МИНИСТЕРСТВО НАУКИ И ВЫСШЕГО ОБРАЗОВАНИЯ
РОССИЙСКОЙ ФЕДЕРАЦИИ
федеральное государственное бюджетное образовательное учреждение
высшего образования
МОСКОВСКИЙ ГОСУДАРСТВЕННЫЙ УНИВЕРСИТЕТ
ГЕОДЕЗИИ И КАРТОГРАФИИ
(МИИГАиК)

Факультет оптического приборостроения
Кафедра лингвистики

**ДОКУМЕНТ ПОДПИСАН
ЭЛЕКТРОННОЙ ПОДПИСЬЮ**

Сертификат: 5387FD2AF5B17FED816FDE9A1D4973B1
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Действителен: с 21.07.2025 по 14.10.2026

«УТВЕРЖДАЮ»
Проректор
А. Л. Степанченко
16 февраля 2024 г.

# ФОНД ОЦЕНОЧНЫХ СРЕДСТВ ПО ДИСЦИПЛИНЕ (МОДУЛЮ) «Б1.О.05 ИНОСТРАННЫЙ ЯЗЫК»

Уровень высшего образования: бакалавриат

Направление подготовки: 12.03.05 Лазерная техника и лазерные технологии

Направленность(профиль) подготовки: Лазерная техника и лазерные технологии

Квалификация (степень) выпускника: бакалавр

Форма обучения: очная

Год набора (приема на обучение): 2024

Срок получения образования: 4 года

Объем: в зачетных единицах: 7 з.е.
в академических часах: 252 ак.ч.

Москва, 2024

**Разработчики:**
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Фонд оценочных средств по дисциплине (модулю) составлен в соответствии с требованиями ФГОС ВО по направлению подготовки 12.03.05 Лазерная техника и лазерные технологии, утвержденного приказом Минобрнауки от 19.09.2017 № 951

Согласование и утверждение

| № | Подразделение | Ответственное лицо | ФИО | Виза | Дата, протокол (при наличии) |
|---|---|---|---|---|---|
| 1 | факультет Оптического приборостроения | Председатель ученого совета факультета | Торшина И. П. | Рассмотрено | 15.02.2024, № 2/23-24 |

## 1. Планируемые результаты обучения, соотнесенные с планируемыми результатами освоения образовательной программы

УК-4 Способен осуществлять деловую коммуникацию в устной и письменной формах на государственном языке Российской Федерации и иностранном(ых) языке(ах)

УК-4.1 Выбирает стиль общения на государственном языке РФ и иностранном языке в зависимости от цели и условий партнерства; адаптирует речь, стиль общения и язык жестов к ситуациям взаимодействия

*Знать:*

УК-4.1/Зн1 Лексический минимум в объеме 2000 учебных лексических единиц общего и терминологического характера, необходимого для возможности получения информации профессионального содержания из зарубежных источников

*Уметь:*

УК-4.1/Ум1 Выполнять переводы технических текстов с иностранного языка

*Владеть:*

УК-4.1/Нв1 Навыками чтения, аудирования, разговорной речи, письмо в профессиональной области.

УК-4.2 Выполняет перевод профессиональных текстов с иностранного языка на государственный язык РФ и с государственного языка РФ на иностранный

*Знать:*

УК-4.2/Зн1 Основные способы работы на языковым и речевым материалом

*Уметь:*

УК-4.2/Ум1 Выполнять перевод технических текстов с иностранного языка

*Владеть:*

УК-4.2/Нв1 Приемами самостоятельной работы с языковым материалом с использованием справочной и учебной литературы

УК-4.3 Ведет деловую коммуникацию в письменной и электронной форме, учитывая особенности стилистики официальных и неофициальных писем, социокультурные различия в формате корреспонденции на государственном и иностранном (-ых) языках

*Знать:*

УК-4.3/Зн1 нормы произношения, лексику иностранного языка общеупотребительного, терминологического и профессионального содержания; типовые способы построения высказываний в устной и письменной речи

*Уметь:*

УК-4.3/Ум1 осуществляет коммуникацию с зарубежными партнерами; переводит научно-техническую литературу, связанную с профессиональной деятельностью

*Владеть:*

УК-4.3/Нв1 стратегиями проведения сопоставительного анализа факторов культуры различных стран

УК-4.4 Представляет свою точку зрения при деловом общении и в публичных выступлениях

*Знать:*

УК-4.4/Зн1 лексический минимум в объеме 2000 лексических единиц общего и терминологического характера, необходимого для возможности получения информации профессиональго содержания из зарубежных источников

*Уметь:*

УК-4.4/Ум1 осуществлять коммуникацию с зарубежными партнерами; переводить научно-техническую литературу по вопросами, связанным с профессиональной деятельностью

*Владеть:*

УК-4.4/Нв1 компенсаторными умениями, помогающими преодолеть "сбои" в коммуникации, вызванные объективными и субъективными, социокультурными причинами

## 2. Показатели и критерии оценивания компетенций

| Планируемые результаты освоения программы | Уровень овладения | Критерии оценивания (перечень сформированных ИДК/ЗУВ по уровням освоения) |
|---|---|---|
| УК-4 Способен осуществлять деловую коммуникацию в устной и письменной формах на государственном языке Российской Федерации и иностранном(ых) языке(ах) | Повышенный | ИДК УК-4.1 Выбирает стиль общения на государственном языке РФ и иностранном языке в зависимости от цели и условий партнерства; адаптирует речь, стиль общения и язык жестов к ситуациям взаимодействия<br><br>Знать:<br>УК-4.1/Зн1 Лексический минимум в объеме 2000 учебных лексических единиц общего и терминологического характера, необходимого для возможности получения информации профессионального содержания из зарубежных источников<br><br>ИДК УК-4.2 Выполняет перевод профессиональных текстов с иностранного языка на государственный язык РФ и с государственного языка РФ на иностранный<br><br>Знать:<br>УК-4.2/Зн1 Основные способы работы на языковым и речевым материалом |

## 3. Шкала оценивания

| Оценка | Критерии оценивания (перечень сформированных ИДК/ЗУВ) |
|---|---|
| Отлично | УК-4.1 Выбирает стиль общения на государственном языке РФ и иностранном языке в зависимости от цели и условий партнерства; адаптирует речь, стиль общения и язык жестов к ситуациям взаимодействия<br>УК-4.1/Зн1 Лексический минимум в объеме 2000 учебных лексических единиц общего и терминологического характера, необходимого для возможности получения информации профессионального содержания из зарубежных источников<br>УК-4.2 Выполняет перевод профессиональных текстов с иностранного языка на государственный язык РФ и с государственного языка РФ на иностранный<br>УК-4.2/Зн1 Основные способы работы на языковым и речевым материалом |

| | |
|---|---|
| Неудовле-творительно | Результаты обучения не сформированы на достаточном уровне |
| Оценка | Критерии оценивания (перечень сформированных ИДК/ЗУВ) |
| Не зачтено | Результаты обучения не сформированы на достаточном уровне |

## 4. Контрольные мероприятия по дисциплине

| Вид контроля | Форма контроля/Оценочное средство |
|---|---|
| Текущий контроль | Контрольная работа |
| Промежуточная аттестация | Зачет<br>Экзамен |

| № п/п | Наименование раздела | Контролируемые ИДК | Вид контроля/ используемые оценочные материалы | |
|---|---|---|---|---|
| | | | Текущий | Промежут. аттестация |
| 1 | Вводно-коррективный курс | УК-4.1 | | Зачет<br>Экзамен |
| 2 | Общий курс иностранного языка | УК-4.1 | Контрольная работа | Зачет<br>Экзамен |
| 3 | Профессионально-ориентированный иностранный язык | УК-4.1 УК-4.2 УК-4.3 УК-4.4 | Контрольная работа | Зачет<br>Экзамен |

## 5. Порядок проведения промежуточной аттестации

Порядок проведения промежуточной аттестации регламентируется локальными нормативными актами Университета:

- Положением о формах, периодичности, порядке текущего контроля успеваемости и промежуточной аттестации обучающихся по основным образовательным программам высшего образования – программам бакалавриата, программам специалитета, программам магистратуры в федеральном государственном бюджетном образовательном учреждении высшего образования «Московский государственный университет геодезии и картографии», п.6 «Организация и проведение промежуточной аттестации».
- Положением о порядке осуществления образовательного процесса, проведения текущего контроля успеваемости и промежуточной аттестации обучающихся с применением электронного обучения и дистанционных образовательных технологий в федеральном государственном бюджетном образовательном учреждении высшего образования «Московский государственный университет геодезии и картографии», п.8 «Проведение промежуточной аттестации с применением ЭО и ДОТ».

*Промежуточная аттестация: Зачет, 2 семестр.*

*Промежуточная аттестация: Экзамен, 3 семестр.*

## 6. Оценочные материалы текущего контроля

***Раздел 2. Общий курс иностранного языка***

*Контролируемые ИДК: УК-4.1*

*Тема 2.5. Россия в современном мире, Москва, мой родной город.*

Форма контроля/оценочное средство: Контрольная работа

Вопросы/Задания:

1. Answer the question:

What does the science of history of architecture study?

1. Architecture development process in connection with the biological processes
2. The relationship between people and animals
3. Architecture development process in connection with the historical processes

2. Choose the correct expression:

The detailed study of a site is

1. site analysis
2. bird analysis
3. cat analysis

3. Complete the sentence using the correct word:

_____ is your address?

1. What
2. How
3. That

4. Do you speak Japanese? No, I _____.

1. speaking not
2. speak not
3. don't

5. Pick up the correct word:

a person or company, responsible for the physical construction of a building is _____

1. scientist
2. constructor
3. doctor

6. What do we call:

a thin tall structure usually rising above the castle or building that it is attached to?

1. tower
2. table
3. tree

7. When was the University of .Geodesy and Cartograpy founded?

1. 1779
2. 1920
3. 2000

8. What do modal verbs show?

1. modality
2. time
3. voice

9. Choose the correct sentence:

1. I am a student.
2. A student I am.
3. A student am I.

10. Раскройте скобки, употребляя глаголы в требующемся времени.

When I (to come) to Pete's house last Sunday, he (to read) a new book

11. Раскройте скобки, употребляя глаголы в требующемся времени.

Yesterday I (to buy) a new pair of gloves, as I (to lose) the old ones.

12. Раскройте скобки, употребляя глаголы в требующемся времени.

I (to meet) him when he (to walk) across the park.

13. Раскройте скобки, употребляя глаголы в требующемся времени.

Don't enter the bedroom! The child (to sleep) there, and he always (to wake) up when somebody (to open) the door.

14. Раскройте скобки, употребляя глаголы в требующемся времени.

What the children (to do) now? — Oh, they (to play) the new table game which I (to buy) for them the day before yesterday.

15. Раскройте скобки, употребляя глаголы в требующемся времени.

We could not go out because it (to rain) hard since early morning.

16. Раскройте скобки, употребляя глаголы в требующемся времени.

When I (to come) home yesterday, my sister already (to return) and (to sit) at the fireplace looking through some old photographs.

17. Раскройте скобки, употребляя глаголы в требующемся времени.

When morning came, the storm already (to stop), but the snow still (to fall).

18. Раскройте скобки, употребляя глаголы в требующемся времени.

I (to hear) this song several times already, but I cannot remember the words.

19. Передайте следующие предложения в Passive Voice.

I bought potatoes yesterday.

20. Передайте следующие предложения в Passive Voice.

We will bring the books tomorrow.

21. Передайте следующие предложения в Passive Voice.

They are repairing the clock now.

22. Передайте следующие предложения в Passive Voice.

I have translated the whole text.

23. Передайте следующие предложения в Passive Voice.

They broke the window last week

24. Передайте следующие предложения в Passive Voice.

They were playing tennis from four till five.

25. Передайте следующие предложения в Passive Voice.

By six o'clock they had finished the work.

26. Передайте следующие предложения в Passive Voice.

They are building a new concert-hall in our street.

27. Передайте следующие предложения в Passive Voice.

Livingstone explored Central Africa in the 19th century.

28. Передайте следующие предложения в Passive Voice.

They haven't brought back my skates.

29. Передайте предложения в косвенную речь.

“My friend lives in Moscow”, said Alec.

30. Передайте предложения в косвенную речь.

“I can’t explain this rule to you”’ said my classmate to me.

31. Передайте предложения в косвенную речь.

He said:” I have just received a letter from my uncle”

32. Передайте предложения в косвенную речь.

She asked me: ”What will you do tomorrow?”

33. Передайте предложения в косвенную речь.

She asked me:”Why did you come here yesterday?”

34. Передайте предложения в косвенную речь.

I asked me uncle: ”How long did you stay in Moscow?”

35. Передайте предложения в косвенную речь.

The teacher said to me:”Does your father work at a factory?”

36. Передайте предложения в косвенную речь.

“Did you go shopping yesterday?”, said grandmother to Mary

37. Передайте предложения в косвенную речь.

Father said to Nick:”Have you done your homework?”

38. Передайте предложения в косвенную речь.

“Tom, go to bed”, said his mother.

39. Передайте предложения в косвенную речь.

Kate said to her grandmother:”Help me to cook the soup, please”.

40. Передайте предложения в косвенную речь.

“Don’t play in the street”, said the van to the boys.

41. Составьте предложения с модальными глаголами, расставив слова в нужном порядке. Переведите получившиеся предложения.

the party / Linda / to / come / might / tonight.

42. Составьте предложения с модальными глаголами, расставив слова в нужном порядке. Переведите получившиеся предложения.

round / work / have to / farmers / the year / all.

43. Составьте предложения с модальными глаголами, расставив слова в нужном порядке. Переведите получившиеся предложения.

you / not / hospital / noise / must / make / in.

44. Составьте предложения с модальными глаголами, расставив слова в нужном порядке. Переведите получившиеся предложения.

the light / I / switch / may / on ?

45. Составьте предложения с модальными глаголами, расставив слова в нужном порядке. Переведите получившиеся предложения.

your / look / could / passport / I / at ?

46. Составьте предложения с модальными глаголами, расставив слова в нужном порядке. Переведите получившиеся предложения.

catch / last / able to / we / were / train / the.

47. Составьте предложения с модальными глаголами, расставив слова в нужном порядке. Переведите получившиеся предложения.

didn’t / you / drink / have to / much / yesterday / so.

48. Составьте предложения с модальными глаголами, расставив слова в нужном порядке. Переведите получившиеся предложения.

ought to / bill / Robert / the electricity / pay / today.

49. Составьте предложения с модальными глаголами, расставив слова в нужном порядке. Переведите получившиеся предложения.

better / we / find / a / should / job.

50. Составьте предложения с модальными глаголами, расставив слова в нужном порядке. Переведите получившиеся предложения.

too much / you / salt / and / eat / sugar / shouldn’t.

***Раздел 3. Профессионально-ориентированный иностранный язык***

*Контролируемые ИДК: УК-4.1 УК-4.2 УК-4.3 УК-4.4*

*Тема 3.2. Моя специальность: История изучаемой науки и видные ученые*

Форма контроля/оценочное средство: Контрольная работа

Вопросы/Задания:

1. Translate the text

Light is refracted in going from a vacuum to air. Let a ray of light from the sun (Fig 10) enter the earth’s atmosphere at B. This ray will be bent toward the radius of the earth and will reach an observer at O as if it had come in the direction AO instead of in its true direction.

For this reason the observed altitude of the sun appears too great, so that it must be corrected to obtain the true altitude. On account of the irregular change in the density of the atmosphere, this correction is not easy to calculate. A body which is already below the horizon may appear to be above the horizon. Consequently the sun really sets before its last rays disappear. On the other hand, the rays of the sun become visible in the morning a little while before the sun is above the horizon. The bending of a ray being, the greater the more nearly horizontal the ray becomes, the rays from the lower edge.

This produces a shortening of the vertical diameter, while the horizontal diameter is unchanged. This results in the sun or moon appearing elliptical when near the horizon.

When the sun is at zenith, no correction is necessary.

## 7. Оценочные материалы промежуточной аттестации

*2 семестр, Зачет*

*Контролируемые ИДК: УК-4.1 УК-4.2 УК-4.3 УК-4.4*

Вопросы/Задания:

1. Выполните полный письменный перевод со словарем текста с английского языка на русский (1000-1200 п.зн. за 45 мин.)

The flag of the UK is known as the Union Jack. It has its history. It all began in 1603 when Scotland was joined to England and Wales. The flag is made up of 3 crosses. The upright cross is the Cross of St. Jeorge the patron saint of England. The white diagonal cross is the cross of St. Andrew, the patron saint of Scotland. The red diagonal cross is the cross is the cross of St. Patrick, the patron saint of Ireland. All of them are on the blue background. The national anthem is . The national currency is pound. Geographically the island of Great Britain is subdivided into 2 main regions: Lowland Britain and Highland Britain. Lowland Britain comprises southern and eastern England. Highland Britain consists of Scotland, most of Wales, the Pennines (or the Pennine Chain) and the Lake District. The highest mountain top is Ben Nevis in Scotland. The chief rivers of Great Britain are: the Severn, separating England and Wales, the Thames (the longest and the deepest one). The swiftest flowing river is the Spray. Also the Tweed is famous (the woolen fabric is made here). Every country in the UK has its own national emblem. The red rose is the national emblem of England, the thistle is the national emblem of Scotland, the daffodils and the leek are the emblems of Wales, and the shamrock (a kind of clover) is the emblem of Ireland.

2. Выполните полный письменный перевод со словарем текста с английского языка на русский (1000-1200 п.зн. за 45 мин.)

The United Kingdom is a constitutional monarchy. It has a monarch - a King or a Queen. The present British monarch is Queen Elizabeth the Second. She become Queen in 1952. The monarch has little power and can reign with the support of Parliament. British Parliament is the legislative body at the country. It consists of two Houses. The House of Commons and House of Lords. Parliament and the monarch have different roles in the Government of the country. In reality, the House of Commons has truth power. It introduces new bills. Then they go to the House of Lords for approval. The functions of the Queen are: to open the sessions of the Parliament, to head the commonwealth, to be Commander-in-Chief, to declare the war, to make peace. The house of commons is made up of 650 elected knows of members of parliament. The party which has the majority of suits in the Government and its leader usually becomes prime minister. The prime minister forms his or her Cabinet Ministers. The chairman of the House of Commons is the Speaker. The chairman of the House of Lords is the Lord Chancellor. He sits on a special place, which is called the woolsack. It means that wool made England rich. The members of the House of Lords are not elected, there are live peers. There are several political parties in Great Britain. They are the Conservative, the Liberal, the Labor, the Social Democratic and the Communist parties. Prime minister of the country Boris Johnson is leader of the Conservative Party.

3. Выполните полный письменный перевод со словарем текста с английского языка на русский (1000-1200 п.зн. за 45 мин.)

Siberia, in the north of Russia, is one of the coldest, harshest places on earth. Famed for its inhospitable climate, it is also mineral-wealthy and unexploited – a true frontier region. Although it has attracted mining companies for decades, the challenging landscape and conditions have meant they have only just begun to scratch the surface of the area's potential.

This could now be changing; as climate change leads to warmer temperatures, ice and permafrost are melting and potentially easing the mining process. The mining sector is the second biggest contributor to GDP in Russia, and is expected to continue to play an important role in its economy.

Mining in Siberia grew exponentially during the 20th century, as successive governments and leaders sought to take advantage of it. "The Siberian region is rich in minerals including coal, gold, diamond and iron ore," says Globaldata analyst Alok Shukla. "Coal is largely extracted from Kemerovo, Krasnoyarsk Krai, Sakha (Yakutia), Republic of Khakassia, and Irkutsk Oblast. Gold originates mainly from Krasnoyarsk Krai and Irkutsk Oblast."

Russia is responsible for 7% of global aluminium production, and 95% of this takes place in Siberia. It is home to Russia's largest coal mine, the Arshanovsky pit in the Khakassia Republic which opened in 2015. When at full capacity it is expected to produce 10 million tonnes of coal, and there are already plans to expand it further. Siberia and the Far East also hold 84% of Russia's known gold reserves.

But much remains unexplored or inaccessible in Siberia still, leaving the true mineral wealth of the region uncertain. In 2016, a mineral was discovered in Siberia unlike any ever found naturally occurring on earth. Instead it appears to be similar to lab-grown metal-organic frameworks. Such discoveries highlight the potential of a region so long hidden under ice and thick forests.

4. Выполните полный письменный перевод со словарем текста с английского языка на русский (1000-1200 п.зн. за 45 мин.)

In recent years, climate change has been a much talked about issue, with many debates over its possible impact on the world, and some even going so far as to question its very existence. However, with the undeniable increase in greenhouse emissions on Earth, there can be no doubt that the earth is becoming warmer.

So what exactly does this mean for the future of our planet? In chilly places like the UK, we may think to ourselves: 'Finally, warmer weather!' But global warming will in fact cause extreme weather conditions, meaning that our winters would be even colder than they are now. More than that, warmer temperatures will lead to the melting of ice in the north and south poles, which in turn will lead to rising sea levels across the globe. This is particularly troubling for low coastal regions such as Florida in the USA which would be among the first to be flooded, along with many islands around the world, including the United Kingdom. In 1000 years or so, all these places and more will be submerged underwater.

So where will be able to live? Unless we can find a way to evolve into mermaids and mermen, which doesn't look promising, the only solution is to move elsewhere. There will be little choice left once a large proportion of the land is lost to the sea, and other remaining places will be so hot that they will be absolutely impossible to survive in. It is possible, then, that the once frozen poles of the Arctic and Antarctica will be suitable enough to live in, having melted its ice and warmed up.

It's a scary thought to imagine such devastation on Earth. Perhaps if people start to realize how their actions now can have such a profound impact on future generations, they will change their attitude and start to think more about caring for the environment, in order to save it.

5. Выполните полный письменный перевод со словарем текста с английского языка на русский (1000-1200 п.зн. за 45 мин.)

Inland Weather in Wales

The higher you get in Wales, the colder and wetter it gets. And as you move away from the coasts, Wales is quilted with river valleys separated by increasingly higher hills. The Brecon Beacons in south Wales, are softly rolling but enormous, windswept hills where winter temperatures below freezing and snowfalls are not uncommon. Further north, in the inland mountains of Snowdonia National Park, heavy precipitation can be extreme. One mountain peak, Crib Goch, may be the wettest place in the entire country with an astonishing 176 inches of rainfall annually.2 And on the highest peaks, it snows a great deal.

Mount Snowdon, at 3,560 feet and the highest U.K. mountain south of Scotland, can experience

snowfall from October to May.
Snowfall at lower altitudes is rare, with an average of only 10 days a year with snow lying on the ground in the south and west Wales. On the other hand, the mountains of Snowdonia average 30 days a year with snowfall lying on the ground.
Autumn and Winter in Wales
In September, temperatures linger in the 60s but fall away rapidly through October and November into the high 40s. January and February are the coldest months with temperatures hovering around freezing or slightly above in higher areas and in the high 40s along the coast. Temperatures at night are usually 10 to as much as 15 degrees Fahrenheit colder depending on where you are in the country.
October through January are the wettest months. Rain tends to fall in short, sharp and very heavy showers. November is particularly squally with rain accompanied by gusty winds.

6. Выполните полный письменный перевод со словарем текста с английского языка на русский (1000-1200 п.зн. за 45 мин.)

Scotland is a country in the north of Great Britain. It is a part of the United Kingdom. Scotland is divided into three natural regions: the Southern Uplands, the Central Lowlands and the Highlands and islands. A lot of places in Scotland are a natural paradise, still untouched by man.
The capital of Scotland is Edinburgh, well known for its castle. Glasgow is the industrial capital of Scotland. It is the third largest city in Great Britain. The typical products of Scotland are timber, whisky, salmon. Golf is the Scottish natural sport and it seems to have originated in this country.
Scotland is also the land of myths and mysteries; every castle has its ghost. Glamis Castle is said to have nine of them. And of course everyone knows about the Loch Ness Monster. 'Nessie" is said to be about six meters long, with a long, thin neck. The first report of the monster in Loch Ness was in 565 A.D. Since 1934, thousands of people claimed to they had seen the monster. Scientists have investigated the Loch and taken pictures but no scientific explanation of the mystery has been given.
Scotland is the north part of Great Britain. Five million people live in Scotland. Edinburgh is the capital of Scotland.

7. Выполните полный письменный перевод со словарем текста с английского языка на русский (1000-1200 п.зн. за 45 мин.)

The London Eye, or the Millennium Wheel, is a cantilevered observation wheel on the South Bank of the River Thames in London. It is Europe's tallest cantilevered observation wheel, and is the most popular paid tourist attraction in the United Kingdom with over 3 million visitors annually. It has made many appearances in popular culture.
The structure is 135 metres (443 ft) tall and the wheel has a diameter of 120 metres (394 ft). When it opened to the public in 2000 it was the world's tallest Ferris wheel. Its height was surpassed by the 167 metres (548 ft) High Roller (Las Vegas) in 2014. Supported by an A-frame on one side only, unlike the taller Nanchang and Singapore wheels, the Eye is described by its operators as "the world's tallest cantilevered observation wheel".
The London Eye used to offer the highest public viewing point in London until it was superseded by the 245-metre-high (804 ft) observation deck on the 72nd floor of The Shard, which opened to the public on 1 February 2013.
In March 2020, the London Eye celebrated its 20th birthday by turning several of its pods into experiences themed around London, in partnership with its sponsor lastminute.com. The special experiences included a pub in a capsule, a west end theatre pod and a garden party with flower arrangements to represent the eight London Royal parks.

8. Выполните полный письменный перевод со словарем текста с английского языка на русский (1000-1200 п.зн. за 45 мин.)

