([ˈɪtrɪəm əˈluːmɪnəm ˈgɑːnɪt]) – алюмоиттриевый гранат, иттрийалюминиевый гранат (*ИАГ*)
YAG laser [ˈjægˌleɪzə] – лазер на алюмоиттриевом гранате
yield [jiːld] – давать, выдавать, производить, вырабатывать

Z

zero phonon line [ˈzɪərəuˌfəunɔnˈlaɪn] – бесфононная линия
zero-phonon-line energy [ˈzɪərəu ˈfəunɔnˌlaɪn ˈenəʤɪ] – нулевой энергетический уровень фонона
zinc selenide (ZnSe) [ˌzɪŋkˈselənaɪd] – цинк селенид

Appendix 3

Answer key

Module 1

Supplementary reading tasks
Task 1: 2, 4, 1, 6, 3, 5.

The Cause and Effect Relationship in Vision
Despite its title, this chapter is far from your first look at light. That familiarity might seem like an advantage, but most people have never thought carefully about light and vision. Even smart people who have thought hard about vision have come up with incorrect ideas. The ancient Greeks, Arabs and Chinese had theories of light and vision, all of which were mostly wrong, and all of which were accepted for thousands of years.

One thing the ancients did get right is that there is a distinction between objects that emit light and objects that don't. When you see a leaf in the forest, it's because three different objects are doing their jobs: the leaf, the eye, and the sun. But luminous objects like the sun, a flame, or the filament of a light bulb can be seen by the eye without the presence of a third object. Emission of light is often, but not always, associated with heat. In modern times, we are familiar with a variety of objects that glow without being heated, including fluorescent lights and glow-in-the-dark toys.

How do we see luminous objects? The Greek philosophers Pythagoras (b) ca. 560 BC. and Empedocles of Acragas (b) ca. 492 BC., who unfortunately were very influential, claimed that when you looked at a candle flame, the flame and your eye were both sending out some kind of mysterious stuff, and when your eye's stuff collided with the candle's stuff, the candle would become evident to your sense of sight.

Bizarre as the Greek "collision of stuff theory" might seem, it had a couple of good features. It explained why both the candle and your eye had to be present for your sense of sight to function. The theory could also easily be expanded to explain how we see nonluminous objects. If a leaf, for instance, happened to be present at the site of the collision between your eye's stuff and the candle's stuff, then the leaf would be stimulated to express its green nature, allowing you to perceive it as green.

Modern people might feel uneasy about this theory, since it suggests that greenness exists only for our seeing convenience, implying precedence over natural phenomena. Nowadays, people would expect the cause and effect relationship in vision to be the other way around, with the leaf doing something to our eye rather than our eye doing something to the leaf. But how can you tell? The most common way of distinguishing cause from effect is to determine which happened first, but the process of seeing seems to occur too quickly to determine the order in which things happened.

Today, photography provides the simplest experimental evidence that nothing has to be emitted from your eye and hit the leaf in order to make it "greenify." A camera can take a picture of a leaf even if there are no eyes anywhere nearby. Since the leaf appears green regardless of whether it is being sensed by a camera, your eye, or an insect's eye, it seems to make more sense to say that the leaf's greenness is the cause, and something happening in the camera or eye is the effect.

Task 2. *Para 2*: to come up with = (b) to think of an idea; *Para 4:* to get right = (c) to understand correctly; to be familiar with = (c) to have a good knowledge or understanding of something; a variety of = (a) a lot of things of the same type that are different from each other in some way; *Para 1*: luminous = (c) shining in the dark; stuff = (a) things (such as substances, materials, or groups of objects) when you do not know what they are called, or it is not important to say exactly what they are; *Para 6*: bizarre = (c) very unusual or strange; *Para 3*: to feel uneasy = (b) to be worried or slightly afraid; to imply = (a) to suggest that something is true or that you feel or think something, without saying so directly; precedence over = (c) the condition of being more important than somebody or something else; rather than = (a) instead of something; *Para 5*: regardless of = without being affected or influenced by something; to make sense = (c) to have a clear meaning and be easy to understand)

Module 2

Supplementary reading tasks
Task 1: 1) g; 2) d; 3) h; 4) a; 5) c; 6) b; 7) e; 8) i; 9) f.
Task 2: 4; 6; 5; 2; 3; 1.

Huygens' Principle
Returning to the example of double-slit diffraction, f, note the strong visual impression of two overlapping sets of concentric semicircles. This is an example of Huygens' Principle, named after a Dutch physicist and astronomer. (The first syllable rhymes with "boy)". Huygens' principle states that any wavefront can be broken down into many small side-by-side wave peaks, g, which then spread out as circular ripples, h, and by the principle of superposition, the result of adding up these sets of ripples must give the same result as allowing the wave to propagate forward, i. In the case of sound or light waves, which propagate in three dimensions, the "ripples" are actually spherical rather than circular, but we can often imagine things in two dimensions for simplicity.

In double-slit diffraction the application of Huygens' Principle is visually convincing: it is as though all the sets of ripples have been blocked except for two. It is a rather surprising mathematical fact, however, that Huygens'

Principle gives the right result in the case of an unobstructed linear wave, h and i. A theoretically infinite number of circular wave patterns somehow conspire to add together and produce the simple linear wave motion with which we are familiar.

Since Huygens' Principle is equivalent to the principle of superposition, and superposition is a property of waves, what Huygens had created was essentially the first wave theory of light. However, he imagined light as a series of pulses, like hand claps, rather than as a sinusoidal wave.

The history is interesting. Isaac Newton loved the atomic theory of matter so much that he searched enthusiastically for evidence that light was also made of tiny particles. The paths of his light particles would correspond to rays in our description; the only significant difference between a ray model and a particle model of light would occur if one could isolate individual particles and show that light had "graininess" to it. Newton never did this, so although he thought of his model as a particle model, it is more accurate to say he was one of the builders of the ray model.

Almost all that was known about reflection and refraction of light could be interpreted equally well in terms of a particle model or a wave model, but Newton had one reason for strongly opposing Huygens' wave theory. Newton knew that waves exhibited diffraction, but diffraction of light is difficult to observe, so Newton believed that light did not exhibit diffraction, and therefore must not be a wave. Although Newton's criticisms were fair enough, the debate also took on the overtones of a nationalistic dispute between England and continental Europe, fueled by English resentment over Leibniz's supposed plagiarism of Newton's calculus. Newton wrote a book on optics, and his prestige and political prominence tended to discourage questioning of his model.

Thomas Young (1773–1829) was the person who finally, a hundred years later, did a careful search for wave interference effects with light and analyzed the results correctly. He observed double-slit diffraction of light as well as a variety of other diffraction effects, all of which showed that light exhibited wave interference effects, and that the wavelengths of visible light waves were extremely short. The crowning achievement was the demonstration by the experimentalist Heinrich Hertz and the theorist James Clerk Maxwell that light was an electromagnetic wave. Maxwell is said to have related his discovery to his wife one starry evening and told her that she was the only person in the world who knew what starlight was.

Task 3: 1) m; 2) h; 3) e; 4) a; 5) r; 6) n; 7) p; 8) b; 9) k; 10) d; 11) f; 12) i; 13) c; 14) q; 15) j; 16) o; 17) l; 18) g.

Module 3

Ex. 4: 1) i; 2) e; 3) h; 4) c; 5) g; 6) b; 7) f; 8) j; 9) a; 10) d.

Supplementary reading tasks
Task 1: 1) e; 2) c; 3) h; 4) g; 5) d; 6) b; 7) f; 8) a.
Task 2: 1) to; 2) to; 3) through; 4) to; 5) by; 6) between; 7) from.
Task 3: 1) e; 2) c; 3) i; 4) a; 5) g; 6) b; 7) h; 8) f; 9) d.

Task 4: 1) against; 2) by; 3) back; 4) to; 5) to; 6) to; 7) to, of, on; 8) at; 9) to; 10) from.

Module 4

Ex. 3: 1) h; 2) j; 3) e; 4) l; 5) b; 6) k; 7) d; 8) i; 9) f; 10) g; 11) a;12) c.
Supplementary reading tasks
Task 1: 1) b; 2) g; 3) e; 4) a; 5) h; 6) c; 7) f; 8) d.
Task 2: 1) for; 2) to; 3) on; 4) to; 5) at; 6) for.
Task 4: 1) f; 2) h; 3) g; 4) a; 5) c; 6) e; 7) b; 8) d.
Task 6: 1) f; 2) a; 3) e; 4) g; 5) b; 6) c; 7) d.