The Shard, located in London, is one of the most iconic skyscrapers in the United Kingdom and a prominent feature of the city’s skyline. Completed in 2012, it was designed by the renowned architect Renzo Piano and stands at a height of 310 meters (1,016 feet), making it the tallest building in the UK and the fifth tallest in Europe. The Shard's unique design resembles a shard of glass, with its tapering form and reflective façade that changes appearance with the weather and time of day.
The construction of The Shard began in 2009 and was part of a larger redevelopment project for London Bridge Station and its surrounding area. The building consists of 95 floors, with a mix of

office space, restaurants, a hotel, and residential apartments. The top floors house an observation deck known as "The View from The Shard," which offers breathtaking panoramic views of London and beyond, attracting millions of visitors each year.

One of the most notable features of The Shard is its innovative use of glass. The façade is made up of 11,000 glass panels that create a shimmering effect, allowing natural light to flood the interior spaces while providing stunning views for those inside. The building is also designed with sustainability in mind; it incorporates energy-efficient systems and has achieved a BREEAM rating for its environmental performance.

The Shard has become a symbol of modern London and is often featured in films, television shows, and promotional materials for the city. Its presence has also spurred further development in the surrounding area, contributing to London's status as a global financial hub.

In addition to its architectural significance, The Shard has played host to various cultural events and exhibitions since its opening. It has become a popular venue for corporate events, weddings, and private functions due to its stunning views and luxurious amenities.

Overall, The Shard represents not only an architectural achievement but also a testament to London's ongoing evolution as a vibrant metropolis. Its striking design and multifunctional use make it an essential part of the city's landscape and an enduring attraction for both locals and tourists alike.

9. Выполните полный письменный перевод со словарем текста с английского языка на русский (1000-1200 п.зн. за 45 мин.)

As one of the world’s leading cities, London is at the forefront of addressing climate change and environmental sustainability. The Greater London Authority (GLA) has set an ambitious target to achieve net-zero carbon emissions by 2030. This goal reflects a commitment to creating a cleaner, healthier, and more sustainable urban environment for current and future generations.

Understanding the Zero Carbon Target

The zero carbon target means that London aims to balance the amount of greenhouse gases emitted with the amount removed from the atmosphere. This involves reducing emissions across various sectors, including transportation, buildings, energy production, and waste management. The target is not just about reducing carbon footprints but also about fostering resilience against climate impacts.

To achieve its zero carbon goal, London is implementing strategies across several key areas:

Energy Efficiency in Buildings: A significant portion of London’s emissions comes from buildings. The GLA is promoting retrofitting existing structures to improve energy efficiency and encouraging new developments to meet stringent sustainability standards. Initiatives include the London Plan, which mandates higher energy performance standards for new buildings.

Renewable Energy Transition: Increasing the use of renewable energy sources is crucial for reducing carbon emissions. London aims to expand solar energy installations, wind power projects, and other renewable technologies. The city is also exploring community energy schemes that empower residents to generate and share renewable energy.

Sustainable Transport: Transportation is another major contributor to London's carbon footprint. The city is investing in public transport infrastructure, expanding cycling networks, and promoting electric vehicles (EVs). Initiatives like the Ultra Low Emission Zone (ULEZ) aim to reduce air pollution and encourage cleaner modes of transport.

Waste Management: Reducing waste and increasing recycling rates are essential components of London's sustainability strategy. The city is working towards a circular economy model that minimizes waste generation and maximizes resource recovery through recycling and composting programs.

Innovation and Technology

London recognizes that innovation plays a critical role in reaching its zero carbon goal. The city is investing in smart technologies that enhance energy efficiency and reduce emissions. This includes smart grids for better energy management, data analytics for optimizing transport systems, and digital platforms that facilitate sustainable practices among residents.

London's zero carbon target represents a bold vision for a sustainable future—a future where economic growth does not come at the expense of environmental health. By prioritizing energy efficiency, renewable energy adoption, sustainable transport solutions, waste reduction strategies, community engagement, and technological innovation, London aims to lead by example in the global

fight against climate change. Achieving this ambitious goal will not only benefit the environment but also enhance the quality of life for all Londoners by creating a cleaner, greener city for generations to come.

10. Выполните полный письменный перевод со словарем текста с английского языка на русский (1000-1200 п.зн. за 45 мин.)

The climate of the United Kingdom is characterized by its temperate maritime conditions, which result in relatively mild temperatures, moderate rainfall, and a lack of extreme weather events compared to many other regions. However, the UK is not immune to the impacts of climate change, which pose significant challenges to its environment, economy, and society. Understanding the current climate dynamics and the implications of climate change is crucial for developing effective strategies for mitigation and adaptation.

The UK experiences four distinct seasons, with average temperatures ranging from about 1°C (34°F) in winter to 20°C (68°F) in summer. Rainfall is distributed fairly evenly throughout the year, with some regions, particularly in the west and north, receiving significantly more precipitation than others. The climate varies across the country:

Southern England: Generally warmer and drier, with milder winters.

Northern England and Scotland: Cooler temperatures and higher rainfall.

Coastal Areas: Influenced by maritime conditions, leading to milder winters but also increased vulnerability to storms and flooding.

The effects of climate change are becoming increasingly evident in the UK:

Rising Temperatures: Average temperatures have increased by approximately 1°C since the late 19th century. This trend is expected to continue, leading to hotter summers and milder winters.

Increased Rainfall and Flooding: While overall rainfall may not significantly increase, extreme weather events are becoming more frequent. Heavy rainfall can lead to flooding, particularly in urban areas with inadequate drainage systems.

Sea Level Rise: Coastal areas are at risk due to rising sea levels caused by melting ice caps and thermal expansion of seawater. This threatens communities, infrastructure, and ecosystems along the coast.

Biodiversity Loss: Changing climates can disrupt ecosystems and habitats, leading to shifts in species distribution and increased risks for native wildlife.

Climate Adaptation Strategies: The government is developing strategies to adapt to climate impacts through improved infrastructure resilience, flood defenses, and sustainable land management practices.

Investment in Renewable Energy: The UK has made significant strides in transitioning to renewable energy sources such as wind (both onshore and offshore), solar power, and biomass. This shift aims to reduce reliance on fossil fuels and lower carbon emissions.

Local communities play a vital role in addressing climate change. Initiatives such as community-led renewable energy projects, tree planting campaigns, and local sustainability programs empower residents to take action at a grassroots level. Public awareness campaigns also aim to educate citizens about their carbon footprints and encourage sustainable practices.

The UK's climate presents both challenges due to the impacts of climate change and opportunities for innovation towards a sustainable future. By committing to ambitious targets like net-zero emissions, investing in renewable energy sources, engaging communities in sustainability efforts, and adapting infrastructure for resilience against extreme weather events, the UK aims not only to mitigate its own environmental impact but also to serve as a global leader in addressing one of humanity's most pressing issues—climate change. As these efforts continue to evolve, they will shape the future landscape of both the environment and society across the nation.

11. Выполните полный письменный перевод со словарем текста с английского языка на русский (1000-1200 п.зн. за 45 мин.)

The population of the United Kingdom (UK) is a dynamic and diverse entity, reflecting a rich tapestry of cultures, ethnicities, and histories. As of 2023, the estimated population stands at approximately 67 million people, making the UK one of the most populous countries in Europe. Understanding the demographic trends and characteristics of the UK population is essential for addressing social, economic, and political challenges.

The UK is characterized by its multicultural society. The population includes a wide range of ethnic groups, with White British being the largest demographic, followed by significant communities of South Asian, Black, Mixed, and other ethnic backgrounds. Major cities like London, Birmingham, Manchester, and Leicester are particularly known for their cultural diversity. London alone is home to over 300 languages spoken by its residents.

The UK has experienced fluctuating population growth rates over the years. Following a period of steady growth in the early 21st century, recent trends indicate a slowdown in growth due to various factors such as declining birth rates and changes in immigration patterns. The fertility rate in the UK has fallen below the replacement level of 2.1 children per woman, leading to concerns about an aging population.

One of the most significant demographic challenges facing the UK is its aging population. Advances in healthcare and living standards have contributed to increased life expectancy, which currently averages around 81 years. As a result, the proportion of older adults (aged 65 and over) is rising rapidly. This shift presents challenges for healthcare services, pensions, and social care systems as they adapt to meet the needs of an older demographic.

Migration has played a crucial role in shaping the UK's population dynamics. Historically a destination for immigrants seeking better opportunities, recent years have seen changes in migration patterns due to political events such as Brexit and global crises like the COVID-19 pandemic. While net migration has fluctuated, it remains a vital component of population growth and contributes to workforce diversity.

The population of the United Kingdom is characterized by its diversity and complexity. As it navigates challenges such as an aging demographic and changing migration patterns, understanding these dynamics will be crucial for shaping effective policies that promote social cohesion and economic stability. By embracing its multicultural identity while addressing regional disparities and demographic shifts, the UK can work towards a future that benefits all its residents.

12. Выполните полный письменный перевод со словарем текста с английского языка на русский (1000-1200 п.зн. за 45 мин.)

The economy of the United Kingdom (UK) is one of the largest and most developed in the world, characterized by a diverse range of industries, a strong services sector, and a significant global presence. As of 2023, the UK economy is recovering from the impacts of the COVID-19 pandemic and navigating challenges such as inflation, supply chain disruptions, and geopolitical uncertainties.

The UK economy is primarily service-oriented, with services accounting for approximately 80% of GDP. Key sectors include finance, healthcare, education, retail, and tourism. London serves as a global financial hub, hosting numerous banks, investment firms, and insurance companies. The City of London and Canary Wharf are central to this financial activity, attracting international investment and talent.

Manufacturing remains an important part of the economy, contributing around 10% to GDP. The UK has a strong manufacturing base in industries such as aerospace, automotive, pharmaceuticals, and food production. Despite facing challenges from globalization and competition, British manufacturers continue to innovate and adapt to changing market demands.

The UK is a significant player in international trade. It exports goods and services worth hundreds of billions annually, with major trading partners including the European Union (EU), the United States, China, and Japan. Key exports include machinery, vehicles, pharmaceuticals, and financial services.

Post-Brexit trade dynamics have shifted as the UK navigates new trade agreements outside the EU framework. The government has sought to establish free trade agreements with various countries to enhance market access for British businesses.

Despite its strengths, the UK economy faces several challenges:

Inflation: Rising inflation rates have impacted consumer purchasing power and business costs. The Bank of England has responded with monetary policy adjustments to stabilize prices.

Supply Chain Disruptions: Global supply chain issues have affected various sectors, leading to delays in production and increased costs for businesses.

Geopolitical Uncertainties: Ongoing geopolitical tensions can influence trade relationships and economic stability.

The economy of the United Kingdom is marked by its resilience and adaptability in the face of challenges. With a strong services sector at its core and ongoing efforts towards innovation and

sustainability, the UK continues to play a vital role in the global economic landscape. As it navigates post-pandemic recovery while addressing inflationary pressures and labor market dynamics, strategic policies will be essential for fostering growth that benefits all segments of society.

13. Выполните полный письменный перевод со словарем текста с английского языка на русский (1000-1200 п.зн. за 45 мин.)

London, the capital city of England and the United Kingdom, boasts a rich and diverse history that spans over two millennia. Its origins can be traced back to the Roman period when it was established as Londinium around AD 43. The Romans recognized the strategic importance of the River Thames for trade and transportation, leading to the rapid growth of the settlement. By the end of the first century, Londinium had developed into a bustling town with a population of around 60,000, complete with a forum, basilica, and defensive walls.

Following the decline of Roman rule in the early 5th century, London experienced a period of instability and fragmentation. The Anglo-Saxons began to settle in the area, and by the 9th century, it had become an important trading hub known as Lundenwic. However, this prosperity was threatened by Viking invasions, leading to the establishment of fortified settlements.

The Norman Conquest in 1066 marked a significant turning point in London's history. William the Conqueror built the Tower of London as a symbol of power and control over the city. The subsequent centuries saw London grow in importance as a political and economic center. The establishment of institutions such as Parliament and the Church further solidified its status.

The medieval period was marked by significant events such as the Black Death in 1348, which decimated London's population but also led to social and economic changes. The city continued to expand during the Tudor period, becoming a cultural hub under monarchs like Henry VIII and Elizabeth I.

The Great Fire of London in 1666 was another pivotal moment that reshaped the city. It destroyed much of medieval London but also provided an opportunity for reconstruction. Sir Christopher Wren played a crucial role in redesigning St. Paul's Cathedral and other buildings that defined London's skyline.

The Industrial Revolution in the 18th and 19th centuries transformed London into one of the world's largest cities. It became a center for finance, trade, and industry, attracting millions from rural areas and abroad. This rapid urbanization brought challenges such as overcrowding and pollution but also led to advancements in infrastructure, including railways and public transport.

The 20th century saw London endure two World Wars, which caused significant destruction but also fostered resilience among its inhabitants. Post-war reconstruction efforts led to modernization while preserving historical landmarks.

Today, London is a vibrant global city known for its cultural diversity, economic significance, and historical heritage. From its Roman roots to its status as a modern metropolis, London's history is a testament to its ability to adapt and thrive through centuries of change.

14. Выполните полный письменный перевод со словарем текста с английского языка на русский (1000-1200 п.зн. за 45 мин.)

Moscow, the capital city of Russia, has a rich and complex history that dates back to its founding in the 12th century. The city was first mentioned in historical records in 1147 when Prince Yuri Dolgoruky invited other princes to a feast. Initially, Moscow was a small settlement on the banks of the Moskva River, but its strategic location made it an important center for trade and politics.

In the late 13th century, Moscow began to rise in prominence under the leadership of Prince Ivan I, also known as Ivan Kalita. He managed to consolidate power and expand the territory, establishing Moscow as a significant principality. The city became the center of the Russian Orthodox Church after the fall of Kiev to the Mongols in 1240, further enhancing its influence.

The Mongol invasion in the 13th century led to several decades of domination known as the "Tatar Yoke." Despite this oppression, Moscow gradually gained strength and autonomy. By the late 15th century, under Grand Prince Ivan III (Ivan the Great), Moscow successfully overthrew Mongol rule and expanded its territory significantly. Ivan III also initiated major construction projects, including the Kremlin's stone walls and towers, which still stand today.

The 16th century saw the rise of Ivan IV (Ivan the Terrible), who was crowned as Russia's first tsar in

1547. His reign marked both expansion and turmoil; while he expanded Russian territory into Siberia, his later years were characterized by paranoia and violence, leading to a period of instability after his death in 1584.

The Time of Troubles (1598-1613) followed, marked by political chaos and foreign intervention. This period ended with the establishment of the Romanov dynasty in 1613, which would rule Russia for over three centuries. Under Peter the Great in the late 17th and early 18th centuries, Moscow faced competition from St. Petersburg as a political center but remained culturally significant.

The 19th century brought significant changes with industrialization and social upheaval. The Decembrist revolt in 1825 highlighted growing discontent among Russian elites. The city also played a crucial role during events such as Napoleon's invasion in 1812 when much of Moscow was burned to prevent French forces from using it.

The early 20th century was marked by revolutionary fervor. The Bolshevik Revolution in 1917 led to significant political changes; Moscow became the capital of Soviet Russia and later the Soviet Union. Under communist rule, extensive urban development transformed Moscow into a symbol of Soviet power.

After World War II, Moscow emerged as a global superpower's capital during the Cold War era. The city continued to grow economically and culturally despite facing challenges such as political repression.

With the dissolution of the Soviet Union in 1991, Moscow underwent significant transformations as Russia transitioned towards a market economy. Today, it stands as a vibrant metropolis known for its rich history, diverse culture, and economic significance on both national and global stages.

15. Выполните полный письменный перевод со словарем текста с английского языка на русский (1000-1200 п.зн. за 45 мин.)

Three Famous Places in London

London, a city steeped in history and culture, is home to numerous iconic landmarks. Among them, the Tower of London, Buckingham Palace, and the British Museum stand out as must-visit destinations that reflect the city's rich heritage.

1. The Tower of London

The Tower of London, a UNESCO World Heritage Site, is one of the most famous historical landmarks in the city. Founded by William the Conqueror in 1066, this imposing fortress has served various roles throughout its history, including royal palace, prison, and treasury. The Tower is perhaps best known for housing the Crown Jewels, a stunning collection of royal regalia that includes crowns, scepters, and other ceremonial items. Visitors can explore its medieval architecture, learn about its storied past through guided tours led by the Yeoman Warders (commonly known as Beefeaters), and hear tales of intrigue and imprisonment associated with figures like Anne Boleyn and Sir Thomas More.

2. Buckingham Palace

Buckingham Palace serves as the official residence of the British monarch and is an enduring symbol of the British monarchy. Originally built in 1703 as a townhouse for the Duke of Buckingham, it became a royal residence in 1837 when Queen Victoria ascended to the throne. The palace features 775 rooms and is surrounded by beautiful gardens. One of its most popular attractions is the Changing of the Guard ceremony, which takes place daily during summer and every other day during winter. Visitors can also tour the State Rooms during certain months when they are open to the public, offering a glimpse into royal life and opulence.

3. The British Museum

The British Museum is one of the world's oldest and most comprehensive museums dedicated to human history and culture. Established in 1753, it houses an extensive collection of over eight million works from various civilizations across the globe. Highlights include the Rosetta Stone, which was key to deciphering Egyptian hieroglyphs; the Elgin Marbles from the Parthenon; and mummies from ancient Egypt. The museum's architecture is equally impressive, featuring a stunning glass-roofed Great Court that provides a modern contrast to its historic galleries. Admission to the museum is free, making it accessible to millions who come to explore its vast array of artifacts.

16. Выполните полный письменный перевод со словарем текста с английского языка на русский (1000-1200 п.зн. за 45 мин.)

The Center of London: A Vibrant Hub of Culture and History

The center of London is a bustling metropolis that serves as the heart of the United Kingdom's capital. This area is not only a financial powerhouse but also a cultural epicenter, rich in history and diversity. Spanning several boroughs, including Westminster and the City of London, the central area is home to iconic landmarks, world-class museums, and vibrant neighborhoods.

One of the most recognizable features of central London is its historic architecture. The Houses of Parliament, with the iconic Big Ben (now known as the Elizabeth Tower), stands majestically along the River Thames. This Gothic Revival masterpiece is not only a symbol of British democracy but also a UNESCO World Heritage Site. Nearby, Westminster Abbey has been the site of royal ceremonies for centuries, including coronations and weddings, making it a significant religious and historical landmark.

Just a short walk away lies Trafalgar Square, a lively public space that commemorates Admiral Nelson’s victory at the Battle of Trafalgar. The square is adorned with the impressive Nelson's Column and is surrounded by notable institutions such as the National Gallery, which houses an extensive collection of European paintings. This area often hosts events and gatherings, making it a focal point for both locals and tourists.

Shopping enthusiasts flock to Oxford Street, one of Europe’s busiest shopping streets, featuring over 300 shops ranging from high-street brands to luxury boutiques. Nearby Regent Street offers a more upscale shopping experience with its elegant architecture and flagship stores. For those seeking a more eclectic vibe, Covent Garden provides a mix of shops, street performances, and dining options in a charming setting.

Cultural experiences abound in central London. The West End is renowned for its theaters showcasing world-class productions ranging from classic plays to contemporary musicals. Visitors can enjoy everything from Shakespearean dramas to modern hits like "The Lion King" or "Hamilton." The area’s vibrant nightlife also includes an array of pubs, bars, and restaurants offering diverse cuisines from around the globe.

Central London is well-connected by an extensive public transport system that includes buses and the iconic London Underground (the Tube). This accessibility makes it easy for visitors to explore various neighborhoods such as Soho, known for its lively atmosphere and nightlife; Chinatown, with its authentic Asian cuisine; and Southbank, which offers stunning views along the Thames River.

In addition to its historical significance and cultural offerings, central London is also home to green spaces like Hyde Park and St. James's Park. These parks provide a tranquil escape from the urban hustle and bustle where visitors can relax or enjoy outdoor activities.

In summary, the center of London is a dynamic blend of history, culture, shopping, and entertainment. Its iconic landmarks tell stories of Britain’s past while contemporary attractions reflect its vibrant present. Whether you’re exploring historic sites or indulging in modern experiences, central London offers something for everyone—a true testament to its status as one of the world’s great cities.

17. Выполните полный письменный перевод со словарем текста с английского языка на русский (1000-1200 п.зн. за 45 мин.)

The center of Moscow is a vibrant and bustling area that serves as the heart of Russia's capital. Known for its rich history, stunning architecture, and cultural significance, this part of the city attracts millions of visitors each year. The blend of historical landmarks and modern developments creates a unique atmosphere that reflects both the past and the present.

At the core of Moscow lies the iconic Red Square, one of the most famous squares in the world. This UNESCO World Heritage Site is surrounded by remarkable structures, including the colorful St. Basil's Cathedral with its distinctive onion domes, which has become a symbol of Russia itself. The square also features the imposing walls of the Kremlin, a fortified complex that serves as the official residence of the President of Russia. The Kremlin is home to several palaces and cathedrals, showcasing stunning examples of Russian architecture and art.

Adjacent to Red Square is Lenin's Mausoleum, where visitors can pay their respects to the founder of the Soviet Union. The mausoleum stands as a reminder of Russia's tumultuous history and its impact

on contemporary society. Nearby, GUM (Glavny Universalny Magazin), a historic department store with an elegant glass roof, offers a luxurious shopping experience with high-end boutiques and cafes. Moscow's central area is also known for its impressive metro system, often referred to as one of the most beautiful in the world. Many metro stations are adorned with intricate mosaics, chandeliers, and sculptures that reflect Soviet-era art and design. Stations like Komsomolskaya and Mayakovskaya are particularly noteworthy for their stunning aesthetics.

Cultural experiences abound in central Moscow. The Bolshoi Theatre is renowned for its ballet and opera performances, attracting art lovers from around the globe. Just a short walk away lies Tverskaya Street, one of Moscow's main thoroughfares lined with shops, restaurants, and theaters. This bustling street epitomizes modern Moscow while still retaining elements of its historical charm.

For those seeking green spaces amidst the urban landscape, Gorky Park offers a refreshing escape. This expansive park features walking paths, open-air cafes, and recreational activities such as cycling and rollerblading. It serves as a popular gathering place for locals and tourists alike.

The center of Moscow is also home to numerous museums that showcase Russian art and history. The State Tretyakov Gallery houses an extensive collection of Russian fine art from various periods, while the Pushkin State Museum of Fine Arts features works from European masters.

As night falls, central Moscow transforms into a lively hub filled with nightlife options ranging from trendy bars to traditional Russian restaurants offering local cuisine. The illuminated skyline adds to the city's charm as visitors enjoy evening strolls along the Moskva River or through historic streets.

18. Выполните полный письменный перевод со словарем текста с английского языка на русский (1000-1200 п.зн. за 45 мин.)

The Moscow Kremlin is one of the most iconic landmarks in Russia and serves as a powerful symbol of the nation's history and political authority. Located in the heart of Moscow, this fortified complex has been the center of Russian power for centuries, housing the offices of the President of Russia and serving as a UNESCO World Heritage Site.

The Kremlin's history dates back to the 12th century when it was established as a wooden fort. Over the years, it evolved into a grand stone fortress, with its walls and towers constructed from red brick in the late 15th century under the direction of Italian architects. The Kremlin's imposing walls stretch for over two kilometers and are punctuated by 20 towers, each with its own unique design and historical significance. The most famous of these is the Spasskaya Tower, adorned with a clock that chimes on the hour and serves as a symbol of Moscow itself.

Within the Kremlin's walls lies a treasure trove of architectural marvels and historical sites. The Cathedral Square is at its heart, surrounded by three magnificent cathedrals: the Assumption Cathedral, where Russian tsars were crowned; the Archangel Cathedral, which houses the tombs of many Russian princes; and the Annunciation Cathedral, known for its stunning frescoes. These cathedrals showcase exquisite examples of Russian Orthodox architecture and art.

Another significant structure within the Kremlin is the Grand Kremlin Palace, which was built in the 19th century as a residence for Russian tsars. Today, it serves as an official residence for the President and hosts important state ceremonies. The palace features opulent interiors adorned with lavish decorations that reflect Russia's imperial past.

The State Armory Museum (Оружейная Палата) is another highlight within the Kremlin complex. It houses an impressive collection of royal artifacts, including crowns, thrones, ceremonial weapons, and carriages used by Russian monarchs. Visitors can explore exhibits that showcase Russia's rich cultural heritage and craftsmanship.

The Kremlin is not only a historical site but also an active political center. It has witnessed significant events throughout Russian history, from grand coronations to pivotal political decisions. Today, it remains a symbol of national pride and authority.

Surrounding the Kremlin are beautiful gardens and parks that offer stunning views of this historic site. The Alexander Garden features well-maintained pathways, fountains, and monuments commemorating key figures in Russian history. Visitors can stroll through these green spaces while enjoying picturesque views of the Kremlin's towers.

Access to the Kremlin is available to tourists who wish to explore its rich history firsthand. Guided tours provide insights into its architectural wonders and historical significance while allowing visitors to appreciate its beauty up close.

19. Выполните полный письменный перевод со словарем текста с английского языка на русский (1000-1200 п.зн. за 45 мин.)

The Tower of London, one of the most famous landmarks in England, has a rich and complex history that spans over 1,000 years. Founded by William the Conqueror in 1066 as part of the Norman Conquest, the Tower was originally built to assert his power over the newly acquired territory. The White Tower, its central structure, is an impressive example of Norman military architecture and served as a royal palace and fortress.

Throughout its history, the Tower has played various roles: it has been a royal residence, a treasury, an armory, and even a menagerie. Its strategic location on the banks of the River Thames made it an essential defensive stronghold for London. The Tower's walls have witnessed numerous significant events, including royal ceremonies and political intrigue.

One of the most notorious aspects of the Tower's history is its use as a prison. Over the centuries, it has housed many high-profile prisoners, including Anne Boleyn, Thomas More, and Lady Jane Grey. The executions that took place within its walls have contributed to its dark reputation. Anne Boleyn was famously executed on Tower Green in 1536; her ghost is said to haunt the grounds to this day.

The Tudor period marked a significant transformation for the Tower. Under King Henry VIII, it became a symbol of royal power and authority. The infamous Beefeaters (Yeoman Warders) were established during this time to guard the Tower and its prisoners. Today, they serve as tour guides and custodians of its rich history.

In addition to its role as a prison, the Tower has also been a place of great ceremony. It is home to the Crown Jewels of England, which include some of the most magnificent regalia in the world. These treasures are displayed in a secure exhibition within the Tower and attract millions of visitors each year.

The 17th century saw further changes as the Tower's military significance diminished. It became more associated with ceremonial functions than with defense. However, it remained an important symbol of monarchy and national identity.

In 1840, Queen Victoria designated the Tower as a historical monument rather than an active fortress or prison. This shift marked the beginning of its transformation into a major tourist attraction. Restoration efforts were undertaken to preserve its structures and artifacts for future generations.

Today, the Tower of London is recognized as a UNESCO World Heritage Site and remains one of London's most visited attractions. Visitors come from around the globe to explore its storied past through guided tours that reveal tales of intrigue, betrayal, and royal grandeur.

The annual Ceremony of the Keys continues to be performed each night at precisely 9:53 PM—a tradition that dates back centuries—symbolizing that all gates are locked for security.

20. Выполните полный письменный перевод со словарем текста с английского языка на русский (1000-1200 п.зн. за 45 мин.)

The British Museum: A Chronicle of Human History

The British Museum, located in the heart of London, is one of the world’s most renowned cultural institutions, dedicated to human history, art, and culture. Established in 1753, it was founded on the collections of Sir Hans Sloane, a physician and naturalist who bequeathed his vast array of artifacts to the nation. The museum opened its doors to the public in 1759, making it one of the first public museums in the world.

From its inception, the British Museum aimed to make knowledge accessible to all. Its founding principle was to collect and preserve objects that represented the diversity of human experience. The museum's original collection included around 71,000 items, ranging from antiquities to natural specimens. Over time, this collection has expanded exponentially and now encompasses over eight million objects.

The museum's architecture is as impressive as its collections. The original building was designed by Sir Robert Smirke in a neoclassical style and features the iconic Great Court (Большой Двор), which was completed in 2000. The Great Court houses the stunning glass-roofed Reading Room and serves as a central hub for visitors.

One of the most significant aspects of the British Museum is its vast collection of artifacts from ancient civilizations. Among its most famous exhibits are the Rosetta Stone, which played a crucial

role in deciphering Egyptian hieroglyphs; the Elgin Marbles from the Parthenon in Athens; and an extensive collection of Egyptian mummies. These items not only showcase artistic achievement but also provide invaluable insights into ancient cultures.

Throughout its history, the museum has been at the center of debates regarding cultural heritage and repatriation. Many artifacts were acquired during periods of colonial expansion, leading to ongoing discussions about their rightful ownership. The museum has faced criticism for holding items that some argue should be returned to their countries of origin. In response, it has engaged in dialogue with various nations regarding cultural restitution while emphasizing its role in preserving global heritage.

The British Museum has also played a significant role in education and research. It offers numerous programs for schools and communities, aiming to foster understanding and appreciation for world cultures. Scholars from around the globe utilize its extensive library and archives for research purposes.

In addition to its permanent collections, the museum hosts temporary exhibitions that explore specific themes or cultures in greater depth. These exhibitions often draw on loans from other institutions or private collections, further enriching visitors' experiences.

Today, the British Museum attracts millions of visitors each year from all corners of the globe. It remains free to enter (though some special exhibitions may charge), reflecting its commitment to accessibility and public engagement with history and culture.

21. Просмотрите текст и ответьте на вопрос: Why do we call Russia the largest county in the world?

Located in the north, west and east latitudes of the Northern Hemisphere, most of Russia is much closer to the North Pole than to the equator. Individual country comparisons are of little value in gauging Russia's enormous size and diversity. The country's 17.1 million square kilometers include one-eighth of the Earth's inhabited land area. Its European portion, which occupies a substantial part of continental Europe, is home to most of Russia's industrial and agricultural activity and is where, roughly between the Dnieper River and the Ural Mountains, the Russian Empire took shape. Russia includes the entire northern portion of Asia.

From west to east, the country stretches from Kaliningrad to Ratmanov Island in the Bering Strait. This distance is roughly equivalent to the distance from Glasgow, Scotland, to Nome, Alaska. From north to south, the country ranges from the northern tip of the Russian Arctic islands at Franz Josef Land to the southern tip of the Republic of Dagestan on the Caspian Sea, spanning about 4,500 kilometres of extremely varied, often inhospitable terrain.

Extending for 57,792 kilometres, the Russian border is the world's longest.

22. Просмотрите текст и ответьте на вопрос: Why are there no skyscrapers in Washington, D.C?

One can hardly find a park, a square or an open area in Washington without a monument or a memorial. The most impressive and the best-known ones are the Lincoln Memorial and the Washington Monument. There are some important museums in Washington where you can see all kinds of things: famous paintings and sculptures, the dresses of President’s wives, the original of the Declaration of Independence, the largest blue diamond in the world, etc. There are 5 universities in Washington.

There are no skyscrapers in Washington, because they would hide the city's many monuments from view. No building in the city may be more than 40 meters tall. Thousands of tourists visit Washington every day. People from all parts of the United States come to see then- capital.

The Jefferson Memorial was built in memory of the third President of the USA, Thomas Jefferson, who was also the author of the Declaration of Independence. The memorial is surrounded by cherry-trees. The Lincoln Memorial devoted to the memory of the 16th President of the US, the author of the Emancipation Proclamation, which gave freedom to Negro slaves in America.

23. Просмотрите текст и ответьте на вопрос: What factors contribute to the air pollution problem?

Air pollution and climate change.

Problem: Overloading of the atmosphere and of ocean waters with carbon. Atmospheric $CO_2$ absorbs and re-emits infrared-wavelength radiation, leading to warmer air, soils, and ocean surface waters - which is good: The planet would be frozen solid without this.
Unfortunately, there's now too much carbon in the air. Burning of fossil fuels, deforestation for agriculture, and industrial activities have pushed up atmospheric $CO_2$ concentrations from 280 parts per million (ppm) 200 years ago, to about 400 ppm today. That's an unprecedented rise, in both size and speed. The result: climate disruption.
Carbon overloading is only one form of air pollution caused by burning coal, oil, gas and wood. The World Health Organization recently estimated that one in nine deaths in 2012 were attributable to diseases caused by carcinogens and other poisons in polluted air.
Solutions: Replace fossil fuels with renewable energy. Reforestation. Reduce emissions from agriculture. Change industrial processes.
The good news is that clean energy is abundant - it just needs to be harvested. Many say a 100 percent renewable-energy future is feasible with existing technology now.
But the bad news is that even though renewable energy infrastructure - solar panels, wind turbines, energy storage and distribution systems - are already widespread, and getting cheaper and more efficient all the time, experts say we're not applying them quickly enough to prevent catastrophic climate disruption. Barriers in policy and finance remain to be overcome.

24. Просмотрите текст и ответьте на вопрос: What factors contribute to the pollution problem?

WE MUST PROTECT OUR ENVIRONMENT

Our country. Our environment. There are many big and small rivers, green forests, high mountains, lakes and seas in Russia. Our Earth is our home. I think people must take care of our Motherland. But the problem of pollution now is very important. There are some factors that increase the problem.
First of all, our plants and factories put their waste materials into water and atmosphere and pollute the environment. There are many kinds of transport in our cities. We can’t ignore their effect on the environment, that is why we must pay attention to the protection of our nature and the health of the people.
Radiation. Now it has become one of the main problems. It is not good for health of people. Many people died from radiation some years ago in Chernobol. It was a tragedy. The other problem is an earthquake. We know some terrible earthquakes in Chile, Haiti, Japan. Our scientists try to forecast earthquakes, then we can protect ourselves from them.

25. Просмотрите текст и ответьте на вопрос: What are key features of the green economy?

KEY FEATURES OF THE GREEN ECONOMY

Simply put, a green economy is low-carbon, resource efficient, and socially inclusive. Some of it's key features include:
Abundant opportunities for good green jobs that pay a living wage.
A price on carbon, either through a cap-and-trade program or an economy-wide tax on carbon.
More efficient use of energy and other resources. For example, huge economic and environmental gains could be made if we had more energy efficient buildings and transportation.
Greater use of renewable resources, like wind and solar, instead of non-renewable resources, such as coal and oil.
Greener manufacturing which is resource efficient and doesn’t use toxic chemicals
Proper value assigned to natural environments and ecosystems, in recognition of all the services the environment provides such as carbon sequestration, flood protection, and waste water treatment.
A robust recycling and reuse industry, with minimal waste sent to landfill.

26. Просмотрите текст и ответьте на вопрос: Why is it important to plant and restore forests?

Deforestation.
Problem: Species-rich wild forests are being destroyed, especially in the tropics, often to make way for cattle ranching, soybean or palm oil plantations, or other agricultural monocultures.
Today, about 30 percent of the planet's land area is covered by forests - which is about half as much as before agriculture got started around 11,000 years ago. About 7.3 million hectares (18 million

acres) of forest are destroyed each year, mostly in the tropics. Tropical forests used to cover about 15 percent of the planet's land area; they're now down to 6 or 7 percent. Much of this remainder has been degraded by logging or burning.
Not only do natural forests act as biodiversity reserves, they are also carbon sinks, keeping carbon out of the atmosphere and oceans.
Solutions: Conserve of what's left of natural forests, and restore degraded areas by replanting with native tree species. This requires strong governance - but many tropical countries are still developing, with increasing populations, uneven rule-of-law, and widespread cronyism and bribery when it comes to allocating land use.

27. Просмотрите текст и ответьте на вопрос: What is green economy?

WHAT IS THE GREEN ECONOMY?
Today, many people realize that it's not about the environment versus the economy, not a tradeoff between unemployment and pollution. It's not about picking one or the other.
We cannot choose between the environment and the economy. We need both.
This realization is at the heart of an emerging economic and environmental concept, often termed " the green economy."
It reflects a growing recognition that, on the one hand, the challenge of sustainability rests almost entirely in getting the economy right. Putting a price on carbon, valuing natural capital and ending perverse subsidies, among other things, are all vital to meaningful environmental reform.
And, on the other hand, if we wish to create a sustainable economy, we must pay more attention to the environment. Against a backdrop of climate change, resource scarcity, the massive loss of biodiversity and a variety of other environmental issues, business as usual is increasingly risky.
The green economy was initially driven by an environmental imperative, the recognition that climate change and ecological degradation threaten our future prosperity. But today, it is driven equally by opportunity, the recognition that a green economy opens up new possibilities for jobs and growth. As a recent report from the U.N. put it, “the greening of economies is not generally a drag on growth but rather a new engine of growth…a net generator of decent jobs…”

28. Просмотрите текст и ответьте на вопрос: “What are the pivotal moments in the history of medieval London?

London, the capital city of England and the United Kingdom, boasts a rich and diverse history that spans over two millennia. Its origins can be traced back to the Roman period when it was established as Londinium around AD 43. The Romans recognized the strategic importance of the River Thames for trade and transportation, leading to the rapid growth of the settlement. By the end of the first century, Londinium had developed into a bustling town with a population of around 60,000, complete with a forum, basilica, and defensive walls.
Following the decline of Roman rule in the early 5th century, London experienced a period of instability and fragmentation. The Anglo-Saxons began to settle in the area, and by the 9th century, it had become an important trading hub known as Lundenwic. However, this prosperity was threatened by Viking invasions, leading to the establishment of fortified settlements.
The Norman Conquest in 1066 marked a significant turning point in London's history. William the Conqueror built the Tower of London as a symbol of power and control over the city. The subsequent centuries saw London grow in importance as a political and economic center. The establishment of institutions such as Parliament and the Church further solidified its status.
The medieval period was marked by significant events such as the Black Death in 1348, which decimated London's population but also led to social and economic changes. The city continued to expand during the Tudor period, becoming a cultural hub under monarchs like Henry VIII and Elizabeth I.
The Great Fire of London in 1666 was another pivotal moment that reshaped the city. It destroyed much of medieval London but also provided an opportunity for reconstruction. Sir Christopher Wren played a crucial role in redesigning St. Paul's Cathedral and other buildings that defined London's skyline.
The Industrial Revolution in the 18th and 19th centuries transformed London into one of the world's largest cities. It became a center for finance, trade, and industry, attracting millions from rural areas

and abroad. This rapid urbanization brought challenges such as overcrowding and pollution but also led to advancements in infrastructure, including railways and public transport.
The 20th century saw London endure two World Wars, which caused significant destruction but also fostered resilience among its inhabitants. Post-war reconstruction efforts led to modernization while preserving historical landmarks.
Today, London is a vibrant global city known for its cultural diversity, economic significance, and historical heritage. From its Roman roots to its status as a modern metropolis, London's history is a testament to its ability to adapt and thrive through centuries of change.

29. Просмотрите текст и ответьте на вопрос: What time does London's origin trace back?

London's origins trace back to a strategic decision by Roman invaders in 43 AD, when Emperor Claudius established Londinium as a key military and trading settlement. This foundational period shaped the city's enduring character through several critical developments:
Roman Establishment (43-60 AD)
- Founded as a river port at the narrowest Thames crossing point
- Initial settlement covered 1.4 km² (modern City of London area)
- Strategic location connected roads to major Roman British towns

Boudican Revolt & Rebuilding (60-120 AD)
- Destroyed in 60 AD by Iceni tribe led by Queen Boudica (королева Боадицея), a queen of the ancient British Iceni tribe (племя иценов), who led a failed uprising against the conquering forces of the Roman Empire in AD 60 or 61.
- Reconstructed with improved stone defenses and grid-pattern streets
- Built first London Bridge (wooden, near modern bridge location)

Peak Roman Development (2nd-4th Century)
- Became provincial capital of Britannia by 100 AD
- Constructed major infrastructure:
  - Basilica (largest north of Alps)
  - Amphitheater (discovered under Guildhall)
  - 3 km defensive wall (sections still visible)
- Reached population of 30,000-45,000

Key Foundations for Future Growth
- Established as England's first international trade hub
- Created enduring street patterns still visible today
- Built original Thames embankments
- Developed as administrative center (traits continuing today)

Decline and Transition (5th Century)
- Roman withdrawal around 410 AD led to urban decline
- Settlement continued at reduced scale (Saxon Lundenwic)
- Original walls maintained through Middle Ages

The Roman foundation established London's lasting advantages: strategic location, commercial orientation, and administrative importance - qualities that would eventually propel it to global prominence.

30. Просмотрите текст и ответьте на вопрос: "What are the key economic changes London has undergone in the 21st Century (2000–Present) "

London's Transformation in the 21st Century (2000–Present)
Since 2000, London has undergone dramatic changes, solidifying its status as a global city while facing new challenges. From urban regeneration to economic shifts, the capital has evolved in response to globalization, technological advances, and socio-political changes.
1. Urban Regeneration & Architecture
- The Shard (Шард – название небоскреба ввиде «осколка» (2012): Europe's tallest skyscraper (310m), symbolizing modern London.
- Olympic Legacy (2012): Stratford's transformation with Queen Elizabeth Olympic Park and new neighborhoods.
- Crossrail (Elizabeth Line, 2022): Europe's largest infrastructure project, improving east-west

transit.
2. Economic Shifts
• Tech Boom: Rise of "Silicon Roundabout" (Old Street) as a rival to California's tech hubs.
• Brexit Impact: Financial sector adjustments, though London remains Europe's top financial center.
• Green Economy: Growth in renewable energy startups and low-emission policies (ULEZ expansion).
3. Cultural & Demographic Changes
• Population Growth: From 7.2 million (2000) to nearly 9 million today.
• Super-Diversity: Over 300 languages spoken; 45% of residents foreign-born.
• Cultural Landmarks: Tate Modern extension (2016), V&A East (2025).
4. Challenges
• Housing Crisis: Soaring prices push residents farther out; "Generation Rent" struggles.
• Climate Resilience: Flood risks (Thames Barrier upgrades) and urban heat island effect.
• Social Inequality: Wealth gaps widen despite economic growth.
The Future of London

31. Просмотрите текст и ответьте на вопрос: " Why are smart homes and low-power devices considered to be key solutions for sustainable living? "

Smart Homes and Low-Power Devices: Green Technology for Sustainable Living
As energy demands rise and environmental concerns grow, smart homes and low-power devices are emerging as key solutions for sustainable living. By integrating energy-efficient technologies with automation, modern households can significantly reduce electricity consumption, minimize waste, and lower carbon footprints.
Smart homes use IoT (Internet of Things) devices to optimize energy usage by:
• Automated lighting systems (e.g., motion sensors, smart bulbs like Philips Hue) that turn off when not needed.
• Smart thermostats (e.g., Nest, Ecobee) that learn user habits and adjust heating/cooling to save energy.
• Energy monitoring systems that track real-time electricity usage and suggest optimizations.
Low-Power Devices: Reducing Energy Waste
Advances in semiconductor technology have led to ultra-efficient electronics:
• Low-power processors (e.g., ARM Cortex-M for IoT) that extend battery life in smart sensors.
• Energy Star-certified appliances (refrigerators, washing machines) that consume 10–50% less power.
• Solar-powered smart gadgets (e.g., smart blinds, outdoor cameras) that rely on renewable energy.
Green Technology in Smart Homes
1. Energy Storage & Renewable Integration
o Home battery systems (e.g., Tesla Powerwall) store solar energy for nighttime use.
o Smart inverters optimize solar panel output, feeding excess power back to the grid.
2. AI-Driven Energy Management
o AI algorithms predict usage patterns and shift high-power tasks (e.g., EV charging) to off-peak hours.
3. E-Waste Reduction
o Modular smart devices (e.g., Framework Laptop) allow easy upgrades, reducing electronic waste.
o Companies like Apple use recycled materials in products like HomePod.
Smart homes and low-power devices exemplify how green technology can merge sustainability with convenience. By adopting these solutions, households can cut energy bills, reduce reliance on fossil fuels, and contribute to a zero-waste future.

32. Просмотрите текст и ответьте на вопрос: " How does the Gulf Stream work"

The Gulf Stream's Vital Role in Europe's Climate
The Gulf Stream is a powerful Atlantic Ocean current that transports warm water from the Gulf of Mexico to Northwestern Europe. This "heat conveyor belt" is responsible for Europe's unusually mild climate given its high latitudes, making winters in London warmer than those in Newfoundland at the same latitude.

How the Gulf Stream Works

1. Current Mechanics:
   - Begins in the Gulf of Mexico (water heated to 30°C)
   - Flows northeast at 2-5 mph (100x Amazon River volume)
   - Cools near Greenland, sinks, and returns south (AMOC circulation)
2. Heat Transfer:
   - Releases heat equivalent to 1.5 million nuclear power plants
   - Raises European temperatures by 5-10°C in winter

Europe's Climate Dependence

Temperature Regulation:

- UK/Ireland: 10°C warmer than same-latitude Canada
- Norway: Coastal ports remain ice-free year-round
- France: Enables wine-growing at 48°N (parallel to Canada's cold Newfoundland)

Precipitation Patterns:

- Brings moisture for Western Europe's rainfall
- Supports agriculture from Ireland to Ukraine

Climate Change Threats

1. AMOC Weakening:
   - 15% slowdown since 1950 (IPCC data)
   - Melting Greenland ice dilutes salty water, disrupting sinking mechanism
2. Potential Collapse:
   - Could lower European temperatures by 3-5°C
   - May increase storms and shift rain belts southward

Economic and Ecological Impacts

1. Agriculture:
   - UK growing seasons could shorten by 30 days
   - Mediterranean drought intensification
2. Energy:
   - Increased winter heating demands
   - Reduced hydropower in Scandinavia
3. Ecosystems:
   - North Sea fisheries disruption
   - Boreal forest migration

Monitoring and Solutions

33. Просмотрите текст и ответьте на вопрос: “What is the history of the Union Jack“

The flag of the UK is known as the Union Jack. It has its history. It all began in 1603 when Scotland was joined to England and Wales. The flag is made up of 3 crosses. The upright cross is the Cross of St. Jeorge the patron saint of England. The white diagonal cross is the cross of St. Andrew, the patron saint of Scotland. The red diagonal cross is the cross is the cross of St. Patrick, the patron saint of Ireland. All of them are on the blue background. The national anthem is . The national currency is pound. Geographically the island of Great Britain is subdivided into 2 main regions: Lowland Britain and Highland Britain. Lowland Britain comprises southern and eastern England. Highland Britain consists of Scotland, most of Wales, the Pennines (or the Pennine Chain) and the Lake District. The highest mountain top is Ben Nevis in Scotland. The chief rivers of Great Britain are: the Severn, separating England and Wales, the Thames (the longest and the deepest one). The swiftest flowing river is the Spray. Also the Tweed is famous (the woolen fabric is made here). Every country in the UK has its own national emblem. The red rose is the national emblem of England, the thistle is the national emblem of Scotland, the daffodils and the leek are the emblems of Wales, and the shamrock (a kind of clover) is the emblem of Ireland.

34. Просмотрите текст и ответьте на вопрос: “ What are the functions of the monarch in the United Kingdom? “

The United Kingdom is a constitutional monarchy. It has a monarch - a King or a Queen. The present British monarch is Queen Elizabeth the Second. She become Queen in 1952. The monarch has little

power and can reign with the support of Parliament. British Parliament is the legislative body at the country. It consists of two Houses. The House of Commons and House of Lords. Parliament and the monarch have different roles in the Government of the country. In reality, the House of Commons has truth power. It introduces new bills. Then they go to the House of Lords for approval. The functions of the Queen are: to open the sessions of the Parliament, to head the commonwealth, to be Commander-in-Chief, to declare the war, to make peace. The house of commons is made up of 650 elected knows of members of parliament. The party which has the majority of suits in the Government and its leader usually becomes prime minister. The prime minister forms his or her Cabinet Ministers. The chairman of the House of Commons is the Speaker. The chairman of the House of Lords is the Lord Chancellor. He sits on a special place, which is called the woolsack. It means that wool made England rich. The members of the House of Lords are not elected, there are live peers. There are several political parties in Great Britain. They are the Conservative, the Liberal, the Labor, the Social Democratic and the Communist parties. Prime minister of the country Boris Johnson is leader of the Conservative Party.

35. Просмотрите текст и ответьте на вопрос: " What natural resources is the Siberian region rich in?"

Siberia, in the north of Russia, is one of the coldest, harshest places on earth. Famed for its inhospitable climate, it is also mineral-wealthy and unexploited – a true frontier region. Although it has attracted mining companies for decades, the challenging landscape and conditions have meant they have only just begun to scratch the surface of the area's potential.

This could now be changing; as climate change leads to warmer temperatures, ice and permafrost are melting and potentially easing the mining process. The mining sector is the second biggest contributor to GDP in Russia, and is expected to continue to play an important role in its economy.

Mining in Siberia grew exponentially during the 20th century, as successive governments and leaders sought to take advantage of it. "The Siberian region is rich in minerals including coal, gold, diamond and iron ore," says Globaldata analyst Alok Shukla. "Coal is largely extracted from Kemerovo, Krasnoyarsk Krai, Sakha (Yakutia), Republic of Khakassia, and Irkutsk Oblast. Gold originates mainly from Krasnoyarsk Krai and Irkutsk Oblast."

Russia is responsible for 7% of global aluminium production, and 95% of this takes place in Siberia. It is home to Russia's largest coal mine, the Arshanovsky pit in the Khakassia Republic which opened in 2015. When at full capacity it is expected to produce 10 million tonnes of coal, and there are already plans to expand it further. Siberia and the Far East also hold 84% of Russia's known gold reserves.

But much remains unexplored or inaccessible in Siberia still, leaving the true mineral wealth of the region uncertain. In 2016, a mineral was discovered in Siberia unlike any ever found naturally occurring on earth. Instead it appears to be similar to lab-grown metal-organic frameworks. Such discoveries highlight the potential of a region so long hidden under ice and thick forests.

36. Просмотрите текст и ответьте на вопрос: "What are the consequences of global warming"

In recent years, climate change has been a much talked about issue, with many debates over its possible impact on the world, and some even going so far as to question its very existence. However, with the undeniable increase in greenhouse emissions on Earth, there can be no doubt that the earth is becoming warmer.

So what exactly does this mean for the future of our planet? In chilly places like the UK, we may think to ourselves: 'Finally, warmer weather!' But global warming will in fact cause extreme weather conditions, meaning that our winters would be even colder than they are now. More than that, warmer temperatures will lead to the melting of ice in the north and south poles, which in turn will lead to rising sea levels across the globe. This is particularly troubling for low coastal regions such as Florida in the USA which would be among the first to be flooded, along with many islands around the world, including the United Kingdom. In 1000 years or so, all these places and more will be submerged underwater.

So where will be able to live? Unless we can find a way to evolve into mermaids and mermen, which doesn't look promising, the only solution is to move elsewhere. There will be little choice left once a large proportion of the land is lost to the sea, and other remaining places will be so hot that they will

be absolutely impossible to survive in. It is possible, then, that the once frozen poles of the Arctic and Antarctica will be suitable enough to live in, having melted its ice and warmed up.
It's a scary thought to imagine such devastation on Earth. Perhaps if people start to realize how their actions now can have such a profound impact on future generations, they will change their attitude and start to think more about caring for the environment, in order to save it.

37. Просмотрите текст и ответьте на вопрос: "What is the weather like in Wales in autumn and winter?"