Module 5

Ex. 8. Classes of laser sources

Class	Type	Method of pumping
Gas	1) neutral electronic transitions 2) ionic atomic active species 3) electronic transitions 4) vibrational 5) rotational (neutral molecular active species) 6) molecular-ion active species	electrical discharge: cw; b) pulsed; c) dc or rf; d) glow or arc electron-beam excitation gas-dynamic expansion chemical reactions optical pumping by primary laser
Liquid	1) organic dye 2) rare-earth chelate (organic molecules) 3) lasers utilizing inorganic solvents and trivalent rare-earth ion active centers	Optical pumping by: 1) flashlamps 2) pulsed primary lasers 3) cw primary lasers
Solid state	1) dielectric insulator a) impurity-doped crystal b) impurity-doped amorphous material (such as glass) c) insulating crystals (stoichiometric, color center)	Optical pumping by: 1) flashlamps 2) cw arc-lamps 3) other laser sources
	2) semiconductor	Optical pumping by: 1) electron beam 2) injection of electrons in a p-n junction

Supplementary reading tasks

Task 1: 1) e; 2) g; 3) a; 4) b; 5) f; 6) c; 7) d.
Task 3: 1) d; 2) a; 3) l; 4) g; 5) b; 6) k; 7) i; 8) f; 9) e; 10) h; 11) c; 12) j.

Task 4:

locate	location locator	located	investigate	investigation investigator	investigable investigative
dedicate	dedication dedicatee dedicator	dedicated	clarity	clarification clarifier	clarified clarifying
surround	surround surroundings	surrounding	install	installation installer	installed installable
explore	exploration explorer	explored	detect	detecting detection detector	detected detectable

Module 6

Ex. 3: 1) i; 2) d; 3) g; 4) c; 5) h; 6) j; 7) k; 8) e; 9) f; 10) b; 11) a.

Supplementary reading tasks

Task 1: 1) of; 2) to; 3) from; 4) of; 5) on; 6) for; 7) in.
Task 2: 1) f; 2) a; 3) d; 4) e; 5) b; 6) h; 7) g; 8) c.

Module 7

Ex. 2: 1) c; 2) f; 3) a; 4) i; 5) b; 6) g; 7) j; 8) e; 9) h; 10) d.
Ex. 3: 1) i; 2) g; 3) j; 4) h; 5) c; 6) e; 7) a; 8) k; 9) f; 10) d; 11) b.
Supplementary reading tasks
Task 1: 2, 4, 5, 1, 7, 8, 6, 3.

Light is a Thing and it Travels from One Point to Another

An important issue that few people have considered is whether a candle's flame simply affects your eye directly, or whether it sends out light which then gets into your eye. Again, the rapidity of the effect makes it difficult to tell what's happening. If someone throws a rock at you, you can see the rock on its way to your body, and you can tell that the person affected you by sending a material substance your way, rather than just harming you directly with an arm motion, which would be known as "action at a distance." It is not easy to do a similar observation to see whether there is some "stuff" that travels from the candle to your eye, or whether it is a case of action at a distance.

Newtonian physics includes both action at a distance (e.g. the earth's gravitational force on a falling object) and contact forces such as the normal force, which only allow distant objects to exert forces on each other by shooting some substance across the space between them (e.g), a garden hose spraying out water that exerts a force on a bush).

One piece of evidence that the candle sends out stuff that travels to your eye is that intervening transparent substances can make the candle appear to be in the wrong location, suggesting that light is a thing that can be bumped off course. Many people would dismiss this kind of observation as an optical illusion, however. (Some optical illusions are purely neurological or psychological effects, although some others, including this one, turn out to be caused by the behavior of light itself).

A more convincing way to decide in which category light belongs is to find out if it takes time to get from the candle to your eye; in Newtonian physics, action at a distance is supposed to be instantaneous. The fact that we speak casually today of "the speed of light" implies that at some point in history, somebody succeeded in showing that light did not travel infinitely fast. Galileo tried, and failed, to detect a finite speed for light, by arranging with a person in a distant tower to signal back and forth with lanterns. Galileo uncovered his lantern, and when the other person saw the light, he uncovered his lantern. Galileo was unable to measure any time lag that was significant compared to the limitations of human reflexes.