Inland Weather in Wales

The higher you get in Wales, the colder and wetter it gets. And as you move away from the coasts, Wales is quilted with river valleys separated by increasingly higher hills. The Brecon Beacons in south Wales, are softly rolling but enormous, windswept hills where winter temperatures below freezing and snowfalls are not uncommon. Further north, in the inland mountains of Snowdonia National Park, heavy precipitation can be extreme. One mountain peak, Crib Goch, may be the wettest place in the entire country with an astonishing 176 inches of rainfall annually.2 And on the highest peaks, it snows a great deal.
Mount Snowdon, at 3,560 feet and the highest U.K. mountain south of Scotland, can experience snowfall from October to May.
Snowfall at lower altitudes is rare, with an average of only 10 days a year with snow lying on the ground in the south and west Wales. On the other hand, the mountains of Snowdonia average 30 days a year with snowfall lying on the ground.
Autumn and Winter in Wales
In September, temperatures linger in the 60s but fall away rapidly through October and November into the high 40s. January and February are the coldest months with temperatures hovering around freezing or slightly above in higher areas and in the high 40s along the coast. Temperatures at night are usually 10 to as much as 15 degrees Fahrenheit colder depending on where you are in the country.
October through January are the wettest months. Rain tends to fall in short, sharp and very heavy showers. November is particularly squally with rain accompanied by gusty winds.

38. Просмотрите текст и ответьте на вопрос: "Why is Scotland is the land of myths and mysteries? "

Scotland is a country in the north of Great Britain. It is a part of the United Kingdom. Scotland is divided into three natural regions: the Southern Uplands, the Central Lowlands and the Highlands and islands. A lot of places in Scotland are a natural paradise, still untouched by man.
The capital of Scotland is Edinburgh, well known for its castle. Glasgow is the industrial capital of Scotland. It is the third largest city in Great Britain. The typical products of Scotland are timber, whisky, salmon. Golf is the Scottish natural sport and it seems to have originated in this country.
Scotland is also the land of myths and mysteries; every castle has its ghost. Glamis Castle is said to have nine of them. And of course everyone knows about the Loch Ness Monster. 'Nessie" is said to be about six meters long, with a long, thin neck. The first report of the monster in Loch Ness was in 565 A.D. Since 1934, thousands of people claimed to they had seen the monster. Scientists have investigated the Loch and taken pictures but no scientific explanation of the mystery has been given.
Scotland is the north part of Great Britain. Five million people live in Scotland. Edinburgh is the capital of Scotland.

39. Просмотрите текст и ответьте на вопрос: "What is the London Eye?"

The London Eye, or the Millennium Wheel, is a cantilevered observation wheel on the South Bank of the River Thames in London. It is Europe's tallest cantilevered observation wheel, and is the most popular paid tourist attraction in the United Kingdom with over 3 million visitors annually. It has made many appearances in popular culture.
The structure is 135 metres (443 ft) tall and the wheel has a diameter of 120 metres (394 ft). When it opened to the public in 2000 it was the world's tallest Ferris wheel. Its height was surpassed by the 167 metres (548 ft) High Roller (Las Vegas) in 2014. Supported by an A-frame on one side only,

unlike the taller Nanchang and Singapore wheels, the Eye is described by its operators as "the world's tallest cantilevered observation wheel".
The London Eye used to offer the highest public viewing point in London until it was superseded by the 245-metre-high (804 ft) observation deck on the 72nd floor of The Shard, which opened to the public on 1 February 2013.
In March 2020, the London Eye celebrated its 20th birthday by turning several of its pods into experiences themed around London, in partnership with its sponsor lastminute.com. The special experiences included a pub in a capsule, a west end theatre pod and a garden party with flower arrangements to represent the eight London Royal parks.

40. Просмотрите текст и ответьте на вопрос: "The Global Waste Crisis"

The Global Waste Crisis
Every year, the world generates over 2 billion tons of municipal solid waste, with plastic, electronic waste (e-waste), and food waste being major contributors. Landfills and incineration—traditional waste disposal methods—release harmful greenhouse gases (like methane and $CO_2$) and toxic chemicals, accelerating climate change and pollution.
Green Technology Solutions for Waste Management
1. Smart Recycling Systems
o AI-powered waste sorting robots (e.g., ZenRobotics) use machine learning to separate recyclables with high precision.
o Blockchain-based tracking ensures transparent recycling processes, reducing illegal dumping.
2. Waste-to-Energy (WtE) Technologies
o Biogas plants convert organic waste into renewable energy.
o Plasma gasification breaks down non-recyclable waste into clean syngas for electricity.
3. Circular Economy & Sustainable Materials
o Companies like TerraCycle upcycle hard-to-recycle waste into new products.
o Biodegradable packaging (e.g., Mushroom-based materials, seaweed plastics) replaces single-use plastics.
4. E-Waste Innovations
o Urban mining extracts precious metals (gold, lithium) from discarded electronics.
o Modular smartphones (e.g., Fairphone) reduce e-waste by enabling easy repairs.
5. Zero-Waste Initiatives
o Cities like San Francisco aim for zero waste through strict recycling/composting laws.
o Edible cutlery and reusable container programs cut down disposable waste.

41. Ответьте на вопрос:

What places of interest are there in London?

42. Ответьте на вопрос:

What can you say about the system of higher education in Russia?

43. Ответьте на вопрос:

Does Russia have a borderline with the USA?

44. Ответьте на вопрос:

What is the longest river in the European part of Russia? What can you say about it?

45. Ответьте на вопрос:

What do you know about climate in England?

46. Ответьте на вопрос:

In what wat have computers changed our life?

47. Ответьте на вопрос:

What do you know about theaters in Moscow?

48. Ответьте на вопрос:

“How do you feel about artificial intelligence like Siri and Alexa?”

49. Ответьте на вопрос:

“How have technological advances affected communication ?”

50. Ответьте на вопрос:
“How have technological advances affected education?”
51. Ответьте на вопрос:
“ What do you think is the biggest advantage of modern technology?”
52. Ответьте на вопрос:
“Is there a tech product you want these days? What is it? How will it make your life better?”
53. Ответьте на вопрос:
“ How has technology impacted our work, studies and career?”
54. Ответьте на вопрос:
“What do you think is the most important breakthrough in history ?”
55. Ответьте на вопрос:
“What industrial applications of electricity do you know ?”
56. Ответьте на вопрос:
“What makes it possible to eliminate air and water pollution?”
57. Ответьте на вопрос:
“What actions are necessary to take to deal successfully with the problem of protecting the environment throughout the world ?”
58. Ответьте на вопрос:
“What interesting facts do you know about the University of Cambridge?”
59. Ответьте на вопрос:
“What sights are there in London ?”
60. Ответьте на вопрос:
“What are you favorite places of interest in Moscow ?”

*3 семестр, Экзамен*
*Контролируемые ИДК: УК-4.1 УК-4.2 УК-4.3 УК-4.4*
Вопросы/Задания:
1. Answer the question:
What is the difference between ordinary light and laser light?
2. Answer the question:
Who proposed the atomic structure theory of light emission? How many models do you know?
3. Answer the question:
Do electric and magnetic fields deflect light beams?
4. Answer the question:
What are the typical components of a laser?
5. Answer the question:
When are the wave and particle models of light required? Provide examples.
6. Answer the question:
How did Newton describe light?
7. Answer the question:
What type of laser is the most widely used?
8. Answer the question:
What kinds of lasers are you familiar with?
9. Answer the question:
Where are gas lasers used?
10. Answer the question:
Are solid-state lasers used in medical applications?
11. Answer the question:
What is a laser? Can you provide a definition?

12. Answer the question:
What types of lasers are most commonly used in telecommunications?

13. Answer the question:
What laser equipment is used in surveying?

14. Answer the question:
How are lasers classified?

15. Answer the question:
How many wavelengths are emitted by monochromatic lasers?

16. Answer the question:
How are lasers classified based on their active medium—the material that generates the laser beam?

17. Answer the question:
In what types of lasers are carbon dioxide ($CO_2$) and helium-neon (HeNe) used?

18. Answer the question:
Are lasers used in 3D printing (additive manufacturing)?

19. Answer the question:
What laser applications are you familiar with?

20. Answer the question:
Are beam quality and stability exceptional features of gas or solid-state lasers?

21. Translate the text (1800 printed characters; time – 60 min.)

Laser physics

The gain medium of a laser is a material of controlled purity, size, concentration, and shape, which amplifies the beam by the process of stimulated emission. It can be of any state: gas. liquid, solid or plasma. The gain medium absorbs pump energy, which raises some electrons into higher-energy ("excited") quantum states. Particles can interact with light by either absorbing or emitting photons. Emission can be spontaneous or stimulated. In the latter case, the photon is emitted in the same direction as the light that is passing by. When the number of particles in one excited state exceeds the number of particles in some lower-energy state, population inversion is achieved and the amount of stimulated emission due to light that passes through is larger than the amount of absorption. Hence, the light is amplified. By itself, this makes an optical amplifier.

When an optical amplifier is placed inside a resonant optical cavity, one obtains a laser. The light generated by stimulated emission is very similar to the input signal in terms of wavelength, phase, and polarization. This gives laser light its characteristic coherence, and allows it to maintain the uniform polarization and often monochromaticity established by the optical cavity design.

The optical resonator is sometimes referred to as an "optical cavity", but this is a misnomer: lasers use open resonators as opposed to the literal cavity that would be employed at microwave frequencies in a maser. The resonator typically consists of two mirrors between which a coherent beam of light travels in both directions, reflecting back on itself so that an average photon will pass through the gain medium repeatedly before it is emitted from the output aperture or lost to diffraction or absorption. If the gain (amplification) in the medium is larger than the resonator losses, then the power of the recirculating light can rise exponentially.

22. Translate the text (1800 printed characters; time – 60 min.)

Laser

A laser is a device that emits light (electromagnetic radiation) through a process of optical amplification based on the stimulated emission of photons. The term "laser" originated as an acronym for Light Amplification by Stimulated Emission of Radiation. The emitted laser light is notable for its high degree of spatial and temporal coherence, unattainable using other technologies.

Spatial coherence typically is expressed through the output being a narrow beam which is diffraction-limited, often a so-called "pencil beam." Laser beams can be focused to very tiny spots, achieving a very high irradiance. Or they can be launched into a beam of very low divergence in order to concentrate their power at a large distance.

Temporal (or longitudinal) coherence implies a polarized wave at a single frequency whose phase is correlated over a relatively large distance (the coherence length) along the beam. A beam produced

by a thermal or other incoherent light source has an instantaneous amplitude and phase which vary randomly with respect to time and position, and thus a very short coherence length.
Most so-called "single wavelength" lasers actually produce radiation in several modes having slightly different frequencies (wavelengths), often not in a single polarization. And although temporal coherence implies monochromaticity, there are even lasers that emit a broad spectrum of light, or emit different wavelengths of light simultaneously. There are some lasers which are not single spatial mode and consequently their light beams diverge more than required by the diffraction limit. However all such devices are classified as "lasers" based on their method of producing that light: stimulated emission. Lasers are employed in applications where light of the required spatial or temporal coherence could not be produced using simpler technologies.

23. Translate the text (1800 printed characters; time – 60 min.)

LIDAR in geology and soil science.
High-resolution digital elevation maps generated by airborne and stationary LIDAR have led to significant advances in geomorphology, the branch of geoscience concerned with the origin and evolution of Earth's surface topography. LIDAR's abilities to detect subtle topographic features such as river terraces and river channel banks, measure the land surface elevation beneath the vegetation canopy, better resolve spatial derivatives of elevation, and detect elevation changes between repeat surveys have enabled many novel studies of the physical and chemical processes that shape landscapes. In addition to LIDAR data collected by private companies, academic consortia have been created to support the collection, processing and archiving of research- grade, publicly available LIDAR datasets. The National Center for Airborne Laser Mapping (NCALM), supported by the National Science Foundation, collects and distributes LIDAR data in support of scientific research and education in a variety of fields, particularly geoscience and ecology.
In geophysics and tectonics, a combination of aircraft-based LIDAR and GPS have evolved into an important tool for detecting faults and measuring uplift. The output of the two technologies can produce extremely accurate elevation models for terrain that can even measure ground elevation through trees. This combination was used most famously to find the location of the Seattle Fault in Washington, USA. This combination is also being used to measure uplift at Mt. St. Helens by using data from before and after the 2004 uplift. Airborne LIDAR systems monitor glaciers and have the ability to detect subtle amounts of growth or decline. A satellite based system is NASA's ICES at which includes a LIDAR system for this purpose. NASA's Airborne Topographic Mapper is also used extensively to monitor glaciers and perform coastal change analysis. The combination is also used by soil scientists while creating a soil survey. The detailed terrain modeling allows soil scientists to see slope changes and landform breaks which indicate patterns in soil spatial relationships.

24. Translate the text (1800 printed characters; time – 60 min.)

LIDAR. General description.
The primary difference between LIDAR and radar is that LIDAR uses much shorter wavelengths of the electromagnetic spectrum. Typically in the ultraviolet, visible, or near infrared range. In general it is possible to image a feature or object only about the same size as the wavelength, or larger. Thus lidar is highly sensitive to aerosols and cloud particles and has many applications in atmospheric research and meteorology.
An object needs to produce a dielectric discontinuity to reflect the transmitted wave. At radar (microwave or radio) frequencies, a metallic object produces a significant reflection. However non-metallic objects, such as rain and rocks produce weaker reflections and some materials may produce no detectable reflection at all, meaning some objects or features are effectively invisible at radar frequencies. This is especially true for very small objects (such as single molecules and aerosols).
Lidars provide one solution to these problems. The beam densities and coherency are excellent. Moreover the wavelengths are much smaller than can be achieved with radio systems, and range from about 10 micrometers to the UV (ca. 250 nm). At such wavelengths, the waves are "reflected" very well from small objects. This type of reflection is called backscattering.
Different types of scattering are used for different lidar applications, most common are Rayleigh scattering. Mie scattering and Raman scattering as well as fluorescence. Based on different kinds of

backscattering, the LIDAR can be accordingly called Rayleigh LiDAR, Mie LiDAR, Raman LiDAR and Na/Fe/K Fluorescence LIDAR and so on. The wavelengths are ideal for making measurements of smoke and other airborne particles (aerosols), clouds, and air molecules.

A laser typically has a very narrow beam which allows the mapping of physical features with very high resolution compared with radar. In addition, many chemical compounds interact more strongly at visible wavelengths than at microwaves, resulting in a stronger image of these materials. Suitable combinations of lasers can allow for remote mapping of atmospheric contents by looking for wavelength-dependent changes in the intensity of the returned signal.

25. Translate the text (1800 printed characters; time – 60 min.)

Several major components to a LIDAR system:

1. Laser — 600-1000 nm lasers are most common for non-scientific applications. They are inexpensive but since they can be focused and easily absorbed by the eye the maximum power is limited by the need to make them eye-safe. Eye-safety is often a requirement for most applications. A common alternative 1550 nm lasers are eye-safe at much higher power levels since this wavelength is not focused by the eye, but the detector technology is less advanced and so these wavelengths are generally used at longer ranges and lower accuracies. They are also used for military applications as 1550 nm is not visible in night vision goggles unlike the shorter 1000 nm infrared laser. Airborne topographic mapping lidars generally use 1064 nm diode pumped YAG lasers, while bathymetric systems generally use 532 nm frequency doubled diode pumped YAG lasers because 532 nm penetrates water with much less attenuation than does 1064 nm. Laser settings include the laser repetition rate (which controls the data collection speed). Pulse length is generally an attribute of the laser cavity length, the number of passes required through the gain material (YAG, YLF, etc.), and Q-switch speed. Better target resolution is achieved with shorter pulses, provided the LIDAR receiver detectors and electronics have sufficient bandwidth.

2. Scanner and optics — How fast images can be developed is also affected by the speed at which it can be scanned into the system. There are several options to scan the azimuth and elevation, including dual oscillating plane mirrors, a combination with a polygon mirror, a dual axis scanner. Optic choices affect the angular resolution and range that can be detected. A hole mirror or a beam splitter are options to collect a return signal.

3. Photodetector and receiver electronics — Two main photodetector technologies are used in lidars: solid state photodetectors, such as silicon avalanche photodiodes, or photomultipliers. The sensitivity of the receiver is another parameter that has to be balanced in a LIDAR design.

4. Position and navigation systems — LIDAR sensors that are mounted on mobile platforms such as airplanes or satellites require instrumentation to determine the absolute position and orientation of the sensor. Such devices generally include a Global Positioning System receiver and an Inertial Measurement Unit (IMU).

26. Translate the text (1800 printed characters; time – 60 min.)

LIDAR for meteorological applications

The first LIDAR systems were used for studies of atmospheric composition, structure, clouds, and aerosols. Initially based on ruby lasers, LIDAR for meteorological applications was constructed shortly after the invention of the laser and represent one of the first applications of laser technology.

Elastic backscatter LIDAR is the simplest type of lidar and is typically used for studies of aerosols and clouds. The backscattered wavelength is identical to the transmitted wavelength, and the magnitude of the received signal at a given range depends on the backscatter coefficient of scatterers at that range and the extinction coefficients of the scatterers along the path to that range. The extinction coefficient is typically the quantity of interest.

Differential Absorption LIDAR (DIAL) is used for range-resolved measurements of a particular gas in the atmosphere, such as ozone, carbon dioxide, or water vapor. The LIDAR transmits two wavelengths: an "on-line" wavelength that is absorbed by the gas of interest and an off-line wavelength that is not absorbed. The differential absorption between the two wavelengths is a measure of the concentration of the gas as a function of range. DIAL LIDARs are essentially dual-wavelength backscatter LIDARS.

Raman LIDAR is also used for measuring the concentration of atmospheric gases, but can also be used to retrieve aerosol parameters as well. Raman LIDAR exploits inelastic scattering to single out

the gas of interest from all other atmospheric constituents. A small portion of the energy of the transmitted light is deposited in the gas during the scattering process, which shifts the scattered light to a longer wavelength by an amount that is unique to the species of interest. The higher the concentration of the gas, the stronger the magnitude of the backscattered signal.

Doppler LIDAR is used to measure wind speed along the beam by measuring the frequency shift of the backscattered light. Scanning LIDARs, such as NASA's HARLIE LIDAR, have been used to measure atmospheric wind velocity in a large three dimensional cone.

27. Translate the text (1800 printed characters; time – 60 min.)

Introduction to Laser Equipment and Technologies

The term "laser" stands for Light Amplification by Stimulated Emission of Radiation, a technology that has transformed modern science, industry, and medicine. Unlike conventional light sources, lasers produce a highly focused, coherent beam of light with a single wavelength, allowing for unprecedented precision in various applications. Since its invention in 1960, laser technology has evolved rapidly, leading to advancements in manufacturing, healthcare, communications, and defense.

What is a Laser?

A laser is an optical device that generates an intense beam of light through the process of stimulated emission. This process occurs when electrons in atoms or molecules are excited to a higher energy state and then release photons (light particles) as they return to their original state. The emitted light is then amplified within an optical cavity, producing a beam that is:

- Monochromatic (single wavelength)
- Coherent (waves are in phase)
- Directional (low divergence, allowing long-distance focus)

These unique properties make lasers indispensable in applications requiring high precision, such as microfabrication, surgical procedures, and high-speed data transmission.

Types of Lasers and Their Applications

Lasers are classified based on their active medium (the material that generates the laser beam), which can be a gas, liquid, solid, or semiconductor. Some of the most widely used laser types include:

1. Gas Lasers

Gas lasers use a gaseous medium, such as carbon dioxide ($CO_2$) or helium-neon (HeNe), to produce laser light. $CO_2$ lasers are particularly important in industrial applications due to their high power and efficiency in cutting, welding, and engraving materials like metals, plastics, and wood. HeNe lasers, on the other hand, are often used in scientific research, barcode scanners, and alignment systems due to their stable and visible red light.

2. Solid-State Lasers

These lasers use a solid crystalline or glass medium doped with rare-earth elements, such as neodymium-doped yttrium aluminum garnet (Nd:YAG) or ruby. Solid-state lasers are known for their high energy output and are widely used in:

- Material processing (cutting, drilling, and welding metals)
- Medical applications (laser surgery, tattoo removal)
- Military systems (target designation and rangefinding)

3. Fiber Lasers

Fiber lasers utilize an optical fiber doped with rare-earth elements (e.g., erbium or ytterbium) as the gain medium. They are highly efficient, compact, and require minimal maintenance, making them ideal for:

- Industrial cutting and welding (automotive and aerospace industries)
- Telecommunications (signal amplification in fiber-optic networks)
- Laser marking (permanent engravings on metals and plastics)

4. Diode Lasers (Semiconductor Lasers)

Diode lasers are among the most compact and energy-efficient lasers, commonly found in:

- Consumer electronics (DVD/Blu-ray players, laser pointers)
- Medical devices (hair removal, dental procedures)
- Telecommunications (data transmission through fiber optics)

5. Excimer Lasers

These ultraviolet (UV) lasers use reactive gases like argon fluoride (ArF) or krypton fluoride (KrF)

and are primarily used in:
- Eye surgery (LASIK) for vision correction
- Microelectronics manufacturing (semiconductor lithography)

Key Applications of Laser Technology

The versatility of lasers has led to their adoption across multiple industries:

Manufacturing & Material Processing

Lasers have revolutionized manufacturing by enabling high-precision cutting, welding, and engraving without mechanical contact. Industries such as automotive, aerospace, and electronics rely on lasers for producing intricate components with minimal waste.

Medical & Aesthetic Treatments

In medicine, lasers provide minimally invasive surgical solutions, including:
- Laser eye surgery (refractive corrections)
- Dermatology (tattoo removal, skin resurfacing)
- Dentistry (cavity treatment, gum surgery)

Communication & Data Transfer

Fiber-optic communication systems use laser diodes to transmit data at the speed of light, forming the backbone of modern internet and telecommunications infrastructure.

Defense & Security

Military applications include laser targeting, missile defense systems, and LiDAR (Light Detection and Ranging) for surveillance and autonomous vehicles.

Scientific Research & Metrology

Lasers are crucial in spectroscopy, holography, and quantum physics experiments, helping scientists study atomic structures and develop new technologies.

Advantages of Laser Technology
- High Precision: Enables micrometer-level accuracy in manufacturing and surgery.
- Non-Contact Processing: Reduces wear and tear on tools and materials.
- Speed & Automation: Faster than traditional methods and easily integrated with robotics.
- Minimal Thermal Distortion: Ideal for delicate materials.

Future Trends in Laser Technology

Emerging advancements include:
- Ultrafast Lasers (femtosecond lasers) for nanoscale manufacturing.
- Quantum Lasers for next-generation computing.
- Green & Blue Lasers for improved efficiency in industrial applications.

Laser technology continues to push the boundaries of innovation, offering solutions that enhance productivity, improve medical treatments, and enable cutting-edge research. As lasers become more powerful, compact, and energy-efficient, their applications will expand further, shaping the future of multiple industries.

28. Translate the text (1800 printed characters; time – 60 min.)

Working Principle of Gas Lasers

Gas lasers operate on the fundamental principles of quantum electronics and optical amplification through stimulated emission of radiation. The underlying physics involves the interaction of electrical energy with gaseous atoms or molecules to produce a coherent, monochromatic, and highly directional beam of light. The operational mechanism can be comprehensively understood through several key stages that transform electrical input into laser output.

At the core of a gas laser is the active medium, which consists of a specific gas or gas mixture contained within an optical cavity. Common gaseous media include carbon dioxide, helium-neon, argon, and various excimer gases. The laser process begins with the excitation of this gaseous medium, typically achieved through an electrical discharge applied between electrodes within the gas-filled tube. This discharge provides the energy necessary to promote electrons in the gas atoms or molecules from their ground state to higher energy levels.

The excitation process creates what is known as a population inversion, a critical condition where more atoms or molecules exist in an excited state than in lower energy states. This non-equilibrium

distribution is essential for laser action, as it enables the amplification of light through stimulated emission. In this state, when photons of the appropriate wavelength pass through the excited medium, they stimulate the excited atoms or molecules to emit additional photons that are identical in phase, frequency, polarization, and direction to the incident photons. This process results in the coherent amplification of light.

The optical cavity, formed by mirrors placed at each end of the gas discharge tube, serves to reinforce this amplification process. One mirror is fully reflective while the other is partially transparent, allowing a portion of the light to escape as the laser beam. The photons bounce back and forth between these mirrors, each pass through the excited medium producing additional stimulated emissions and thus increasing the intensity of the light. This feedback mechanism continues until the light reaches sufficient intensity to emerge through the partially transparent mirror as a collimated laser beam.

The wavelength of the emitted laser light is determined by the specific energy transitions occurring in the gas medium. Different gases exhibit characteristic emission lines corresponding to particular atomic or molecular transitions. For instance, the helium-neon laser primarily emits at 632.8 nm (red light) due to specific transitions in neon atoms, while carbon dioxide lasers produce infrared radiation at 10.6 μm resulting from vibrational transitions in $CO_2$ molecules.

The efficiency and performance of gas lasers depend on several factors including gas composition, pressure, discharge current, and cavity design. Many gas lasers require precise control of these parameters to maintain optimal operation. Some variants, particularly high-power industrial lasers, incorporate cooling systems to manage the heat generated during operation, while others may use gas flow systems to maintain the appropriate gas mixture and pressure.

The unique properties of gas lasers, including their excellent beam quality, wavelength specificity, and ability to operate in continuous or pulsed modes, stem directly from these fundamental operating principles. The gaseous nature of the active medium allows for uniform excitation and efficient heat dissipation, contributing to the stability and reliability that make gas lasers indispensable in numerous scientific and industrial applications.

29. Translate the text (1800 printed characters; time – 60 min.)

Carbon Dioxide ($CO_2$) Lasers: Principles and Applications

Carbon dioxide lasers stand as one of the most versatile and widely implemented gas laser systems, renowned for their exceptional power output and efficiency in the mid-infrared spectrum. These lasers operate on the fundamental principle of molecular gas excitation, where the $CO_2$ gas mixture serves as the active lasing medium. The operational mechanism of $CO_2$ lasers involves intricate quantum mechanical processes occurring within the vibrational-rotational energy levels of carbon dioxide molecules, making them particularly efficient at converting electrical energy into coherent optical radiation.