The first person to prove that light's speed was finite, and to determine it numerically, was Ole Roemer, in a series of measurements around the year 1675. Roemer observed Io, one of Jupiter's moons, over a period of several years. Since Io presumably took the same amount of time to complete each orbit of Jupiter, it could be thought of as a very distant, very accurate clock.

A practical and accurate pendulum clock had recently been invented, so Roemer could check whether the ratio of the two clocks' cycles, about 42.5 hours to 1 orbit, stayed exactly constant or changed a little. If the process of seeing the distant moon was instantaneous, there would be no reason for the two to get out of step. Even if the speed of light was finite, you might expect that the result would be only to offset one cycle relative to the other.

The earth does not, however, stay at a constant distance from Jupiter and its moons. Since the distance is changing gradually due to the two planets' orbital motions, a finite speed of light would make the "Io clock" appear to run faster as the planets drew near each other, and more slowly as their separation increased. Roemer did find a variation in the apparent speed of Io's orbits, which caused Io's eclipses by Jupiter (the moments when Io passed in front of or behind Jupiter) to occur about 7 minutes early when the earth was closest to Jupiter, and 7 minutes late when it was farthest.

Based on these measurements, Roemer estimated the speed of light to be approximately 2 × 108 m/s, which is in the right ballpark compared to modern measurements of 3 × 108 m/s. (I'm not sure whether the fairly large experimental error was mainly due to imprecise knowledge of the radius of the earth's orbit or limitations in the reliability of pendulum clocks).

Task 2. *Para 2*: to affect = (b) to do something that produces an effect or change in something or in someone's situation, to send out = (c) to broadcast or produce a signal, light, sound etc); *Para 4*: to spray out = (a) to force liquid out of a container so that it comes out in a stream of very small drops and covers an area; *Para 5*: a piece of evidence = (c) facts or signs that show clearly that something exists or is true; to bump off course = (a) to move something into a different direction; to dismiss = (c) to refuse to consider someone's idea, opinion etc), because you think it is not serious, true, or important; to turn out = (a) to happen in a particular way, or to have a particular result, especially one that you did not expect; *Para 1*: a more convincing way = (b) making you believe that something is true or right, to find out = (a) to get information, after trying to discover it or by chance; to succeed in = (c) to do what you tried or wanted to do; to fail = (a) to not succeed in achieving something; back and forth = (c) going in one direction and then in the opposite direction, and repeating this several times; *Para 8*: pendulum clock = (a) a long metal stick with a weight at the bottom that swings regularly from side to side to control the working of a clock; *Para 6*: to draw near = (b) to approach, come closer; *Para 3*: a ballpark = (c) a range of values.

Task 3: 1) f; 2) c; 3) h; 4) a; 5) e; 6) d; 7) g; 8) b.
Task 4: 1) g; 2) a; 3) d; 4) f; 5) h; 6) i; 7) e; 8) b; 9) j; 10) c; 11) l; 12) k.

Module 8

Supplementary reading tasks

Task 1: 4, 6, 2, 5, 3, 1.

Production of fiber lasers in Russia

The Russian Corporation of Nanotechnologies will invest in expansion of Russian production of advanced fiber lasers for cutting, welding, deposition, and engraving of metal items and high-technology telecommunications equipment for long-distance trunk communication at IRE-Polus, a subsidiary of US-based IPG Photonics Corporation.

Founded by Russian scientists, IPG Photonics Corp. has, over the last five years, become the world leader in high-performance fiber lasers and amplifiers and systems based on them.

Fiber lasers offering a broad range of power (from 5 watts to 50 kilowatts) are gradually replacing gas and many solid-state lasers. A diode pump and nano-structured fiber make it possible to reach high output power, gain and efficiency factor of up to 30 percent in commercial production, and reduce cost of ownership up to 50 percent.

"This is our first partnership with a US listed company.The technology used in the project is a great breakthrough. Its power, compactness, and low cost of ownership open doors to more and more new applications for fiber lasers.Already they can be used in solar batteries, medicine and electronics. Domestic production of laser complexes based on these innovations will enable Russia to re-fit strategic sectors - telecommunications, mechanical engineering, and medicine with the latest equipment and instruments," said RUSNANO managing director Konstantin Demetriou.

IRE-Polus is expected to earn most of its income under the project from sales of high-power fiber amplifiers and lasers with broad applications and from telecommunications equipment. The company will manufacture communications systems that use proprietary fiber optic technology: 40-Gbps DWDM-transponders, reconfigurable optical multiplexers, optical amplifiers, multiport 10-Gbps multiplexer/transponders, and other communications equipment.

IRE-Polus develops and manufactures fiber lasers and amplifiers, optical components, modules, instruments, subsystems, and systems for fiber, atmospheric, and free-space optical communication; cable television; optical radar; remote control of industrial objects and atmospheres; industrial complexes for laser welding, tempering, thermal processing, and marking; control and measurement systems; sensors; scientific research; surgery; and biomedicine.

Task 3: 1) f; 2) b; 3) g; 4) c; 5) i; 6) a; 7) d; 8) e; 9) g; 10) h.

Module 9

Ex. 3:

research	research, researcher	—	—
complete	completion	complete, completed	completely
transpire	transparence, transparency	transparent	transparently
develop	development	developed, developing, underdeveloped	—
vary	variation, variable, variability	various, variable, varied	variously, variably, invariably
distinguish	distinction, distinguisher	distinct, distinguishing	distinctly
displace	displacement, displaceability, displacer	displacing, displaceable, displaced	—
arrange	arrangement	arranged, prearranged	—
observe	observation, observer, observancy, observance, observatory	observant, observed	observantly
separate	separation, separator	separated, separating	separately
apply	applicability, application, applicant	applied, applicable	—
create	creation, creator	creative	creatively

Ex. 6: 1) b; 2) f; 3) a; 4) e; 5) d; 6) c.
Ex. 14: 1) d; 2) a; 3) b; 4) e; 5) c.
Ex. 16: Denisyuk's discovery.

Module 10

Ex. 2: 1) e; 2) d; 3) a; 4) g; 5) j; 6) k; 7) l; 8) i; 9) b; 10) f; 11) h; 12) c.

Ex. 5: Making a power measurement is often a simple process – just place a photodetector head into a laser beam and read the digital display from the power meter. This simplicity commonly leads to X novice mistakes, however) The sensitivity of the detector can easily vary by ±5% or more over its surface. Even X miniscule reflections from the detector surface back into the laser will cause X power fluctuations. Another commonly overlooked factor is the effect of X transmissive optics on some measurements. And for low X light levels or fast pulses, care must be taken to keep connecting cables short to avoid X noise pickup or added capacitance, which slows X dynamic response. The operation of other instruments, particularly when measuring low signal levels, can also cause X spurious results.

Supplementary reading tasks

Task 1: 1) k; 2) h, 3) a; 4) e; 5) j; 6) c; 7) g; 8) i; 9) l; 10) f; 11) d; 12) b.
Task 2: 1) d; 2) e; 3) b; 4) f; 5) a; 6) c.
Task 4: 7; 3; 2; 8; 5; 1; 6; 4.

Apollo 11 Experiment Still Going Strong after 35 Years

It was the summer of '69. Director John Schlesinger's "Midnight Cowboy" had won the Oscar for Best Picture; the Rolling Stones' newly released "Honky Tonk Women" was climbing the charts; 400,000 people were gearing up to attend Woodstock...and America landed on the Moon, making "one giant leap for mankind."

On the afternoon of July 20, 1969, Apollo 11 astronauts Neil Armstrong and Edwin "Buzz" Aldrin explored the surface of the Moon for two and a half hours, collecting samples and taking photographs while Michael Collins orbited in the command module Columbia. On July 21, about an hour before the end of their final moonwalk, they left an experiment on the lunar surface which, after 35 years, continues to work as well as it did the day it got there. Called the lunar laser ranging experiment, it studies the Earth-Moon system and returns data to scientific centers around the world, including NASA's Jet Propulsion Laboratory.

The experiment consists of an instrument called the lunar laser ranging reflector, designed to reflect pulses of laser light fired from the Earth. The idea was to determine the round-trip travel time of a laser pulse from the Earth to the Moon and back again, thereby calculating the distance between the two bodies to unprecedented accuracy. Unlike the other scientific experiments left on the Moon, this reflector requires no power and is still functioning perfectly after 35 years.