The heart of a $CO_2$ laser system consists of a gas discharge tube containing a carefully optimized mixture of carbon dioxide, nitrogen, and helium gases. This specific combination plays a crucial role in the laser's operation through a multi-stage energy transfer process. When electrical discharge excites the gas mixture, nitrogen molecules first absorb the energy due to their favorable excitation characteristics. These excited nitrogen molecules then collide with $CO_2$ molecules, efficiently transferring their energy and creating population inversion in the vibrational levels of the carbon dioxide molecules. The helium gas serves multiple purposes: it helps maintain the population inversion by depopulating the lower laser level through thermal conduction, improves discharge stability, and enhances heat transfer from the gas mixture to the cooling system.

The laser transition in $CO_2$ occurs between specific vibrational-rotational energy levels of the molecule, primarily producing radiation at 10.6 μm wavelength, with a secondary line at 9.4 μm. These infrared wavelengths are particularly well-suited for material processing applications due to

their strong absorption by many organic materials and most metals when operated at high power densities. The optical cavity typically consists of a fully reflective mirror on one end and a partially transmissive output coupler on the other, often made from specialized materials like zinc selenide or germanium that are transparent to infrared radiation.

$CO_2$ lasers are manufactured in various configurations to suit different power and application requirements. Sealed tube designs are common for low to medium power applications (up to a few hundred watts), where the gas mixture remains contained indefinitely. For higher power systems (up to multi-kilowatt levels), flowing gas configurations are employed, where the gas mixture is continuously circulated and often replenished to maintain optimal performance. Waveguide $CO_2$ lasers offer compact designs with excellent beam quality for precision applications, while slab $CO_2$ lasers provide high power with improved thermal management through their unique geometry.

The versatility of $CO_2$ lasers has led to their widespread adoption across numerous industries. In industrial manufacturing, they serve as indispensable tools for cutting, welding, and marking metals, plastics, wood, and composites with exceptional precision and speed. The medical field utilizes $CO_2$ lasers for various surgical procedures, particularly in dermatology and ophthalmology, where their precise tissue ablation characteristics and hemostatic properties are highly valued. Scientific applications include spectroscopy and atmospheric research, while military systems employ high-power $CO_2$ lasers for rangefinding and directed energy applications.

Modern $CO_2$ laser technology continues to evolve, with advancements in RF excitation replacing traditional DC discharge methods, improving efficiency and extending operational lifetimes. The development of compact, fiber-delivered $CO_2$ laser systems has expanded their applicability to more diverse manufacturing environments. Furthermore, ongoing research into novel gas mixtures and cavity designs promises to enhance their performance characteristics, ensuring $CO_2$ lasers remain at the forefront of industrial and scientific laser applications for the foreseeable future. Their unique combination of power, efficiency, and infrared wavelength capabilities maintains their position as one of the most practical and widely used laser systems across multiple disciplines.

30. Translate the text (1800 printed characters; time – 60 min.)

Helium-Neon (HeNe) Lasers: The Quintessential Gas Laser System

The helium-neon laser stands as one of the most iconic and widely recognized laser systems, representing the first continuous-wave gas laser ever developed. These remarkable devices produce their characteristic red glow at 632.8 nanometers through a sophisticated interplay of atomic physics and precision engineering. The HeNe laser operates through an elegant energy transfer mechanism between two noble gases - helium and neon - typically mixed in a 10:1 ratio at low pressure (about 1 torr) within a sealed glass discharge tube.

The operational principle of HeNe lasers involves a multi-step excitation process that begins with an electrical discharge passing through the gas mixture. This discharge primarily excites helium atoms to their metastable $2^1S$ and $2^3S$ states due to their relatively high excitation cross-section. These excited helium atoms then collide with ground-state neon atoms, resonantly transferring their energy through atomic collisions. This energy transfer preferentially populates specific excited states in neon atoms, particularly the $3s_2$ and $2s_2$ levels in Paschen notation, creating the necessary population inversion relative to lower-lying $3p_4$ and $2p_4$ levels.

The actual lasing transition occurs between these neon energy states, with the most prominent and commonly used transition producing the familiar red beam at 632.8 nm ($3s_2$ to $2p_4$ transition). Other possible transitions in the visible spectrum include green (543.5 nm), yellow (594.1 nm), and orange (611.9 nm), though these require specialized mirror coatings and operating conditions. The infrared transition at 3.39 μm was actually the first to be observed in HeNe lasers but is typically suppressed in visible laser designs through careful mirror selection or magnetic suppression.

The optical cavity of a HeNe laser typically consists of a precisely aligned resonator with

high-reflectivity mirrors bonded directly to the ends of the discharge tube - one mirror being totally reflective and the other having about 1% transmission to allow the laser beam to exit. The mirrors are carefully designed with dielectric coatings optimized for the specific wavelength of operation. The discharge tube itself often includes carefully designed electrodes and may incorporate internal Brewster angle windows in higher-quality models to produce polarized output.

HeNe lasers are renowned for their exceptional beam characteristics, including high spatial coherence, excellent beam quality ($TEM_{00}$ mode), and remarkable frequency stability. These properties make them invaluable in applications requiring precise optical alignment and interferometry. Their typical output power ranges from 0.5 mW to about 50 mW, with the lower power versions being most common due to their stability and long lifetime (typically 20,000 to 50,000 hours of operation).

The applications of HeNe lasers are numerous and varied. They serve as fundamental tools in optical research laboratories for alignment and interferometric measurements. In industrial settings, they're used for precision alignment in construction and manufacturing. The barcode scanners that revolutionized retail in the 1970s and 80s relied heavily on HeNe lasers. They remain important in holography, spectroscopy, and as a teaching tool in physics education due to their relative safety and visible output.

Modern HeNe lasers have evolved from their early bulky designs to more compact and efficient configurations. While they have been largely replaced by diode lasers in many applications due to size and efficiency considerations, HeNe lasers maintain their importance in applications requiring superior beam quality and stability. Their relatively simple construction belies the sophisticated physics governing their operation, making them a fascinating subject of study in both laser physics and practical optoelectronics. The HeNe laser's combination of reliability, beam quality, and historical significance ensures its continued relevance in both educational and professional settings.

31. Translate the text (1800 printed characters; time – 60 min.)

Argon-Ion Lasers: High-Power Gas Laser Systems for Specialized Applications

Argon-ion lasers represent a class of ion gas lasers that produce high-power continuous wave output in the visible and ultraviolet spectrum. These sophisticated laser systems operate on the principle of electrical excitation of argon gas atoms to singly-ionized states, creating population inversion in various electronic transitions that give rise to multiple lasing wavelengths. The most prominent emissions occur at 488 nm (blue) and 514.5 nm (green), though argon-ion lasers can produce several other lines throughout the visible and near-UV spectrum.

The operational physics of argon-ion lasers involves a complex excitation process requiring substantial electrical input power. Unlike neutral gas lasers like HeNe, argon-ion lasers must first strip an electron from the argon atom to create the $Ar^+$ ion species that participates in the lasing process. This ionization requires high current densities typically achieved through arc discharge in a narrow bore plasma tube, often with current densities exceeding 100 A/cm². The plasma tube is usually made from beryllium oxide or graphite to withstand the extreme thermal conditions and contains argon gas at low pressure (approximately 0.1-1 Torr).

Once ionized, the $Ar^+$ ions are further excited to higher energy states through electron collisions in the plasma. The lasing transitions occur between specific energy levels of these singly-ionized argon atoms, with the most efficient transitions producing the characteristic blue and green lines. The $4p^4D^o_{5/2} \rightarrow 4s^4P_{3/2}$ transition generates the 488 nm blue line, while the $4p^4D^o_{7/2} \rightarrow 4s^4P_{5/2}$ transition produces the 514.5 nm green line. These transitions benefit from a favorable four-level laser system that helps maintain population inversion.

The optical resonator of an argon-ion laser typically consists of a high-quality plasma tube with Brewster angle windows to produce linearly polarized output, mounted between external mirrors.

The rear mirror is highly reflective, while the output coupler has reflectivity optimized for the desired wavelength combination. Many systems employ wavelength-selective optics or prism tuning to select specific lines from the multiple possible transitions.

Thermal management presents one of the most significant engineering challenges in argon-ion laser design. The high current densities generate substantial heat, requiring sophisticated cooling systems. Smaller systems (up to 5W) may use air cooling, while more powerful lasers require water cooling with carefully designed heat exchangers. The plasma tube itself often features segmented electrodes and special bore designs to manage the intense plasma conditions and extend operational lifetime.

Argon-ion lasers find their most important applications in scientific research and specialized industrial processes. In spectroscopy, they serve as excitation sources for Raman spectroscopy due to their multiple wavelength options and excellent beam quality. The medical field utilizes them in ophthalmology for retinal photocoagulation and in dermatological procedures. They were historically important in laser light shows and entertainment applications due to their bright visible output. In microfabrication, their UV lines (particularly 351 nm and 364 nm) enable precision processing of certain materials.

While diode-pumped solid-state lasers have replaced argon-ion lasers in many applications due to their higher efficiency, argon systems maintain certain advantages. They offer superior beam quality (often $TEM_{00}$ mode) and the ability to simultaneously lase at multiple wavelengths. Some specialized applications still require the unique combination of wavelengths and power levels that only argon-ion lasers can provide.

Modern argon-ion laser technology has evolved to improve efficiency and reliability, though the fundamental physics remains unchanged. Newer designs incorporate advanced plasma tube materials and improved magnetic confinement to enhance performance. Despite their declining use in favor of more efficient alternatives, argon-ion lasers continue to hold niche applications where their specific combination of wavelengths and beam characteristics remains unmatched. Their development contributed significantly to our understanding of ion laser physics and paved the way for other ion laser systems such as krypton-ion and mixed-gas lasers.

32. Translate the text (1800 printed characters; time – 60 min.)

Nitrogen Lasers: Pulsed Ultraviolet Light Sources with Unique Characteristics

Nitrogen lasers represent a distinct class of gas lasers that operate on molecular transitions in nitrogen gas, producing short pulses of ultraviolet light at 337.1 nanometers. These self-terminating laser systems employ a fundamentally different operating principle compared to continuous-wave gas lasers, relying on fast electrical discharge through nitrogen gas at atmospheric or reduced pressure to create a population inversion that rapidly collapses after each pulse. The nitrogen laser's unique properties stem from its three-level energy system in molecular nitrogen ($N_2$), where the upper laser level has a shorter lifetime than the lower level, creating a self-limiting lasing action.

The operational physics of nitrogen lasers involves electronic transitions in the molecular nitrogen energy structure. When a high-voltage electrical discharge passes through the gas, it excites nitrogen molecules to the $C^3\Pi_u$ state, which serves as the upper laser level. The laser transition occurs to the $B^3\Pi g$ state, emitting 337.1 nm ultraviolet radiation. This transition is particularly interesting because the upper state has a lifetime of about 40 nanoseconds, while the lower state persists for approximately 10 microseconds, creating a natural population inversion that automatically terminates when the lower level becomes populated. This self-terminating characteristic limits the laser to pulsed operation, typically producing pulses ranging from a few hundred picoseconds to several nanoseconds in duration.

The electrical excitation of nitrogen lasers requires specialized circuitry capable of delivering extremely fast high-voltage pulses. Most designs use a Blumlein transmission line configuration or a Marx generator to achieve the necessary rapid discharge with rise times on the order of nanoseconds.

The discharge occurs between two electrodes in a channel filled with nitrogen gas, often at pressures ranging from a few Torr to atmospheric pressure. Atmospheric-pressure designs offer simplicity and eliminate the need for vacuum systems but typically produce lower energy pulses compared to reduced-pressure configurations.

The optical cavity in nitrogen lasers is often simpler than in other gas lasers, frequently employing just a single mirror at one end with the other end open or using the Fresnel reflection from the output window. This simplicity is possible because of the high gain of the nitrogen laser medium, which can achieve sufficient amplification in a single pass through the gain medium (superradiant operation). However, more sophisticated designs do incorporate proper optical resonators to improve beam quality and coherence.

Nitrogen lasers produce relatively high peak powers (up to several megawatts in commercial systems) but at low repetition rates, typically ranging from single-shot operation up to about 100 Hz. The pulse energy varies from microjoules in small systems to millijoules in larger devices. The ultraviolet output at 337 nm is particularly useful for applications requiring short-wavelength light, and the natural pulse width in the nanosecond regime makes these lasers suitable for time-resolved measurements.

The primary application of nitrogen lasers has been as pump sources for dye lasers, where their UV output efficiently excites organic dye molecules to produce tunable visible light. In scientific research, they serve as convenient sources for fluorescence spectroscopy and time-resolved measurements. Other applications include matrix-assisted laser desorption/ionization (MALDI) mass spectrometry, air pollution monitoring through LIDAR techniques, and as educational tools for demonstrating laser physics principles.

Compared to other gas lasers, nitrogen lasers offer several unique advantages: they require no mirrors for operation (in superradiant mode), can operate at atmospheric pressure, and produce UV light without nonlinear frequency conversion. However, they also have limitations, including relatively low pulse repetition rates, modest pulse energies, and the self-terminating nature of the laser transition that prevents continuous-wave operation.

Modern developments in nitrogen laser technology have focused on improving pulse-to-pulse stability, increasing repetition rates, and developing compact designs. Some recent research has explored using nitrogen lasers as sources for laser-induced breakdown spectroscopy (LIBS) and other analytical techniques. While excimer lasers and solid-state UV lasers have replaced nitrogen lasers in many applications, they remain important tools in specific scientific and educational contexts due to their relative simplicity and unique output characteristics.

The study of nitrogen lasers has contributed significantly to our understanding of molecular gas lasers and fast discharge phenomena. Their development in the 1960s helped establish important principles of pulsed laser operation and high-speed electrical excitation techniques that later found application in other laser systems. Today, while no longer at the forefront of laser technology, nitrogen lasers continue to serve niche applications where their particular combination of UV output, short pulse duration, and simplicity of operation remains valuable.

33. Translate the text (1800 printed characters; time – 60 min.)

The Fundamental Strengths of Gas Laser Technology

Gas lasers have maintained their prominence in scientific and industrial applications for over six decades due to a unique combination of inherent advantages that stem from their fundamental operating principles. These systems, which utilize gaseous gain media ranging from simple noble gas mixtures to complex molecular compounds, offer capabilities that continue to make them indispensable in many high-precision applications despite the emergence of solid-state and semiconductor alternatives.

One of the most significant strengths of gas lasers lies in their exceptional beam quality and spatial coherence. The homogeneous nature of gaseous gain media allows for the generation of laser beams with near-perfect Gaussian intensity profiles and excellent mode purity, typically operating in the fundamental $TEM_{00}$ mode. This characteristic makes gas lasers particularly valuable in applications requiring diffraction-limited beam performance, such as holography, interferometry, and precision metrology. The helium-neon laser, for instance, remains the gold standard for alignment applications due to its unparalleled beam pointing stability and circular symmetry.

The wavelength diversity available through gas laser systems represents another major advantage. By selecting different gas mixtures and optimizing cavity optics, gas lasers can produce coherent radiation spanning an extraordinarily broad spectral range - from the ultraviolet (excimer lasers at 193 nm) through the visible spectrum (argon-ion at 488/514 nm, helium-neon at 632.8 nm) to the far-infrared (carbon dioxide lasers at 10.6 μm). This versatility enables scientists and engineers to select precisely the optimal wavelength for specific applications, whether it's the strong material absorption characteristics of $CO_2$ laser output for industrial processing or the retinal safety considerations in medical applications.

Gas lasers excel in their ability to produce continuous-wave output with remarkable power stability and temporal coherence. The steady-state plasma conditions in DC-excited gas discharges, particularly in systems like argon-ion and helium-neon lasers, allow for amplitude stability that often exceeds what can be achieved with solid-state systems. This makes them ideal for applications requiring long-term stable operation, such as in spectroscopic reference standards or length metrology. The narrow intrinsic linewidth of gas laser transitions, often measured in MHz or less, provides the spectral purity needed for high-resolution spectroscopy and optical frequency standards.

The scalability of gas laser technology to very high power levels remains unmatched by most alternative technologies. Industrial $CO_2$ lasers routinely deliver multi-kilowatt continuous output for materials processing applications, while excimer laser systems can produce pulsed energies measured in joules. This power scalability stems from the excellent thermal management properties of gaseous gain media - heat can be efficiently removed through gas convection and diffusion, avoiding the thermal lensing and stress fracture problems that limit solid-state lasers. Flowing gas designs further enhance power handling capabilities by continuously refreshing the excited medium.

Gas lasers demonstrate superior reliability and longevity in continuous operation compared to many other laser types. Properly designed systems like helium-neon lasers can operate for tens of thousands of hours without significant degradation in performance. The absence of crystalline degradation mechanisms (common in solid-state lasers) and the ability to replenish the gain medium in flowing gas systems contribute to this exceptional operational lifetime. This reliability makes gas lasers particularly valuable in applications where maintenance access is difficult or system downtime is costly, such as in semiconductor manufacturing equipment or undersea communication systems.

Another often-overlooked strength is the inherent safety of many gas laser systems. The neutral gas fill materials (helium, neon, argon, nitrogen, carbon dioxide) are generally non-toxic and environmentally benign, especially when compared to the hazardous materials used in some solid-state lasers (like neodymium doping elements or semiconductor compounds). This simplifies disposal procedures and reduces regulatory concerns in many jurisdictions. Furthermore, the sealed nature of many gas laser tubes prevents contamination and eliminates the need for regular maintenance of the optical gain medium.

The physics of gas discharges provides gas lasers with unique pulse shaping capabilities. Transverse discharge designs allow for extremely fast current rise times, enabling nanosecond pulse generation without the need for complex Q-switching mechanisms. This characteristic is particularly valuable in nitrogen lasers and excimer systems, where the self-terminating transitions naturally produce short, high-peak-power pulses ideal for applications like laser-induced breakdown spectroscopy or pumping of dye lasers.

Gas lasers also offer superior flexibility in terms of output polarization control. The Brewster windows commonly used in gas laser designs naturally produce linearly polarized output without the need for additional optical components. This inherent polarization purity benefits applications ranging from optical data storage to materials processing where polarization-dependent absorption is exploited.

From an economic perspective, gas lasers often provide better total cost of ownership for certain applications. While the initial capital cost may be higher than some semiconductor alternatives, the long service life, minimal consumable requirements (in sealed tube designs), and consistent performance over time can make them more economical in the long run for industrial and scientific applications where beam quality and stability are paramount.

The ongoing development of gas laser technology continues to build upon these fundamental strengths. Modern innovations such as RF excitation (replacing DC discharges), advanced gas mixture formulations, and improved thermal management techniques have further enhanced the performance and reliability of gas laser systems. While newer laser technologies have displaced gas lasers in some applications, their unique combination of beam quality, wavelength options, power scalability, and operational stability ensures they remain essential tools across scientific research, industrial manufacturing, medical applications, and defense systems. The continued use of helium-neon lasers in optical disk mastering and $CO_2$ lasers in automotive manufacturing demonstrates the enduring value of these technologies where their particular strengths outweigh the advantages of newer alternatives.

34. Translate the text (1800 printed characters; time – 60 min.)

Challenges and Limitations of Gas Laser Systems

While gas lasers offer numerous advantages, they also present several inherent limitations and operational challenges that have led to their replacement by solid-state and semiconductor lasers in many applications. These constraints stem from fundamental physical properties of gaseous gain media and the practical requirements of maintaining gas discharges.

The most significant limitation of gas lasers lies in their relatively poor electrical-to-optical conversion efficiency. Most gas laser systems operate with wall-plug efficiencies below 1%, with even high-performance $CO_2$ lasers typically achieving only 10-15% efficiency. This inefficiency results from multiple energy conversion steps - first from electrical energy to electron excitation in the gas discharge, then to excited atomic or molecular states, and finally to photon emission. Each transition involves substantial energy losses, primarily as heat that must be actively removed from the system. The low efficiency leads to high operating costs, particularly for industrial applications requiring continuous high-power operation, where electrical power consumption becomes a major economic factor.

Thermal management presents another critical challenge for gas laser systems. The combination of low efficiency and high operating power results in significant waste heat generation that must be effectively dissipated. High-power gas lasers such as argon-ion or $CO_2$ systems often require complex cooling systems, including water chillers with precise temperature control. The thermal loading can cause gas density variations within the discharge region, leading to optical distortions that degrade beam quality. In sealed tube designs, excessive heat can accelerate gas contamination through outgassing from electrodes and tube materials, gradually degrading laser performance over time.

The physical size and weight of gas lasers frequently limit their applicability in space-constrained or portable applications. The need for extended discharge paths to achieve sufficient gain, combined with the ancillary equipment for gas handling, power supplies, and cooling systems, results in substantially larger footprints compared to diode-pumped solid-state lasers of equivalent power. Even relatively low-power gas lasers like helium-neon systems occupy significantly more volume

than modern semiconductor alternatives delivering similar output characteristics.

Gas lasers generally exhibit limited modulation capabilities compared to semiconductor lasers. The slow response time of gas discharge plasmas prevents direct high-frequency modulation of most gas laser systems. While some modulation can be achieved through external optical components or discharge current variations, gas lasers cannot match the GHz modulation rates possible with diode lasers. This limitation restricts their use in modern telecommunications and data transmission applications where high-speed modulation is essential.

The maintenance requirements and consumable costs associated with gas lasers present ongoing operational challenges. Sealed tube designs eventually suffer from gas contamination and depletion, requiring tube replacement after tens of thousands of operating hours. Flowing gas systems need periodic gas replenishment and purification to maintain optimal performance. Electrode sputtering in ion lasers gradually coats optical surfaces, reducing output power over time. These maintenance needs result in periodic downtime and contribute to the total cost of ownership.

Gas pressure and composition requirements impose additional constraints. Many gas lasers operate at precise low-pressure conditions that require vacuum systems and pressure regulation equipment. The need for specific gas mixtures (often involving rare or expensive gases like helium or krypton) makes systems vulnerable to supply chain disruptions and price fluctuations. Some excimer laser gas mixtures incorporate toxic or reactive components like fluorine, requiring special handling procedures and exhaust treatment systems.

The startup and stabilization characteristics of gas lasers often limit their usability in applications requiring instant-on capability. Most gas discharge lasers require several minutes of warm-up time to reach stable operating temperature and gas discharge conditions. High-power systems may need even longer stabilization periods before achieving specified output parameters. This contrasts sharply with diode lasers that can begin stable operation within microseconds of being powered on.

Beam quality, while excellent in many gas lasers, becomes challenging to maintain at very high power levels. Thermal gradients in the gain medium can produce optical distortions that degrade beam focusability and mode quality. While sophisticated resonator designs can mitigate these effects, they add complexity and cost to the system. The fundamental diffraction limits imposed by the discharge bore diameter also constrain the minimum achievable beam divergence for a given power level.

From an environmental perspective, gas lasers face increasing regulatory challenges. Many systems use helium, a non-renewable resource with growing supply concerns. The high voltage power supplies required for gas discharge lasers contain hazardous materials and must meet stringent safety standards. Some gas mixtures used in excimer and ion lasers may fall under environmental regulations regarding greenhouse gases or ozone-depleting substances.

The market evolution toward compact, efficient laser sources has rendered many traditional gas laser applications obsolete. While niche applications still justify their use, most consumer and industrial applications have migrated to diode-pumped solid-state or direct diode laser solutions. This market shift has reduced manufacturing volumes for gas lasers, leading to higher unit costs and reduced availability of replacement components.

Despite these challenges, gas lasers continue to occupy specific niches where their unique advantages outweigh these limitations. However, the ongoing development of alternative laser technologies continues to erode these remaining strongholds, pushing gas laser technology toward increasingly specialized applications where their particular combination of wavelength, beam quality, and power characteristics cannot be matched by other approaches. The future of gas lasers likely lies in hybrid systems that combine gaseous gain media with modern pumping and control technologies to mitigate some of these traditional limitations while preserving their essential

advantages.

35. Translate the text (1800 printed characters; time – 60 min.)

Excimer Lasers: Pulsed Ultraviolet Powerhouses for Precision Applications

Excimer lasers represent a specialized class of gas lasers that generate high-energy pulses of ultraviolet light through transitions in short-lived excited molecules called excimers (excited dimers). These unique laser systems derive their name from their working medium - temporary molecular complexes that only exist in an excited state, formed from a noble gas (such as argon, krypton, or xenon) and a halogen (typically fluorine or chlorine). When electrically excited, these normally inert gases form unstable compounds that emit ultraviolet photons as they dissociate back into individual atoms.

The operational principle of excimer lasers relies on this transient molecular formation and subsequent radiative decay. Under normal conditions, noble gas atoms and halogens do not form stable compounds. However, when subjected to a high-voltage electrical discharge in precisely controlled gas mixtures, they temporarily combine into excited molecules with lifetimes measured in nanoseconds. As these excited dimers return to their ground state - where they immediately dissociate - they release photons in the ultraviolet spectrum. This self-terminating transition creates the population inversion necessary for laser action, resulting in pulsed output with pulse durations typically ranging from 10 to 30 nanoseconds.

The most common excimer laser configurations use specific gas mixtures to produce different wavelengths:
- Argon fluoride (ArF) at 193 nm
- Krypton fluoride (KrF) at 248 nm
- Xenon chloride (XeCl) at 308 nm
- Xenon fluoride (XeF) at 351 nm

Each wavelength combination offers distinct characteristics that make it suitable for particular applications. The 193 nm ArF laser, for instance, provides the shortest commercial UV wavelength and highest photon energy, while the 308 nm XeCl laser offers a balance between power and operational stability.

Excimer lasers employ sophisticated discharge excitation systems to create the necessary plasma conditions. The laser chamber contains a precisely controlled mixture of the noble gas, halogen, and a buffer gas (usually neon or helium) at pressures of 2-4 atmospheres. A high-voltage pulsed discharge of several tens of kilovolts creates a microplasma that excites the gas mixture, typically with pulse repetition rates ranging from single shots to several hundred hertz in industrial systems. The optical resonator consists of highly reflective dielectric mirrors designed to withstand the intense UV radiation, with the output coupler allowing partial transmission of the laser beam.

The extreme operating conditions present significant engineering challenges. The highly reactive halogen gases, particularly fluorine, require special handling and corrosion-resistant materials for all wetted components. The high-voltage pulsed discharges subject electrodes to intense erosion, necessitating regular maintenance and replacement. Gas contamination from electrode materials and outgassing requires sophisticated gas purification systems to maintain consistent output characteristics. These factors contribute to the relatively high operational costs of excimer laser systems compared to other laser technologies.

Excimer lasers have found their most prominent application in semiconductor photolithography, where their short UV wavelengths enable the production of increasingly smaller microchip features. The 193 nm ArF laser has been the workhorse of deep-ultraviolet lithography for multiple generations of semiconductor manufacturing, allowing the continued scaling of Moore's Law. In medicine, excimer lasers revolutionized ophthalmology through LASIK vision correction procedures, where their precise tissue ablation with minimal thermal damage enables corneal

reshaping. The 308 nm XeCl laser has become important in dermatological treatments for psoriasis and vitiligo, as well as in cardiovascular angioplasty procedures.

Industrial applications leverage excimer lasers for precision micromachining of polymers, ceramics, and composite materials. The short wavelength allows for extremely fine feature sizes, while the pulsed operation minimizes heat-affected zones. Excimer lasers also serve as pump sources for tunable dye lasers and play crucial roles in scientific research, including laser spectroscopy and plasma diagnostics. In the display industry, they enable the production of organic light-emitting diode (OLED) displays through selective laser annealing processes.

Recent advancements in excimer laser technology focus on improving pulse-to-pulse stability, increasing repetition rates, and reducing operational costs. New electrode materials and gas handling systems extend maintenance intervals, while improved resonator designs enhance beam quality and energy stability. The development of narrow-bandwidth excimer lasers with injection locking has been particularly important for advanced lithography applications requiring extreme precision.

While solid-state UV lasers have replaced excimer systems in some applications, excimer lasers maintain dominance where their unique combination of short wavelength, high pulse energy, and excellent beam uniformity is required. Their continued evolution ensures they remain critical tools in semiconductor manufacturing, medical technology, and advanced materials processing - applications where alternative technologies cannot yet match their performance characteristics. The fundamental physics of excimer formation and the engineering challenges overcome in their development represent a remarkable achievement in laser technology, enabling capabilities that have transformed multiple industries.

36. Translate the text (1800 printed characters; time – 60 min.)

Future Developments in Gas Laser Technology: Pushing the Boundaries of Photonic Applications

Gas laser technology continues to evolve through innovative approaches that address its traditional limitations while expanding its capabilities into new frontiers. The coming decade will witness transformative advancements in gas laser design, performance, and application spaces, driven by emerging materials science, precision engineering breakthroughs, and novel excitation methodologies.

One of the most promising directions involves the development of hybrid excitation systems that combine the best attributes of gas and solid-state technologies. Researchers are making significant progress in diode-pumped gas laser architectures, where high-efficiency semiconductor lasers replace traditional electrical discharges as the excitation mechanism. This approach could dramatically improve wall-plug efficiency while maintaining the superior beam quality and wavelength flexibility of gas systems. For instance, optically pumped rubidium vapor lasers have already demonstrated conversion efficiencies exceeding 60%, pointing toward a new generation of highly efficient gas laser sources.

Advanced materials science is enabling revolutionary changes in gas laser construction. Nanostructured electrode materials incorporating graphene and other two-dimensional materials promise to reduce sputtering effects in ion lasers while improving discharge characteristics. Novel ceramic composites for plasma tubes allow higher operating temperatures and reduced gas contamination. In $CO_2$ lasers, the integration of carbon nanotube-based field emission cathodes may enable more compact designs with improved modulation capabilities. These material innovations are extending operational lifetimes while reducing maintenance requirements.

The field of quantum optics is opening new possibilities for gas laser systems through the development of atomic vapor lasers with unprecedented spectral purity. Alkali metal vapor lasers leveraging coherent population trapping and other quantum interference phenomena could produce

outputs with sub-hertz linewidths, enabling new applications in quantum computing, ultra-precise metrology, and fundamental physics research. Coupled with optical frequency comb techniques, these systems may serve as the backbone for next-generation optical atomic clocks and gravitational wave detectors.

Significant efforts are underway to miniaturize gas laser technology while maintaining performance characteristics. Microfabrication techniques adapted from semiconductor manufacturing are being used to create chip-scale gas discharge channels with integrated optical resonators. These microplasma devices could bring gas laser capabilities to portable analytical instruments and integrated photonic systems. Hollow-core photonic crystal fibers filled with laser-active gases represent another miniaturization pathway, offering meter-long interaction lengths in millimeter-scale packages with unique nonlinear optical properties.

Intelligent control systems incorporating machine learning algorithms are transforming gas laser operation and maintenance. Adaptive discharge control systems can now optimize plasma parameters in real-time, compensating for gas degradation and electrode wear. Predictive maintenance algorithms analyze operational data to anticipate component failures before they occur, significantly improving system reliability. These smart laser systems automatically adjust mirror alignments, gas mixtures, and discharge parameters to maintain optimal performance under varying environmental conditions.

37. Translate the text (1800 printed characters; time – 60 min.)

Future Developments in Gas Laser Technology: Pushing the Boundaries of Photonic Applications

New gas mixtures and excitation schemes are expanding the available wavelength range of gas lasers. Researchers are exploring molecular gases like nitrogen oxide and carbon monosulfide for new mid-infrared emission lines, while heavy noble gas halides may enable vacuum ultraviolet outputs below 150 nm. Microwave excitation of gas discharges offers an alternative to traditional DC or RF pumping, potentially improving efficiency and reducing electrode erosion. Non-equilibrium plasma techniques using pulsed nanosecond discharges could unlock new laser transitions in molecular gases.

Industrial applications are driving the development of high-power gas laser systems with unprecedented reliability. Next-generation $CO_2$ lasers incorporate advanced gas regeneration systems that continuously purify and replenish the active medium, enabling years of continuous operation without maintenance. Fiber-delivered gas laser beams are overcoming traditional limitations in beam delivery, expanding their use in flexible manufacturing systems. The integration of gas lasers with additive manufacturing platforms enables new hybrid processing techniques combining the precision of UV ablation with deposition processes.

In the medical field, gas lasers are evolving toward smarter, more specialized applications. Adaptive beam shaping systems coupled with real-time tissue monitoring are creating new possibilities for laser surgery with subcellular precision. Miniaturized excimer laser systems are being developed for minimally invasive cardiovascular procedures, while novel gas mixtures may enable precise neural tissue ablation for neurological applications. The combination of gas lasers with nanoparticle sensitizers promises to revolutionize photodynamic therapy approaches.

Environmental considerations are shaping the future of gas laser technology, with research focused on reducing or eliminating dependence on rare gases like helium. New gas recycling systems and alternative buffer gas mixtures aim to address supply chain vulnerabilities. The development of "green" gas lasers using environmentally benign working media aligns with global sustainability initiatives while maintaining performance standards.

As these technological advancements mature, gas lasers will likely experience a renaissance in scientific and industrial applications, complementing rather than competing with solid-state and semiconductor laser technologies. Their unique combination of wavelength flexibility, beam quality, and power scalability ensures they will remain vital tools in fields ranging from fundamental research to advanced manufacturing, albeit in increasingly specialized and optimized configurations tailored for specific applications. The future of gas laser technology lies not in replicating the

capabilities of other laser types, but in maximizing its inherent advantages through innovative engineering and novel physical approaches.

38. Translate the text (1800 printed characters; time – 60 min.)

Laser Cutting and Welding: Precision Manufacturing Through Photonic Energy

Laser-based material processing has revolutionized modern manufacturing, with laser cutting and welding standing as two of the most impactful industrial applications of laser technology. These processes leverage the unique properties of laser light—coherence, monochromaticity, and high power density—to achieve levels of precision, speed, and quality unattainable with conventional mechanical or thermal methods. The concentrated photon energy enables clean, narrow kerf cuts and deep, narrow welds with minimal heat-affected zones, transforming production capabilities across industries.

Laser Cutting: The Art of Photonic Material Separation

In laser cutting systems, a focused beam of intense light vaporizes, melts, or burns away material along a programmed path. $CO_2$ lasers operating at 10.6 μm wavelength dominate metal cutting applications up to 25 mm thickness, while fiber lasers in the 1 μm range have gained prominence for thinner materials. The process typically employs assist gases—oxygen for carbon steel to create an exothermic reaction, nitrogen for stainless steel to prevent oxidation, or argon for titanium to avoid contamination.

Automotive manufacturers rely heavily on laser cutting for producing body panels with complex contours. A modern car door panel, for instance, might undergo laser trimming after stamping to create precise window openings and attachment points. The aerospace industry uses multi-axis laser systems to cut turbine blade cooling holes in nickel superalloys, where conventional drilling would cause microcracks. In electronics manufacturing, UV lasers cut fragile graphene sheets and flexible printed circuits without mechanical stress. Architectural metal shops employ high-power lasers to create intricate decorative screens from stainless steel sheets, with tolerances under 0.1 mm.

The medical device industry exemplifies precision laser cutting with applications like stent manufacturing. Cardiovascular stents begin as tiny metal tubes that lasers cut into intricate mesh patterns, with feature sizes smaller than 100 microns. Similarly, laser systems cut biocompatible polymers into precise components for drug delivery devices and surgical tools. Even the consumer goods sector benefits—laser-cut smartphone chassis components achieve the tight tolerances required for modern device assembly.

Laser Welding: Molecular Bonding at Light Speed

Laser welding creates metallurgical bonds by locally melting materials with concentrated optical energy. The process occurs in two primary modes: conduction-limited welding for shallow joins and keyhole welding for deep penetration. Automotive manufacturers have adopted laser welding for body-in-white construction, where robots guide laser beams along flanges to join roof panels to side frames at speeds exceeding 10 meters per minute. The Volkswagen Group's modular transverse matrix platform uses over 4,000 laser welds per vehicle, reducing weight while increasing structural rigidity.

In battery manufacturing for electric vehicles, laser welding assembles lithium-ion cells by joining thin copper and aluminum foils to terminals—a process requiring precise energy control to avoid damaging sensitive battery chemistries. The medical industry employs micro laser welding to hermetically seal pacemaker cases and join miniature components in surgical instruments. Jewelers use pulsed lasers to create nearly invisible joins in precious metals, while aerospace engineers weld turbine blades with minimal thermal distortion.

A notable example of large-scale laser welding appears in shipbuilding, where hybrid laser-arc

processes join thick steel plates for hull construction. The European shipyard Meyer Werft employs this technology to construct cruise ship components, achieving higher productivity than conventional arc welding. Conversely, the semiconductor industry relies on ultrafast lasers for welding delicate sensor packages without generating microcracks in silicon or gallium arsenide components.

Emerging Hybrid Processes and Future Directions

The boundaries between cutting and welding continue to blur with processes like laser-assisted mechanical cutting, which combines a weak laser beam with a mechanical blade to reduce cutting forces in composites. Laser ablation welding represents another innovation, where material removal and joining occur simultaneously for dissimilar material combinations. The Fraunhofer Institute has demonstrated this technique for joining copper to aluminum in electric vehicle battery connections—a traditionally challenging material pair.

Industry 4.0 integration is transforming laser processing through real-time monitoring systems. Smart laser cutting heads now incorporate thermal cameras and spectrometers to adjust parameters dynamically, compensating for material variations. Welding systems use plasma plume spectroscopy to detect defects instantaneously, a capability critical for nuclear component fabrication. The future points toward fully adaptive laser processing where artificial intelligence algorithms optimize beam characteristics for each micron of travel across variable material conditions.

39. Translate the text (1800 printed characters; time – 60 min.)

Medical Lasers: Precision Photonic Tools Transforming Healthcare

The integration of laser technology into medical practice has created a revolution in diagnostic and therapeutic procedures across nearly every medical specialty. These sophisticated photonic instruments provide clinicians with unprecedented control over biological interactions at cellular and even molecular levels, enabling treatments that minimize trauma while maximizing precision. The unique characteristics of laser light—including selective wavelength absorption, precise spatial control, and adjustable pulse parameters—allow medical lasers to perform functions ranging from delicate tissue ablation to non-invasive imaging and stimulation of biological processes.

Ophthalmology: Vision Correction and Retinal Therapies

Ophthalmology represents the most mature medical laser application, where excimer lasers have transformed vision correction through procedures like LASIK (Laser-Assisted In Situ Keratomileusis). In this widely performed refractive surgery, a 193 nm argon fluoride excimer laser precisely reshapes the corneal stroma with sub-micron accuracy, correcting myopia, hyperopia, and astigmatism. The laser removes tissue through a photochemical process called photoablation, where each laser pulse breaks molecular bonds without generating significant heat that could damage surrounding tissue.

For retinal diseases, ophthalmologists employ diode-pumped solid-state lasers (532 nm) to treat diabetic retinopathy through panretinal photocoagulation. The laser creates controlled burns on the retina to reduce abnormal blood vessel growth while preserving central vision. More recently, femtosecond lasers have revolutionized cataract surgery by creating perfectly circular capsulotomies and fragmenting lenses for easier removal, improving outcomes in premium intraocular lens implantation procedures.

Dermatology: From Cosmetic Enhancements to Skin Cancer Treatment

Dermatological applications showcase the remarkable versatility of medical lasers across different wavelengths and pulse durations. Vascular lesions including port-wine stains respond well to pulsed dye lasers (585-595 nm), where selective photothermolysis targets hemoglobin while sparing surrounding tissue. Q-switched lasers (694 nm ruby, 755 nm alexandrite, 1064 nm Nd:YAG)

effectively remove tattoos through photomechanical disruption of ink particles, with wavelength selection based on tattoo color.

For skin resurfacing and wrinkle reduction, fractional $CO_2$ lasers (10,600 nm) create microscopic treatment zones that stimulate collagen remodeling while leaving surrounding tissue intact for faster healing. In skin cancer treatment, photodynamic therapy combines topical aminolevulinic acid with red laser light (635 nm) to selectively destroy actinic keratosis and basal cell carcinoma lesions. Picosecond lasers have recently expanded aesthetic applications by providing more effective pigment clearance with reduced treatment sessions.

Surgical Applications: Precision Cutting and Minimally Invasive Procedures

Across surgical specialties, lasers provide bloodless cutting capabilities with minimal collateral damage. In otolaryngology, $CO_2$ lasers enable precise vocal cord surgery through laryngoscopes, treating lesions while preserving vocal quality. The same wavelength proves valuable in gynecological procedures for cervical dysplasia treatment and endometriosis ablation. Urologists employ holmium:YAG lasers (2100 nm) for lithotripsy, where the laser's pulsed energy safely fragments kidney stones through flexible fiber delivery systems.

Neurosurgery benefits from the precision of laser interstitial thermal therapy (LITT), where MRI-guided diode lasers (980 nm) ablate epileptic foci or brain tumors through a single burr hole. This minimally invasive approach reduces hospital stays and recovery times compared to traditional craniotomies. In cardiovascular medicine, excimer lasers (308 nm) aid in complex angioplasty procedures by photoablating calcified plaque that resists conventional balloon dilation.

Dentistry: Hard and Soft Tissue Applications

Dental lasers have evolved into indispensable tools for both restorative and surgical procedures. Erbium lasers (Er:YAG at 2940 nm and Er,Cr:YSGG at 2780 nm) excel in hard tissue applications, removing carious dentin and preparing cavities with minimal vibration or heat generation—a particular benefit for anxious patients. These same wavelengths effectively perform osseous surgery and crown lengthening with precise bone ablation.

For soft tissue procedures, diode lasers (810-980 nm) offer hemostatic cutting of gingiva during cosmetic gum recontouring or implant uncovering. Laser-assisted periodontal therapy using Nd:YAG lasers (1064 nm) reduces periodontal pathogens while stimulating tissue regeneration. Photobiomodulation with low-level lasers (630-850 nm) accelerates orthodontic tooth movement and reduces postoperative discomfort through cellular stimulation.

Emerging Frontiers and Future Directions

The medical laser field continues to advance with technologies like multiphoton microscopy for non-invasive diagnostics and Raman spectroscopy-guided surgery. Photodynamic therapy is expanding into new cancer treatments with improved photosensitizers and interstitial laser delivery systems. Laser-activated nanoparticles show promise for targeted drug delivery and antimicrobial applications.

Researchers are developing compact, tunable laser systems that can adapt their parameters to real-time tissue feedback, creating "smart" surgical tools. The integration of artificial intelligence with laser systems promises to automate treatment parameter selection based on optical coherence tomography or other imaging modalities. As laser technology becomes more accessible and versatile, its medical applications will continue to grow, offering patients safer, less invasive, and more effective treatment options across the spectrum of healthcare.

40. Translate the text (1800 printed characters; time – 60 min.)

Laser communication, also known as optical communication or free-space optical communication (FSO), is a technology that uses laser beams to transmit data through the atmosphere or space. Unlike traditional radio frequency (RF) communication, laser communication employs light waves in the visible or near-infrared spectrum to achieve high-speed, high-bandwidth data transfer with minimal interference. This method is particularly advantageous for scenarios requiring secure, efficient, and high-capacity communication over long distances.

## How Laser Communication Works

Laser communication systems consist of a transmitter and a receiver. The transmitter converts electrical signals into modulated laser light, which is then directed toward the receiver through free space (air, vacuum, or space). The receiver detects the laser beam using photodetectors or telescopes and demodulates the light back into electrical signals to retrieve the transmitted data. Key components include precise alignment mechanisms, adaptive optics to counteract atmospheric disturbances, and error-correction protocols to ensure data integrity.

## Advantages of Laser Communication

1. High Bandwidth: Laser communication can achieve data rates significantly higher than RF systems, enabling the transmission of large volumes of data, such as high-definition video or scientific measurements, in a short time.
2. Low Interference: Since laser beams are highly directional and operate at optical frequencies, they are less susceptible to electromagnetic interference and eavesdropping compared to RF signals.
3. Smaller Equipment: Laser transmitters and receivers are often more compact and lightweight than RF systems, making them ideal for space missions and mobile applications.
4. Energy Efficiency: Laser systems can transmit data over long distances with relatively low power consumption, as the light beams remain tightly focused.

## Challenges of Laser Communication

1. Atmospheric Effects: Weather conditions like fog, rain, or turbulence can scatter or absorb laser beams, disrupting communication. Adaptive optics and redundant systems are often used to mitigate these issues.
2. Precision Alignment: Maintaining a stable line-of-sight between the transmitter and receiver requires precise pointing and tracking mechanisms, especially for moving platforms like satellites or aircraft.
3. Limited Range in Atmosphere: While laser communication works exceptionally well in space (where there is no atmospheric interference), terrestrial FSO systems are typically limited to line-of-sight applications over shorter distances.

## Examples of Laser Communication Applications

1. Space Missions: NASA and other space agencies use laser communication for high-speed data links between satellites, spacecraft, and ground stations. For instance, NASA's Lunar Laser Communication Demonstration (LLCD) in 2013 achieved record-breaking data rates between the Moon and Earth.
2. Military and Defense: Secure laser communication is employed for encrypted data transfer between ships, aircraft, and ground units, reducing the risk of interception.
3. Undersea Communication: While water scatters light, blue-green lasers can penetrate deeper and are used for short-range communication with submarines.
4. Inter-Satellite Links: Companies like SpaceX and government agencies use laser links to relay data between satellites in constellations, enabling faster and more resilient global communication networks.
5. Urban Networks: Some cities deploy FSO systems for high-speed internet backbone connections where laying fiber-optic cables is impractical.

## Future Prospects

Laser communication is poised to play a critical role in next-generation networks, including quantum communication and deep-space exploration. Projects like the European Space Agency's (ESA)

Optical Ground Station and NASA's Deep Space Optical Communications (DSOC) aim to establish reliable laser links for future Mars missions and beyond. As technology advances, laser communication could become a standard for high-speed, secure, and efficient data transfer across various domains.

41. Look through the text and say what it is about. Give its brief contents.

What are the rules governing refraction? The first thing to observe is that just as with reflection, the new, bent part of the ray lies in the same plane as the normal (perpendicular) and the incident ray, d).
If you try shooting a beam of light at the boundary between two substances, say water and air, you'll find that regardless of the angle at which you send in the beam, the part of the beam in the water is always closer to the normal line, e). It doesn't matter if the ray is entering the water or leaving, so refraction is symmetric with respect to time-reversal, f).
If, instead of water and air, you try another combination of substances, say plastic and gasoline, again you'll find that the ray's angle with respect to the normal is consistently smaller in one and larger in the other. Also, we find that if substance A has rays closer to normal than in B, and B has rays closer to normal than in C, then A has rays closer to normal than C. This means that we can rank-order all materials according to their refractive properties. Isaac Newton did so, including in his list many peculiar substances. Several general rules can be inferred from such a list:
* Vacuum lies at one end of the list. In refraction across the interface between vacuum and any other medium, the other medium has rays closer to the normal.
* Among gases, the ray gets closer to the normal if you increase the density of the gas by pressurizing it more.

42. Look through the text and say what it is about. Give its brief contents.

Earlier, we developed an equation for the percentage of the wave energy that is transmitted and the percentage reflected at a boundary between media. This was only done in the case of waves in one dimension, however, and rather than discuss the full three dimensional generalization it will be more useful to go into some qualitative observations about what happens. First, reflection happens only at the interface between two media, and two media with the same index of refraction act as if they were a single medium. Thus, at the interface between media with the same index of refraction, there is no reflection, and the ray keeps going straight. Continuing this line of thought, it is not surprising that we observe very little reflection at an interface between media with similar indices of refraction.
The next thing to note is that it is possible to have situations where no possible angle for the refracted ray can satisfy Snell's law. Solving Snell's law for Θ2, we find

$$\theta_2 = \sin^{-1}\left( {}_1 / {}_2 \sin \theta 1 \right)$$

and if n1 is greater than n2, then there will be large values of Θ1 for which the quantity (n1/n2)sin Θ is greater than one, meaning that your calculator will flash an error message at you when you try to take the inverse sine. What can happen physically in such a situation? The answer is that all the light is reflected, so there is no refracted ray. This phenomenon is known as total internal reflection, and is used in the fiber-optic cables that nowadays carry almost all long-distance telephone calls.

43. Look through the text and say what it is about. Give its brief contents.

An imperfection or distortion in an image is called an aberration. An aberration can be produced by a flaw in a lens or mirror, but even with a perfect optical surface some degree of aberration is unavoidable. To see why, consider the mathematical approximation we've been making, which is that the depth of the mirror's curve is small compared to do and di. Since only a flat mirror can satisfy this shallow-mirror condition perfectly, any curved mirror will deviate somewhat from the mathematical behavior we derived by assuming that condition. There are two main types of aberration in curved mirrors, and these also occur with lenses.
An object on the axis of the lens or mirror may be imaged correctly, but off-axis objects may be out of focus or distorted. In a camera, this type of aberration would show up as fuzziness or warping near the sides of the picture when the center was perfectly focused. An example of this is shown in figure a), and in that particular example, the aberration is not a sign that the equipment was of low quality or wasn't right for the job but rather an inevitable result of trying to flatten a panoramic view; in the limit of a 360-degree panorama, the problem would be similar to the problem of representing the

Earth's surface on a flat map, which can't be accomplished without distortion.

44. Look through the text and say what it is about. Give its brief contents.

Why should refraction be related to the speed of light? The mechanical model shown in the figure may help to make this more plausible. Suppose medium 2 is thick, sticky mud, which slows down the car. The car's right wheel hits the mud first, causing the right side of the car to slow down. This will cause the car to turn to the right until is moves far enough forward for the left wheel to cross into the mud. After that, the two sides of the car will once again be moving at the same speed, and the car will go straight.

Of course, light isn't a car. Why should a beam of light have anything resembling a "left wheel" and "right wheel?" After all, the mechanical model would predict that a motorcycle would go straight, and a motorcycle seems like a better approximation to a ray of light than a car. The whole thing is just a model, not a description of physical reality.

45. Look through the text and say what it is about. Give its brief contents.

The fundamental physical phenomenon at work in the eye is that when light crosses a boundary between two media (such as air and the eye's jelly), part of its energy is reflected, but part passes into the new medium. In the ray model of light, we describe the original ray as splitting into a reflected ray and a transmitted one (the one that gets through the boundary). Of course the reflected ray goes in a direction that is different from that of the original one, according to the rules of reflection we have already studied. More surprisingly — and this is the crucial point for making your eye focus light — the transmitted ray is bent somewhat as well. This bending phenomenon is called refraction. The origin of the word is the same as that of the word "fracture," i.e., the ray is bent or "broken." (Keep in mind, however, that light rays are not physical objects that can really be "broken.") Refraction occurs with all waves, not just light waves.

The actual anatomy of the eye, b), is quite complex, but in essence it is very much like every other optical device based on refraction. The rays are bent when they pass through the front surface of the eye, c). Rays that enter farther from the central axis are bent more, with the result that an image is formed on the retina. There is only one slightly novel aspect of the situation. In most human-built optical devices, such as a movie projector, the light is bent as it passes into a lens, bent again as it reemerges, and then reaches a focus beyond the lens. In the eye, however, the "screen" is inside the eye, so the rays are only refracted once, on entering the jelly, and never emerge again.