The Apollo 11 laser reflector consists of 100 fused silica half cubes, called corner cubes, mounted in a 46-centimeter (18-inch) square aluminum panel. Each corner cube is 3.8 centimeters (1.5 inches) in diameter. Corner cubes reflect a beam of light directly back toward its point of origin; it is this fact that also makes them so useful in Earth surveying.

Three more reflectors have since been left on the Moon, including two by later Apollo 14 and 15 missions and one (built by the French) on the unmanned Soviet Lunokhod 2 rover. Each of the reflectors rests on the lunar surface in such a way that its flat face points toward the Earth.

Once the laser beam hits a reflector, scientists at the observatories use sensitive filtering and amplification equipment to detect any return signal. The reflected light is too weak to be seen with the human eye, but under good conditions, one photon – the fundamental particle of light – will be received every few seconds.

The lunar laser ranging experiment is the only lunar investigation continuously operating since the Apollo project. Improvements in lasers and electronics over the years have led to measurements currently accurate to about 2 centimeters (less than one inch).

Scientists know the average distance between the centers of the Earth and the Moon is 385,000 kilometers (239,000 miles), implying that the modern lunar ranges have relative accuracies of better than one part in 10 billion.This level of accuracy represents one of the most precise distance measurements ever made and is equivalent to determining the distance between Los Angeles and New York to one hundredth of an inch. “Technical improvements at the observatories rejuvenate the lunar laser ranging effort,” Williams said. “When the range accuracy improves, it is like getting a new experiment on the Moon.”

Task 5: *Para 4*: to climb the charts = (b) to move to a higher position in popularity lists; to gear up = (a) to be prepared to do a particular activity; *Para 2*: a sample = (c) a specimen taken for scientific testing or analysis; moonwalk = (a) an act or period of walking on the surface of the moon; *Para 5*: round-trip = (b) a journey to one or more places and back again; *Para 8*: a corner cube = (c) a retroreflector; *Para 3*: a mission = (b) an expedition into space; *Para 1*: to hit = (b) come into contact with something stationary forcefully; *Para 7*: accurate = (a) correct in all details; *Para 6*: to imply = (b) suggest something as a logical consequence, to rejuvenate = (c) make something more lively and more efficient.

Module 11

Ex. 17: The qualities of detectors

Important detector qualities such as spectral response, rise time, and sensitivity differ not only between types but also between different detectors of the same type. These qualities are also influenced by the design of the overall measurement system, including component specification.

Several parameters are used to characterize detector performance. Quantum efficiency — the number of electrons generated per incident photon — is a fundamental parameter that underlies the performance of many types of detectors. Signal-to-noise ratio, which will be discussed in next month’s article, is the ultimate figure of merit for a detector.

Supplementary reading tasks

Task 1:

Verb	Noun(s)	Adjective	Adverb
—	virtuality, virtue	virtual	virtually
evolve	evolvement, evolving, evolvent	evolved, evolving	—
attain	attainability, attainment	attainable	—
prevent	prevention, preventing	preventive, preventing	preventively
apply	application, applicant, appliance applicability	applied, applicable	applicably
lose	loss, loser, losing	lossy, losing	—
—	spontaneity	spontaneous	spontaneously
store	storing, storage, store	storing, stored	—

Task 3: 1) c; 2) d; 3) h; 4) f; 5) a; 6) e; 7) g; 8) b.
Task 5: 1) e; 2) j; 3) b; 4) c; 5) h; 6) d; 7) a; 8) i; 9) g; 10) f.

Task 6: 5, 6, 4, 2, 3, 1.

Random-number generator gets its input from quantum vacuum fluctuations

Researchers at The Australian National University (ANU) are generating true random (not quasirandom) numbers from a single-mode laser setup that makes broadband measurements of the vacuum field. And, based on this setup, they have a website that anyone who needs live random numbers can access. The vacuum is actually an extent of space that has virtual subatomic particles spontaneously and randomly appearing and disappearing. The setup ANU makes measurements of the vacuum field contained in radio-frequency sidebands of a laser; the resulting photocurrents are then transformed by an algorithm into a string of random numbers that are generated at up to 2 Gbit/s.

Random number generation has many uses in information technology. Global climate prediction, air traffic control, electronic gaming, encryption, and various types of computer modeling all rely on the availability of unbiased, truly random numbers. To date, most random-number generators are based on computer algorithms. Although computer-generated random numbers can be useful, knowing the input conditions to the algorithm will lead to predictable and reproducible output, thus making the numbers not truly random.

To overcome this issue, random number generators relying on inherently random physical processes, such as radioactive decay and chaotic behavior in circuits, have been developed. The ANU random-number-generation process is the fastest true-random-number generation scheme yet.

The random number generator is online and can be accessed from anywhere at anytime around the world at .http://photonics.anu.edu.au/qoptics/Research/qrng.php. Anyone who downloaded live random numbers from the ANU website will get a fresh and unique sequence of numbers that is different from all other users). In collaboration with QuintessenceLabs, an Australian quantum-technology company, the ANU team is now looking into commercializing the system. The team hopes to have this technology miniaturized down to the size of a thumb drive.

Module 12

Ex. 1: 1) b; 2) d; 3) h; 4) a; 5) i; 6) l; 7) e; 8) c; 9) g; 10) k; 11) j; 12) f.
Ex. 2: 1) b; 2) g; 3) j; 4) k; 5) a; 6) f; 7) c; 8) h; 9) b; 10) i;11) e;12) r; 13) t; 14) l; 15) s; 16) m; 17) n; 18) u; 19) o; 20) p; 21) v; 22) q.
Ex. 4: 1) c; 2) d; 3) g; 4) a; 5) k; 6) e; 7) b; 8) j; 9) f; 10) h; 11) i; 12) p; 13) v; 14) l; 15) r; 16) m; 17) t; 18) q; 19) u; 20) s; 21) n; 22) o.
Ex. 5: 1) d; 2) a; 3) c; 4) e; 5) b; 6) f.
Ex. 6: 1) result in; 2) resulted from; 3) bring about; 4) rely on; 5) build up; 6) come from.
Ex. 7: 1) with; 2) on; 3) under; 4) to; 5) to; 6) to; 7) about; 8) without; 9) in; 10) along, up; 11) for; 12) about; 13) on.

Ex. 10: 1) j; 2) k; 3) h; 4) b; 5) g; 6) e; 7) d; 8) c; 9) i; 10) a; 11) f.
Ex. 11: 1) d; 2) g; 3) e; 4) b; 5) i; 6) c; 7) j; 8) f; 9) a; 10) h.
Ex. 14: 4, 5, 1, 3, 2.

Supplementary reading tasks

Task 1: 1) f; 2) d; 3) i; 4) b; 5) c; 6) a; 7) e; 8) g; 9) k; 10) h; 11) j.
Task 4: 1) b; 2) a; 3) h; 4) g; 5) d; 6) f; 7) e; 8) c.
Task 5: 2; 4; 3; 1.

Taking the measure of light

In the early history of the laser, a common method of measuring peak power was to count the number of razor blades through which a pulse could burn. These units were called “Gillettes”, and they serve to illustrate how measuring the brightness of light, one of the most intuitive quantities for humans, has long been a problem for technology.

Manufacturers of instruments that measure power and energy have taken pains to make them user-friendly. Complex optoelectronic measurements — such as bit-error rate, crosstalk ratio, and so on — can be obtained with a push of a button. But underlying all such complex relationships are fundamental measurements of energy, power, pulse duration, and wavelength. Understanding the physical details of these measurements is particularly essential at the boundaries of current technology — for ultrafast pulses, very high or low light levels, and very short or long wavelengths.

The capabilities of an instrument are specified by its resolution, repeatability, and accuracy. Resolution or sensitivity is the minimum quantity that can be discerned in a measurement. The noise present in an instrument during a measurement is a major factor limiting sensitivity. Repeatability quantifies how well an instrument can make one measurement, make a different one, and then return to repeat the first measurement. Accuracy is the ability of an instrument to make a measurement relative to an absolute standard.

As a rule of thumb, the accuracy of an instrument is about ten times greater than its repeatability. Accuracy typically is needed for the most demanding applications. Scheduling routine calibration is particularly important for accurate measurement of optical power and energy, as these instruments in general are more prone to drift over time than other types.

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