46. Look through the text and say what it is about. Give its brief contents.

What neither Snell nor Newton knew was that there is a very simple interpretation of the index of refraction. This may come as a relief to the reader who is taken aback by the complex reasoning involving proportionalities that led to its definition. Later experiments showed that the index of refraction of a medium was inversely proportional to the speed of light in that medium. Since c is defined as the speed of light in vacuum, and n = 1 is defined as the index of refraction of vacuum, we have

$$n = \ /$$

[n = medium's index of refraction, v = speed of light in that medium, c = speed of light in a vacuum]. Many textbooks start with this as the definition of the index of refraction, although that approach makes the quantity's name somewhat of a mystery, and leaves students wondering why c/v was used rather than v/c. It should also be noted that measuring angles of refraction is a far more practical method for determining n than direct measurement of the speed of light in the substance of interest.

47. Look through the text and say what it is about. Give its brief contents.

Laser Engraving and Marking: A Detailed Overview

Laser engraving and marking are advanced manufacturing techniques that use focused laser beams to etch, engrave, or mark materials with high precision. These processes are widely used in industrial, artistic, and commercial applications due to their accuracy, speed, and ability to work with a variety of materials. Unlike traditional mechanical engraving, laser-based methods are non-contact, reducing

wear and tear while enabling intricate designs that would be difficult or impossible to achieve with conventional tools.

How Laser Engraving and Marking Work

The process involves directing a high-intensity laser beam onto the material's surface, which interacts with it in different ways depending on the laser type and material properties. Common laser types used include:

- $CO_2$ Lasers (for organic materials like wood, acrylic, leather, and glass)
- Fiber Lasers (for metals, plastics, and some ceramics)
- Nd:YAG/Nd:$YVO_4$ Lasers (for high-precision metal marking)

The laser beam vaporizes or alters the surface layer, leaving a permanent mark. Engraving removes material to create depth, while marking (such as annealing or color change) modifies the surface without significant material removal.

Key Applications and Examples

1. Industrial Part Identification
   - Laser marking is extensively used in automotive, aerospace, and electronics industries to engrave serial numbers, barcodes, QR codes, and logos on metal and plastic components. This ensures traceability and counterfeit prevention.

2. Personalized Consumer Goods
   - Jewelry, watches, and luxury items often feature laser-engraved names, dates, or intricate patterns. Similarly, promotional products like pens, phone cases, and trophies are customized using laser technology.

3. Medical Device Marking
   - Surgical instruments, implants, and medical equipment require permanent, sterile markings for identification and compliance with regulations. Lasers provide high-contrast, durable engravings without damaging delicate tools.

4. Electronics and Micro-Marking
   - Circuit boards, semiconductor chips, and micro-components are marked with ultra-fine lasers to ensure readability without affecting functionality.

5. Art and Decorative Engraving
   - Artists and designers use lasers to create detailed engravings on wood, glass, and stone for signage, awards, and home décor. Laser-cut architectural models and intricate paper designs are also popular.

6. Security and Anti-Counterfeiting
   - High-security markings, such as microscopic text or tamper-proof serial numbers, are applied to currency, ID cards, and high-value products using specialized laser systems.

Laser engraving and marking continue to expand into new industries, driven by demand for customization, durability, and high-speed production. As technology evolves, these methods will likely become even more accessible and versatile, further revolutionizing manufacturing and design.

48. Look through the text and say what it is about. Give its brief contents.

Operating Principle of Solid-State Lasers

Solid-state lasers operate based on the fundamental principles of stimulated emission and optical amplification within a solid gain medium. Unlike gas or liquid lasers, which rely on fluid or gaseous active materials, solid-state lasers utilize a crystalline or glass host doped with optically active ions.

The process begins with energy input, known as pumping, which excites the dopant ions to higher energy states. When these ions return to lower energy levels, they emit photons coherently, producing a laser beam.

The core components of a solid-state laser include the gain medium, pump source, optical resonator, and cooling system. The gain medium is typically a synthetic crystal or glass, such as yttrium aluminum garnet (YAG), sapphire, or phosphate glass, doped with ions like neodymium ($Nd^{3+}$), ytterbium ($Yb^{3+}$), or erbium ($Er^{3+}$). These dopant ions have specific energy levels that determine the laser's emission wavelength.

The pumping mechanism supplies energy to the gain medium, usually through optical excitation from flashlamps or, more commonly today, laser diodes. When the dopant ions absorb pump light, they transition from the ground state to higher energy levels. Due to rapid non-radiative decay, these ions quickly relax into a metastable state—a relatively long-lived energy level where population inversion can occur. Population inversion, a necessary condition for lasing, means that more ions reside in the metastable state than in the lower energy level, allowing stimulated emission to dominate over absorption.

Once population inversion is achieved, spontaneous emission triggers a cascade of stimulated emission events. Photons emitted in the same direction as the optical axis of the resonator are reflected back and forth between two mirrors, forming the optical cavity. One mirror is fully reflective, while the other is partially transmissive, allowing a fraction of the amplified light to escape as the laser beam. The optical feedback within the cavity ensures that only specific wavelengths (determined by the cavity's length and the gain medium's properties) constructively interfere, resulting in a highly directional and monochromatic output.

The wavelength of the emitted laser light depends on the energy difference between the metastable and lower energy levels of the dopant ions. For example, Nd:YAG lasers emit at 1064 nm due to the $Nd^{3+}$ ion's transition, while Er:YAG lasers produce 2940 nm light, which is strongly absorbed by water and useful in medical applications. Some solid-state lasers employ nonlinear optical crystals for frequency conversion, enabling outputs in the ultraviolet (UV) or visible spectrum through processes like second-harmonic generation (doubling the frequency).

Thermal management is critical in solid-state lasers because the pumping process generates excess heat, which can distort the gain medium and degrade beam quality. Advanced cooling techniques, such as water or thermoelectric cooling, are often employed to maintain stable operation, especially in high-power systems.

In summary, the operating principle of solid-state lasers revolves around the interaction of light with doped solid materials, where controlled excitation and optical feedback produce coherent, high-intensity laser beams. Their versatility in wavelength, power, and pulse duration makes them indispensable in fields ranging from industrial manufacturing to scientific research and medical therapy.

49. Look through the text and say what it is about. Give its brief contents.

Types of Solid-State Lasers

Solid-state lasers encompass a diverse range of systems distinguished by their gain medium, pumping mechanism, and operational characteristics. These lasers are broadly categorized based on the host material, dopant ions, and specific lasing properties, each suited for different applications.

One of the most common types is the Neodymium-doped Yttrium Aluminum Garnet (Nd:YAG) laser, which operates at a wavelength of 1064 nanometers. This laser is highly versatile, used in industrial cutting and welding, medical surgeries, and military targeting systems. Its efficiency, robustness, and ability to produce high-power continuous or pulsed outputs make it a cornerstone of solid-state laser technology. Another variant, the Neodymium-doped Yttrium Orthovanadate

($Nd:YVO_4$) laser, offers higher absorption and gain coefficients, making it ideal for compact, diode-pumped systems in precision engraving and micromachining.

For applications requiring tunable or ultrafast pulses, the Titanium-doped Sapphire (Ti:Sapphire) laser is widely employed. With a broad emission spectrum ranging from 650 to 1100 nanometers, this laser is indispensable in scientific research, particularly in spectroscopy and ultrafast physics, where femtosecond pulses are necessary. Its ability to be mode-locked enables studies in nonlinear optics and attosecond science.

In the realm of high-energy pulsed lasers, Neodymium-doped Glass (Nd:Glass) lasers stand out. These systems are used in inertial confinement fusion experiments due to their ability to store and release large amounts of energy in short bursts. However, their lower thermal conductivity compared to crystalline hosts limits their use in continuous-wave applications.

Ytterbium-doped lasers, such as Yb:YAG and Yb-doped fiber lasers, have gained prominence in industrial and defense applications. Emitting around 1030 nanometers, these lasers are highly efficient, with lower quantum defects and reduced thermal load, making them suitable for high-power cutting and welding. Thin-disk and slab configurations of Yb:YAG lasers further enhance power scalability and beam quality.

Erbium-doped lasers, including Er:YAG and Er-doped fiber lasers, are critical in medical and telecommunications fields. The Er:YAG laser, emitting at 2940 nanometers, is strongly absorbed by water, making it ideal for dermatological and dental procedures. Meanwhile, Erbium-doped fiber amplifiers (EDFAs) are essential for signal boosting in long-distance optical fiber networks, operating in the 1550-nanometer range, which corresponds to the low-loss window of optical fibers.

For mid-infrared applications, Thulium-doped ($Tm^{3+}$) and Holmium-doped ($Ho^{3+}$) lasers are frequently used. Tm-doped lasers, emitting around 2000 nanometers, are employed in laser surgery and material processing, while Ho-doped lasers, with outputs near 2100 nanometers, are effective in military countermeasures and atmospheric sensing due to their eye-safe wavelengths and good transmission through the atmosphere.

Chromium-doped lasers, such as Cr:YAG and Cr:LiSAF, provide tunable outputs in the near-infrared spectrum. Cr:YAG is often used as a passive Q-switch in Nd:YAG lasers to generate high-energy pulses, whereas Cr:LiSAF offers broad tunability, useful in ultrafast laser systems and biomedical imaging.

Emerging technologies, such as ceramic lasers, are expanding the possibilities of solid-state lasers. Polycrystalline ceramic gain media, like YAG, offer advantages in scalability and thermal management, enabling higher power outputs and more compact designs. Additionally, waveguide and photonic crystal lasers represent cutting-edge developments, integrating solid-state gain media into miniature optical circuits for applications in quantum computing and integrated photonics.

Each type of solid-state laser offers unique advantages tailored to specific needs, from industrial material processing and medical therapies to scientific research and telecommunications. The continuous evolution of materials and pumping techniques ensures that solid-state lasers remain at the forefront of photonic technology, driving innovation across multiple disciplines.

50. Look through the text and say what it is about. Give its brief contents.

Key Applications of Solid-State Lasers

Solid-state lasers have become indispensable across a wide range of industries due to their reliability, precision, and ability to deliver high-power outputs in compact configurations. Their versatility stems from the diversity of available gain media, wavelengths, and operational modes, enabling tailored solutions for specialized needs.

## Industrial Manufacturing and Material Processing

In industrial settings, solid-state lasers dominate processes requiring precision and efficiency. High-power Nd:YAG and fiber lasers are extensively used for cutting, welding, and drilling metals in automotive and aerospace manufacturing. Their ability to focus intense energy into small spots allows for clean, burr-free cuts in sheet metal, turbine blades, and structural components. Laser marking and engraving systems, often based on pulsed Nd:$YVO_4$ or Yb-doped lasers, provide permanent identifiers like barcodes, serial numbers, and logos on metals, plastics, and ceramics. Additive manufacturing (3D printing) also benefits from selective laser melting (SLM) and sintering, where Yb-fiber lasers precisely fuse metal or polymer powders into complex geometries.

## Medical and Aesthetic Treatments

The medical field relies heavily on solid-state lasers for both therapeutic and surgical applications. Er:YAG lasers (2940 nm) are ideal for dermatology and dentistry, as their wavelength is strongly absorbed by water and hydroxyapatite, enabling precise ablation of skin lesions and tooth enamel with minimal thermal damage. Nd:YAG lasers (1064 nm) penetrate deeper into tissues, making them suitable for vascular treatments, tattoo removal, and laser-induced thermotherapy for tumors. In ophthalmology, femtosecond Ti:Sapphire and Yb-doped lasers have revolutionized refractive surgeries like LASIK, enabling ultra-precise corneal reshaping with minimal collateral damage.

## Defense and Aerospace Technologies

Military and aerospace applications demand robust, high-performance laser systems. Solid-state lasers serve as rangefinders and target designators in combat scenarios, where eye-safe Er-glass or Raman-shifted Nd:YAG lasers ensure accurate distance measurement and guidance for munitions. More recently, high-energy Yb-doped slab and fiber lasers have been deployed in directed-energy weapons (DEWs) for missile defense and drone neutralization. Their ability to deliver concentrated beams over long distances makes them valuable for countering asymmetric threats. In space, satellite-based laser communication terminals employ Nd:YAG or diode-pumped lasers for high-bandwidth, secure data transmission between spacecraft and ground stations.

## Scientific Research and Instrumentation

Scientific advancements often hinge on the unique capabilities of solid-state lasers. Ti:Sapphire lasers, with their ultrafast pulses and broad tunability, are fundamental in nonlinear optics, attosecond physics, and quantum coherence studies. Mode-locked Yb:KGW or Cr:LiSAF lasers enable time-resolved spectroscopy, allowing researchers to observe molecular dynamics at femtosecond timescales. In nuclear fusion research, Nd:Glass laser systems, such as those at the National Ignition Facility (NIF), generate megajoule-level pulses to compress fuel pellets in inertial confinement experiments. Additionally, narrow-linewidth Nd:YAG lasers are critical for atomic clocks, gravitational wave detection (e.g., LIGO), and cold-atom research in quantum optics.

## Telecommunications and Data Transmission

The backbone of modern optical communication networks relies on erbium-doped fiber amplifiers (EDFAs), which operate at 1550 nm—the wavelength of lowest loss in silica fibers. These amplifiers enable long-haul, high-speed data transmission across undersea cables and terrestrial networks. Raman lasers, another solid-state variant, extend reach in fiber-optic systems by mitigating signal degradation. Emerging free-space optical (FSO) links use diode-pumped Nd:YAG or Yb-doped lasers for high-capacity, low-latency connections between urban rooftops or remote locations where fiber deployment is impractical.

## Consumer Electronics and Microfabrication

The miniaturization of electronics demands precision machining at microscopic scales. UV DPSS lasers (e.g., frequency-tripled Nd:$YVO_4$ at 355 nm) drill microvias in printed circuit boards (PCBs) and trim resistors without thermal damage. In semiconductor manufacturing, ultrafast Yb-doped lasers perform stealth dicing of silicon wafers, enabling thinner, more efficient chips. Laser annealing systems, often using green Nd:YAG (532 nm), optimize thin-film transistor (TFT) properties in flat-panel displays. Even everyday devices like smartphones incorporate laser-cut

components and sensors produced by compact solid-state systems.

Environmental Sensing and Lidar

Atmospheric monitoring and remote sensing leverage the spectral purity of solid-state lasers. Ho:YAG and Tm-doped lasers (2 μm range) are employed in differential absorption lidar (DIAL) to measure greenhouse gases like $CO_2$ and water vapor. Autonomous vehicles rely on 905 nm or 1550 nm pulsed lasers in lidar systems for real-time 3D mapping, with the latter wavelength offering eye-safe operation at higher powers. Space-based lidar instruments, such as NASA's ICESat-2, use high-repetition-rate Nd:YAG lasers to monitor ice-sheet thickness and vegetation canopy structures with centimeter-level accuracy.

Conclusion

From transforming manufacturing floors to enabling groundbreaking scientific discoveries, solid-state lasers underpin technologies that define the modern era. Their adaptability across wavelengths—from ultraviolet to mid-infrared—and operational modes (continuous, pulsed, or ultrafast) ensures their continued dominance in both established and emerging fields. As materials science advances and novel architectures like ceramic lasers gain traction, these systems will further expand their reach into quantum technologies, photonic computing, and beyond, solidifying their role as a cornerstone of photonic innovation.

51. Look through the text and say what it is about. Give its brief contents.

Advantages of Solid-State Lasers Over Other Laser Types

Solid-state lasers hold a distinct edge over gas, liquid, and semiconductor lasers in numerous applications due to their unique structural and operational characteristics. Their superiority stems from inherent material properties, design flexibility, and performance metrics that make them indispensable in fields demanding precision, power, and reliability.

One of the most significant advantages lies in their exceptional beam quality and stability. Unlike gas lasers, which can suffer from plasma instabilities, or dye lasers, which require frequent replenishment of liquid gain media, solid-state lasers generate highly collimated, diffraction-limited beams with minimal divergence. This is particularly evident in Nd:YAG and Yb-doped lasers, where the crystalline host ensures uniform thermal and optical properties, enabling consistent performance in high-power industrial cutting or scientific measurements.

Energy efficiency further distinguishes solid-state systems, especially those employing diode pumping. Traditional $CO_2$ lasers, while powerful, convert only 10–20% of electrical input into laser output, whereas diode-pumped solid-state lasers (DPSSLs) like Yb:YAG or thin-disk lasers achieve efficiencies exceeding 30–50%. This reduces operational costs and thermal load, critical for applications like metal processing or aerospace propulsion systems where energy consumption directly impacts scalability.

The compact and robust design of solid-state lasers offers unparalleled practicality. Gas lasers, such as helium-neon or argon-ion types, require bulky enclosures to maintain gas purity and pressure, while dye lasers need complex fluid circulation systems. In contrast, solid-state gain media—whether crystalline (YAG, sapphire) or glass-based—are mechanically stable, vibration-resistant, and often modular. Fiber lasers, a subset of solid-state technology, exemplify this advantage with their flexible, lightweight architectures deployable in confined spaces like shipyards or medical operating rooms.

Wavelength versatility is another hallmark. While excimer lasers are restricted to specific ultraviolet lines or $CO_2$ lasers to the mid-infrared (10.6 μm), solid-state lasers cover a broad spectral range through host/dopant combinations and nonlinear frequency conversion. For instance, Ti:Sapphire lasers provide tunability across red to near-infrared (650–1100 nm), while optical parametric oscillators (OPOs) coupled to Nd:YAG systems extend outputs into the mid-IR. This adaptability is vital for multispectral applications like lidar, medical diagnostics, or quantum optics research.

Longevity and low maintenance requirements further elevate solid-state lasers above alternatives. Gas lasers degrade as electrodes erode or gas mixtures deplete, and dye lasers suffer from organic dye decomposition. Solid-state gain media, however, exhibit negligible degradation over years of operation. Semiconductor diode pumps, now lasting over 100,000 hours, complement this durability, making systems like fiber lasers ideal for harsh environments—undersea communication repeaters or desert-based military installations.

In pulse performance, solid-state lasers outclass competitors. Q-switched Nd:YAG lasers generate nanosecond pulses with peak powers exceeding gigawatts for precision micromachining, while mode-locked Ti:Sapphire systems produce femtosecond pulses essential for studying ultrafast chemical reactions. Comparable pulse regimes in gas or dye lasers often demand complex cavity designs or suffer from lower repetition rates.

Finally, solid-state lasers excel in thermal management. Although all lasers generate heat, crystalline hosts like YAG or ceramics dissipate it more effectively than gas discharge tubes or liquid dye cells. Advanced cooling techniques, such as conduction-cooled diode stacks or microchannel heat sinks, enable kilowatt-class continuous-wave operation—unthinkable for most helium-cadmium or nitrogen lasers.

These advantages collectively position solid-state lasers as the preferred choice for mission-critical tasks—from spacecraft propulsion and nuclear fusion to real-time medical imaging. As advancements in ceramic gain media and hybrid laser architectures emerge, their dominance will only broaden, leaving alternative laser technologies to niche roles where cost or wavelength constraints prevail. The future of photonics, undoubtedly, will be written in the language of solid-state innovation.

52. Look through the text and say what it is about. Give its brief contents.

Challenges and Limitations of Solid-State Lasers

Despite their numerous advantages, solid-state lasers are not without their constraints. These limitations arise from fundamental physical properties, material characteristics, and engineering challenges that impact their performance, scalability, and applicability in certain domains. Understanding these hurdles is crucial for optimizing existing systems and guiding future advancements in laser technology.

One of the most persistent challenges is thermal management. The very nature of solid-state lasers—where energy is deposited into a solid gain medium—inevitably leads to heat generation. Unlike gas lasers, where heat can be dissipated through convection, solid-state media rely on conduction cooling, which becomes increasingly problematic at higher power levels. Excessive heat causes thermal lensing, where temperature gradients alter the refractive index of the gain medium, distorting the laser beam and degrading its quality. It can also induce thermal stress fracture, particularly in brittle crystalline materials like YAG, leading to catastrophic failure under intense pumping. While advanced cooling techniques such as cryogenic cooling or active heat sinks mitigate these effects, they add complexity and cost to the system.

Another significant limitation is the restricted range of wavelengths available from common solid-state gain media. While nonlinear techniques like harmonic generation and optical parametric oscillation can extend the output spectrum, the fundamental emissions of popular dopants such as $Nd^{3+}$ (1064 nm) or $Yb^{3+}$ (1030 nm) are inherently fixed. This contrasts with dye lasers, which offer broad tunability, or gas lasers like argon-ion, which provide multiple discrete lines. For applications requiring specific wavelengths—such as certain medical procedures or atmospheric sensing—this can necessitate additional frequency conversion stages, reducing overall efficiency and increasing system complexity.

Material quality and availability also pose constraints. High-performance solid-state lasers demand exceptionally pure and defect-free crystalline hosts, which are expensive to produce. For instance, large Ti:Sapphire crystals—crucial for ultrafast lasers—require sophisticated growth techniques and are costly to manufacture. Similarly, specialized materials like sesquioxides (e.g., $Y_2O_3$) or vanadates (e.g., $YVO_4$), while offering superior thermal properties, are not as readily available as conventional YAG. This limits the scalability and affordability of certain high-end laser systems.

Power scaling presents another hurdle. While solid-state lasers can achieve impressive power levels, pushing beyond the kilowatt regime often leads to diminishing returns due to thermal and nonlinear effects. For example, in fiber lasers, stimulated Raman scattering (SRS) and transverse mode instabilities (TMI) become significant at multi-kilowatt outputs, degrading beam quality and limiting usable power. Bulk lasers face similar issues, where amplified spontaneous emission (ASE) and parasitic oscillations sap energy from the desired laser output. These phenomena necessitate intricate designs, such as coherent beam combining or distributed gain architectures, to circumvent power limitations.

The pump source efficiency and lifetime further impact solid-state laser viability. Although diode pumping has largely replaced flashlamps in modern systems, high-power laser diodes themselves are subject to degradation over time, particularly under harsh operating conditions. Diode failures can lead to inconsistent pumping, reducing laser reliability—a critical concern in industrial or medical applications where downtime is costly. Moreover, the spectral mismatch between diode emission and absorption bands of certain gain media (e.g., Nd:YAG) results in wasted energy, lowering overall system efficiency.

In ultrafast pulse generation, solid-state lasers face unique challenges. While Ti:Sapphire lasers dominate femtosecond science, their reliance on bulky pump lasers (typically frequency-doubled Nd:$YVO_4$) makes them less practical for field applications. Alternative gain media like Yb-doped materials, though more robust, often struggle to match the bandwidth needed for sub-100-fs pulses without complex dispersion compensation schemes. Additionally, pulse energy limitations in mode-locked oscillators necessitate amplification stages, introducing further complications like gain narrowing or nonlinear distortions.

Finally, cost and accessibility remain barriers for widespread adoption. High-performance solid-state lasers, especially those tailored for specialized applications like EUV lithography or attosecond science, involve expensive components—precision optics, high-brightness diodes, and exotic nonlinear crystals. This restricts their use to well-funded research institutions or industries where the return on investment justifies the expense. Even in more common applications like material processing, the initial capital outlay for a fiber laser system can be prohibitive for small-scale manufacturers.

Conclusion

While solid-state lasers are a cornerstone of modern photonics, their limitations underscore the need for continued innovation. Advances in materials science—such as the development of composite ceramics or novel dopant-host combinations—promise to alleviate thermal and wavelength constraints. Similarly, improvements in diode technology and cooling methodologies could enhance efficiency and power scalability. By addressing these challenges, the next generation of solid-state lasers will expand their dominance into new frontiers, from quantum computing to space-based energy transmission, ensuring their relevance in an increasingly photonics-driven world.

53. Look through the text and say what it is about. Give its brief contents.

Fiber Lasers: A Comprehensive Overview

Fiber lasers represent a specialized category of solid-state lasers where the gain medium consists of an optical fiber doped with rare-earth elements such as erbium, ytterbium, or thulium. These lasers have revolutionized numerous industries due to their exceptional beam quality, high efficiency, and robust design. The fundamental architecture of a fiber laser involves pumping the doped fiber with laser diodes, creating population inversion that leads to stimulated emission and light amplification within the fiber's core. This unique configuration offers several advantages over traditional bulk solid-state lasers, including superior heat dissipation, excellent mode quality, and remarkable reliability.

The operating principle of fiber lasers centers around the optical fiber's waveguiding properties. The doped fiber core, typically made of silica glass with rare-earth ions, serves as both the gain medium and the light delivery system. When pump light from high-power diodes is launched into the fiber, it excites the dopant ions, which then emit photons at specific wavelengths as they return to lower energy states. The fiber's design ensures that this emitted light remains confined within the core, allowing for efficient amplification over long distances. The laser cavity can be formed either by fiber Bragg gratings written directly into the fiber or by discrete mirrors, with the fiber itself acting as the delivery mechanism for the output beam.

One of the most significant advantages of fiber lasers is their outstanding beam quality, characterized by low divergence and high brightness. This results from the fiber's ability to maintain single-mode operation even at high power levels, a feat difficult to achieve with conventional laser designs. The waveguiding nature of the fiber ensures excellent spatial mode control, producing Gaussian beams with $M^2$ values approaching 1.0. This superior beam quality translates to smaller focused spot sizes and higher power densities, making fiber lasers ideal for precision applications like micromachining and fine cutting.

Thermal management in fiber lasers represents another key advantage. The high surface-area-to-volume ratio of the thin fiber allows for efficient heat dissipation, enabling operation at power levels that would be challenging for bulk lasers. This efficient cooling occurs naturally along the length of the fiber, eliminating the need for complex external cooling systems in many cases. As a result, fiber lasers can maintain stable operation over extended periods without significant performance degradation, a critical factor in industrial environments where continuous operation is required.

The efficiency of fiber lasers stands out among laser technologies. With electrical-to-optical conversion efficiencies often exceeding 30%, and in some configurations reaching 50%, fiber lasers significantly outperform many conventional laser systems. This high efficiency stems from several factors: the excellent overlap between pump and signal modes in the fiber, low quantum defect in certain dopant systems (particularly ytterbium), and minimal parasitic losses. Such efficiency not only reduces operating costs but also enables more compact and portable systems, as less energy is wasted as heat.

Fiber lasers offer remarkable versatility in terms of output characteristics. They can be designed to operate in continuous wave (CW) mode for applications like welding and heat treating, or pulsed mode for marking and micromachining. Pulse durations can range from milliseconds to femtoseconds, with advanced systems employing techniques like Q-switching and mode-locking to generate high-peak-power pulses. The wavelength flexibility is equally impressive, with common outputs including 1 micron (ytterbium), 1.5 micron (erbium), and 2 micron (thulium) regions, each suited to specific material interactions and applications.

In industrial settings, fiber lasers have become the technology of choice for material processing. Their ability to deliver high-power beams with exceptional focusability makes them ideal for cutting and welding metals, with penetration depths and cutting speeds that often surpass those of $CO_2$ lasers. The reliability and low maintenance requirements of fiber lasers have made them particularly attractive for manufacturing environments, where downtime translates directly to lost productivity. Additionally, the flexibility of fiber delivery allows for easy integration into robotic systems and multi-axis workstations, enabling complex three-dimensional processing tasks.

The telecommunications industry has greatly benefited from fiber laser technology, particularly through erbium-doped fiber amplifiers (EDFAs). These devices, operating in the 1550 nm window where optical fibers exhibit minimum loss, form the backbone of long-haul optical communication systems. EDFAs provide lossless signal amplification over thousands of kilometers, enabling the global internet infrastructure we rely on today. More recently, Raman fiber lasers have emerged as important tools for extending the usable bandwidth of optical fibers and compensating for nonlinear effects in dense wavelength-division multiplexing (DWDM) systems.

Medical applications of fiber lasers continue to expand, leveraging their precision and wavelength-specific tissue interactions. Thulium fiber lasers operating around 2 microns are particularly effective in urology and lithotripsy, where their strong water absorption enables precise tissue ablation with minimal collateral damage. In dermatology, pulsed erbium-doped fiber lasers provide controlled skin resurfacing with rapid healing times. The compact nature of fiber laser systems allows for integration into endoscopic devices, bringing laser capabilities to minimally invasive surgical procedures.

Despite these advantages, fiber lasers do face certain limitations. Nonlinear effects such as stimulated Raman scattering and Brillouin scattering can become significant at high power levels, potentially limiting maximum achievable power or requiring specialized fiber designs to mitigate. The relatively small mode area in conventional fibers can also lead to optical damage thresholds that constrain peak power handling. However, ongoing developments in large-mode-area fibers and photonic crystal fibers are addressing these challenges, pushing the boundaries of fiber laser performance.

The military and defense sectors have adopted fiber lasers for various applications, from rangefinding and target designation to directed energy weapons. The inherent ruggedness of fiber laser systems, combined with their efficiency and beam quality, makes them suitable for field deployment. High-energy laser weapon systems based on fiber architectures demonstrate the potential for lightweight, scalable solutions to counter airborne threats, with recent tests showing successful interception of drones and missiles.

Scientific research benefits greatly from fiber laser technology, particularly in fields requiring stable, narrow-linewidth sources or ultrafast pulses. Frequency combs based on mode-locked fiber lasers provide crucial tools for precision metrology and optical clocks. In nonlinear optics research, fiber lasers serve as pump sources for supercontinuum generation, producing ultra-broadband light for spectroscopy and imaging applications. The development of hollow-core fibers has further expanded possibilities by reducing nonlinearities and enabling new spectral regions for fiber-based systems.

Looking to the future, fiber laser technology continues to evolve through several promising directions. Multicore fibers and coherent beam combining techniques aim to overcome power scaling limitations while maintaining beam quality. Advances in specialty fibers, including those with engineered dispersion profiles or novel dopant distributions, promise to unlock new operational regimes. Integration with silicon photonics may lead to chip-scale fiber laser systems with unprecedented compactness and functionality. As these innovations progress, fiber lasers will likely penetrate new markets and applications, solidifying their position as one of the most versatile and important laser technologies available today.

54. Look through the text and say what it is about. Give its brief contents.

Diode Lasers: Fundamental Principles and Applications

Diode lasers, also known as semiconductor lasers, represent one of the most ubiquitous and versatile laser technologies in modern photonics. These compact, efficient light sources operate on the principle of stimulated emission in semiconductor materials, typically fabricated from compound semiconductors like gallium arsenide (GaAs) or indium phosphide (InP). Unlike gas or solid-state lasers that rely on discrete energy transitions in atomic or ionic systems, diode lasers generate light through the recombination of electrons and holes at the p-n junction of a semiconductor diode. When forward-biased with electrical current, the junction creates population inversion in the active region, leading to coherent light emission through stimulated recombination. This fundamental mechanism gives diode lasers their characteristic advantages of small size, high efficiency, and direct electrical pumping.

The architecture of diode lasers reflects their semiconductor origins. The heart of the device consists of multiple quantum wells or a bulk active layer sandwiched between p-type and n-type cladding layers, forming a double heterostructure that confines both charge carriers and photons. This structure is typically grown using precision epitaxial techniques like molecular beam epitaxy (MBE) or metal-organic chemical vapor deposition (MOCVD). The laser cavity itself is formed by cleaving the semiconductor crystal to create mirrored facets, with one facet highly reflective and the other partially transmissive to allow laser emission. More sophisticated designs incorporate distributed feedback (DFB) or distributed Bragg reflector (DBR) structures for wavelength stabilization and single-mode operation. The entire device often measures just a few hundred microns in length, enabling unprecedented miniaturization compared to other laser types.

Wavelength diversity stands as one of the most significant features of diode lasers, made possible by engineering the semiconductor bandgap through material composition. Standard gallium arsenide-based devices emit in the near-infrared (780-980 nm), while aluminum gallium arsenide (AlGaAs) lasers cover the visible red spectrum (630-690 nm). Indium gallium nitride (InGaN) materials enable blue and violet emissions (405-480 nm), crucial for applications like Blu-ray technology. Longer wavelengths in the 1300-1600 nm range, important for telecommunications, are achieved using indium gallium arsenide phosphide (InGaAsP) on InP substrates. This tunability through material design allows diode lasers to address applications across the entire visible and near-infrared spectrum.

The efficiency of diode lasers surpasses most other laser technologies, with wall-plug efficiencies frequently exceeding 50% for high-performance devices. This remarkable efficiency stems from the direct conversion of electrical energy into light without intermediate steps, combined with minimal thermal losses due to the small active volume. Such efficiency enables battery-powered operation in portable devices and reduces cooling requirements in high-power systems. The electrical pumping scheme also permits direct modulation at extremely high frequencies, with some diode lasers capable of gigahertz-rate modulation - a capability essential for fiber optic communication systems.

In telecommunications, diode lasers form the backbone of global data networks. Single-frequency distributed feedback (DFB) lasers provide the stable, narrow-linewidth sources needed for dense

wavelength division multiplexing (DWDM) systems, packing hundreds of channels into a single optical fiber. Vertical-cavity surface-emitting lasers (VCSELs), with their low threshold currents and circular beam profiles, dominate short-reach optical interconnects in data centers. The development of directly modulated lasers (DMLs) and electro-absorption modulated lasers (EMLs) has enabled increasingly higher data rates, with 100 Gbps and beyond now routine in modern optical networks.

Industrial applications leverage the high power and reliability of diode lasers for material processing. Multi-emitter diode bars and stacks can deliver kilowatts of optical power for applications like metal heat treating, plastic welding, and additive manufacturing. Fiber-coupled diode systems provide flexible tools for precision soldering and brazing operations. The direct diode approach eliminates the need for intermediate pumping stages required in diode-pumped solid-state lasers, simplifying system design and improving overall efficiency. Recent advances in beam combining techniques have further increased the brightness of high-power diode systems, expanding their utility in cutting and drilling applications.

The consumer electronics market heavily depends on diode laser technology. Blu-ray players and optical data storage devices utilize blue-violet diode lasers to achieve higher data densities. Laser printers employ near-infrared diodes for high-speed marking, while emerging applications like lidar sensors in smartphones and autonomous vehicles rely on pulsed diode lasers for 3D sensing and ranging. Even everyday devices like barcode scanners and laser pointers incorporate miniature diode laser chips, demonstrating the technology's pervasive presence.

Medical applications benefit from diode lasers' precision and wavelength specificity. Dermatology utilizes various wavelengths for hair removal (808 nm), vascular treatments (532 nm KTP frequency-doubled diodes), and tattoo removal. Dental procedures employ diode lasers for soft tissue surgery and caries detection. Ophthalmology applications include retinal photocoagulation and refractive surgery. The compact size of diode systems enables integration into endoscopic devices for minimally invasive procedures, while their reliability ensures consistent performance in clinical settings.

Scientific research employs diode lasers in diverse roles, from pumping other laser systems to serving as tools for spectroscopy and atom trapping. External cavity diode lasers (ECDLs) provide tunable, narrow-linewidth sources for atomic physics experiments, including laser cooling and Bose-Einstein condensation. Tapered amplifiers boost diode laser outputs while maintaining good beam quality for applications requiring higher power. Quantum cascade lasers, a specialized type of semiconductor laser, cover the mid-infrared to terahertz range for molecular spectroscopy and gas sensing.

Military and defense applications exploit diode lasers' ruggedness and efficiency. Target designators and rangefinders incorporate pulsed diode lasers for precision targeting. Infrared illuminators based on diode arrays enhance night vision systems. More recently, diode-pumped solid-state laser weapons have emerged, where high-power diode stacks serve as the primary pump source for ytterbium-based laser gain media. The reliability of diode lasers under harsh environmental conditions makes them ideal for field-deployed systems.

Despite their advantages, diode lasers face certain limitations. Beam quality typically suffers compared to gas or solid-state lasers, with asymmetric beam profiles and higher divergence due to the small emitting aperture. Spectral width, while narrow enough for many applications, may require additional stabilization for precision scientific uses. Lifetime and reliability, though excellent for most commercial devices, can be challenged in extreme temperature or high-power operation. Thermal management remains critical, as junction temperature directly affects output wavelength, efficiency, and device longevity.

Ongoing research continues to push diode laser capabilities. Quantum dot lasers promise improved temperature stability and lower threshold currents. Silicon photonics integration may lead to chip-scale diode laser systems with advanced functionality. GaN-based green and yellow diode lasers are filling the "green gap" for display and biomedical applications. High-power single-mode diodes are achieving unprecedented brightness levels through novel waveguide designs. As these developments progress, diode lasers will continue to expand their dominance across an ever-widening range of photonic applications, maintaining their position as one of the most transformative optical technologies of the modern era.

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Excimer Lasers: Principles and Applications

Excimer lasers represent a unique class of ultraviolet (UV) lasers that have revolutionized several high-precision industries, from semiconductor manufacturing to ophthalmology. The term "excimer" originates from "excited dimer," referring to the transient molecules formed by noble gas halides that serve as the laser's active medium. These lasers produce high-energy pulses of ultraviolet light with wavelengths typically ranging from 157 to 351 nanometers, making them indispensable for applications requiring precise material removal at microscopic scales.

The operating principle of excimer lasers relies on the formation of short-lived excited molecules (exciplexes) when a noble gas such as argon, krypton, or xenon combines with a halogen like fluorine or chlorine under electrical excitation. These excited dimers exist only in energized states and quickly dissociate after emitting UV photons, creating a population inversion necessary for laser action. The most common excimer combinations include ArF (193 nm), KrF (248 nm), XeCl (308 nm), and $F_2$ (157 nm), each producing a specific wavelength suited to different applications. The laser's pulsed operation, with pulse durations in the nanosecond range, allows for precise energy delivery while minimizing heat transfer to surrounding materials.

In semiconductor manufacturing, excimer lasers have become the workhorse of photolithography systems, particularly in deep ultraviolet (DUV) lithography for producing integrated circuits. The 193 nm wavelength from ArF lasers enables the printing of features smaller than 10 nanometers through advanced techniques like immersion lithography and multiple patterning. As the semiconductor industry pushes toward smaller nodes, excimer lasers continue to evolve with improved pulse stability, higher repetition rates (now exceeding 6 kHz), and enhanced bandwidth control to meet the exacting requirements of modern chip fabrication.

Medical applications have benefited tremendously from excimer laser technology, particularly in ophthalmology. The pioneering LASIK procedure for vision correction relies on 193 nm ArF excimer lasers to precisely reshape the cornea with sub-micron accuracy through a process called photoablation. Unlike thermal lasers, the excimer's cold ablation mechanism removes tissue molecule by molecule without heating adjacent areas, enabling extremely clean cuts with minimal collateral damage. This same principle applies to therapeutic procedures for removing arterial plaque (atherectomy) and treating various dermatological conditions like psoriasis and vitiligo.

Industrial material processing utilizes excimer lasers for micromachining applications requiring exceptional precision. The short UV wavelength allows for extremely small focal spots, while the high photon energy directly breaks molecular bonds in the target material. This makes excimer lasers ideal for drilling micron-sized holes in polymer films for medical devices, creating nozzle arrays for inkjet printers, and patterning transparent conductive oxides for display manufacturing. The ability to process materials with virtually no thermal effect has opened new possibilities in flexible electronics and biomedical device fabrication.

Excimer lasers also play critical roles in scientific research and specialized manufacturing. They serve as pump sources for tunable dye lasers in spectroscopy studies and enable the production of fiber Bragg gratings for telecommunications. In the display industry, excimer laser annealing (ELA) has become the standard process for crystallizing amorphous silicon into polycrystalline form, essential for manufacturing high-performance thin-film transistors in flat-panel displays. The 308 nm XeCl lasers find application in laser-induced breakdown spectroscopy (LIBS) for material analysis and in cleaning delicate artifacts during art restoration.

Despite their widespread use, excimer lasers present several technical challenges. The corrosive nature of halogen gases requires careful handling and specialized gas delivery systems to maintain laser performance. The high voltage discharges needed for excitation (typically 20-40 kV) demand robust electrical components and generate electromagnetic interference that must be mitigated. Gas degradation over time leads to gradual output power reduction, necessitating periodic gas replenishment or regeneration. Thermal management becomes critical at high repetition rates, as excess heat can distort optical components and reduce beam quality.

Recent advancements have addressed many of these limitations through innovative engineering solutions. Long-life electrode designs and halogen injection systems extend maintenance intervals, while solid-state pulsed power supplies improve electrical efficiency. Hybrid laser designs combining excimer technology with solid-state amplifiers offer improved beam quality and stability. The development of narrow-bandwidth excimer lasers with line-narrowing optics meets the

increasingly stringent requirements of advanced lithography nodes.
Looking ahead, excimer laser technology continues to evolve for next-generation applications. The emergence of high-power, high-repetition-rate systems enables new industrial processes like large-area surface treatment and roll-to-roll manufacturing. Research into shorter wavelength systems, including molecular fluorine lasers at 157 nm, explores potential applications in advanced materials processing. As biomedical engineering advances, new therapeutic uses for excimer lasers are being investigated in areas like targeted drug delivery and cellular manipulation.
From enabling the smartphones in our pockets to restoring vision for millions, excimer lasers have established themselves as transformative tools across multiple disciplines. Their unique combination of short wavelength, high photon energy, and precise ablation characteristics ensures their continued relevance in an increasingly miniaturized and precision-driven technological landscape. As material science and optical engineering progress, excimer lasers will likely find new applications at the frontiers of nanotechnology, photonics, and medical therapy, maintaining their vital role in science and industry.

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Laser Additive Manufacturing: Revolutionizing Production Through Layered Fabrication

Laser Additive Manufacturing (LAM) represents a transformative approach to industrial production, enabling the creation of complex, high-performance components through the precise deposition of material layer by layer. Unlike traditional subtractive manufacturing methods that remove material to achieve the desired shape, LAM builds parts directly from digital models using laser energy to fuse powders or wire feedstock into solid structures. This technology has unlocked new possibilities in aerospace, medical, automotive, and energy sectors by offering unparalleled design freedom, reduced material waste, and the ability to produce components with optimized geometries that would be impossible to manufacture conventionally.

Fundamentals of Laser Additive Manufacturing

At the core of LAM processes lies the controlled application of laser energy to selectively melt or sinter metallic, polymeric, or ceramic materials. The most widely adopted techniques include Laser Powder Bed Fusion (LPBF), where a laser scans and fuses thin layers of powder in a bed, and Directed Energy Deposition (DED), which feeds powder or wire into a laser-generated melt pool on a substrate. Both methods rely on high-power fiber or $CO_2$ lasers (typically 200–1000 W for LPBF, up to 10 kW for DED) to achieve precise energy input, ensuring proper metallurgical bonding and minimal porosity. The process is guided by computer-aided design (CAD) data, sliced into layers that dictate the laser's path, enabling the fabrication of intricate internal channels, lattice structures, and topology-optimized parts.

Key Applications and Industry Examples

Aerospace and Defense

The aerospace sector has embraced LAM for producing lightweight, high-strength components that reduce fuel consumption and enhance performance. GE Aviation's LEAP engine fuel nozzles, manufactured via LPBF, consolidate 20 traditionally assembled parts into a single 3D-printed unit, improving durability while cutting weight by 25%. Similarly, Airbus utilizes LAM to produce titanium brackets for the A350 XWB aircraft, achieving a 30% weight reduction without compromising structural integrity. In defense, laser additive manufacturing enables rapid prototyping and on-demand production of mission-critical parts, such as turbine blades and heat exchangers, even in remote locations.

Medical Implants and Biomanufacturing

LAM has revolutionized personalized healthcare by enabling patient-specific implants with porous surfaces that promote bone ingrowth. Companies like Stryker and Zimmer Biomet employ LPBF to create titanium spinal cages and acetabular cups tailored to individual anatomies. The technology also facilitates the production of bioresorbable magnesium scaffolds for bone repair, which gradually dissolve as new tissue forms. Beyond metals, laser sintering of polymers is used to fabricate surgical guides and dental prostheses with sub-millimeter accuracy, streamlining workflows in orthodontics and maxillofacial surgery.

Automotive and High-Performance Engineering

In automotive, LAM accelerates the development of high-efficiency components, from lightweight aluminum alloy wheels to customized piston heads for motorsports. Bugatti's 3D-printed titanium brake calipers, produced via LPBF, withstand extreme thermal and mechanical loads while weighing less than traditional designs. Formula 1 teams leverage DED to repair and modify high-value titanium components, reducing lead times and costs. The technology also supports electric vehicle innovation, such as optimized battery cooling plates with internal lattice structures that enhance thermal management.

Energy and Tooling

The energy sector benefits from LAM's ability to manufacture corrosion-resistant, high-temperature parts for turbines and oil/gas equipment. Siemens Energy has adopted the technology to produce gas turbine burner heads with intricate cooling channels, improving combustion efficiency. In tooling, conformally cooled injection molds with internal cooling channels follow the mold's contour, reducing cycle times by 30% compared to conventional drilled channels.

Advantages Over Conventional Methods

LAM offers unmatched design flexibility, enabling the consolidation of multi-part assemblies into single components, reducing joints and potential failure points. The technology minimizes material waste—critical for expensive alloys like Inconel or titanium—by using only the necessary feedstock, contrasting with subtractive machining that may remove up to 90% of the raw material. Additionally, LAM supports rapid prototyping and customization, allowing iterative design improvements without retooling costs.

Challenges and Future Directions

Despite its promise, LAM faces hurdles such as high equipment costs, limited build volumes for powder-bed systems, and the need for post-processing (e.g., heat treatment, machining) to achieve final tolerances. Residual stresses and anisotropic material properties also require careful process optimization. However, advancements like multi-laser systems (e.g., SLM Solutions' 12-laser machines) are increasing productivity, while hybrid manufacturing combines LAM with CNC machining for finished parts in a single setup. Emerging trends include AI-driven process monitoring to detect defects in real-time and the development of new alloy powders tailored for additive manufacturing.

Laser Additive Manufacturing is reshaping modern industry by bridging the gap between design innovation and functional part production. From life-saving medical implants to fuel-efficient aerospace components, its applications demonstrate how laser precision and additive principles can solve engineering challenges once deemed insurmountable. As the technology matures, its integration with digital twins, automation, and sustainable materials will further solidify LAM as a cornerstone of Industry 4.0, unlocking unprecedented opportunities across global manufacturing landscapes.

57. Look through the text and say what it is about. Give its brief contents.

Laser Engraving & Marking: Precision and Versatility in Modern Manufacturing

Laser engraving and marking have revolutionized the way industries personalize, identify, and decorate a wide range of materials. Utilizing focused laser beams, these techniques offer high precision, speed, and versatility, making them indispensable tools across sectors such as manufacturing, jewelry, electronics, automotive, and aerospace.

What Is Laser Engraving & Marking?

Laser engraving involves removing material from a surface to create a permanent design or pattern. It typically results in a shallow, etched appearance, ideal for detailed artwork, serial numbers, or logos. Conversely, laser marking usually refers to surface treatments that modify the material's appearance or properties without removing material—such as color change, annealing, or surface oxidation—producing clear, durable marks.

Advantages of Laser Technologies

One of the primary benefits of laser engraving and marking is their precision. Laser systems can produce intricate designs with micron-level accuracy, ensuring consistent quality. Additionally, these processes are contactless, reducing the risk of material damage or contamination. They also enable rapid processing speeds, increasing productivity, and can be easily automated for mass production.

Another key advantage is permanence. Laser marks are resistant to wear, corrosion, and fading,

making them ideal for identification and branding purposes that require longevity. Moreover, laser systems are highly flexible—they can be adjusted to work on a variety of materials, including metals, plastics, wood, glass, leather, and ceramics.

Applications Across Industries

- Manufacturing & Industry: Serial numbers, barcodes, QR codes, and part identification marks are routinely applied to components to ensure traceability and quality control.
- Jewelry & Accessories: Intricate designs, initials, and custom engravings add a personalized touch to jewelry pieces.
- Electronics: Marking circuit boards, chips, and electronic devices with logos and identifiers without damaging sensitive components.
- Automotive & Aerospace: Engraving safety labels, part numbers, and certification marks that withstand harsh environments.
- Promotional & Gift Items: Custom logos and messages on corporate gifts, awards, and souvenirs.

Choosing the Right Laser System

Selecting the appropriate laser engraving or marking system depends on several factors, including material type, desired resolution, production volume, and budget. Fiber lasers, CO2 lasers, and UV lasers are among the most common, each suited to specific applications. For example, fiber lasers excel at marking metals, while CO2 lasers are preferred for organic materials like wood and plastics.

Environmental and Cost Benefits

Laser engraving and marking are environmentally friendly processes, often eliminating the need for inks, chemicals, or abrasive materials. This reduces waste and minimizes environmental impact. Additionally, the high speed and automation capabilities lead to cost savings over traditional marking methods.

Laser engraving and marking stand at the forefront of modern manufacturing, offering unparalleled precision, durability, and flexibility. As technology advances, these processes will continue to unlock new possibilities for customization, quality assurance, and branding across diverse industries—making them essential tools in the pursuit of innovation and excellence.

58. Look through the text and say what it is about. Give its brief contents.

Laser Targeting and Designation: An Overview

Introduction

Laser targeting and designation are critical components of modern military operations, enabling precise identification, tracking, and engagement of targets. These techniques utilize laser beams to assist in guiding weapons and improving targeting accuracy, especially in complex or contested environments.

1. Basic Principles of Laser Targeting and Designation

- Laser Energy and Wavelength:

Laser systems emit highly collimated beams of light at specific wavelengths, typically in the visible (around 650 nm), near-infrared (around 800-900 nm), or mid-infrared (around 1.5-3 micrometers) regions. The choice of wavelength depends on the application, atmospheric conditions, and detection considerations.

- Laser Spot Marking:

A laser designator projects a visible or infrared (IR) laser beam onto a target, marking it for guided munitions. The laser spot serves as a beacon for laser-guided bombs, missiles, or artillery shells equipped with laser seekers.

- Laser Spot Tracking:

Laser sensors on aircraft, vehicles, or handheld devices track the laser spot to maintain the designation and guide munitions accurately to the target.

2. Types of Laser Designators and Targeting Devices

- Handheld Laser Designators:

Portable units operated by infantry or forward observers to mark targets at close or extended ranges. They typically emit IR or visible laser pulses and can be manually aimed.

- Vehicle-Mounted or Aircraft-Mounted Laser Designators:

Integrated into vehicles or aircraft for rapid and precise target marking over larger areas or from

higher altitudes.
- Targeting Pods:
  Advanced sensors mounted on aircraft (e.g., LITENING, Sniper) that combine laser designation capabilities with electro-optical and infrared imaging for target acquisition and tracking.
3. Operational Modes
- Point or Spot Targeting:
  Marking a specific point or small object, such as a vehicle or building.
- Area or Pattern Targeting:
  Designating an area or creating a pattern (e.g., a grid) for saturation or suppression operations.
- Continuous vs. Pulsed Laser:
  Continuous lasers provide ongoing illumination, while pulsed lasers emit short bursts, often for identification or to reduce power consumption.
4. Laser-Guided Munitions (LGMs)
- Laser Homing:
  Munitions equipped with laser seekers detect reflected laser energy from the target to home in on the designated spot.
- Types of LGMs:
  - *Semi-Active Laser-Guided Bombs (SAL):* Require external laser illumination.
  - *Fire-and-Forget Missiles:* Use laser guidance for terminal homing, allowing the platform to evade after launch.
5. Advantages of Laser Targeting and Designation
- High Precision:
  Enables accurate strikes with minimal collateral damage.
- Flexibility:
  Can be used in various environments and target types.
- Real-Time Engagement:
  Forward observers or aircraft can update designations dynamically.

6. Challenges and Limitations
- Atmospheric Interference:
  Fog, rain, smoke, or dust can attenuate laser beams, reducing effectiveness.
- Countermeasures:
  Targets may employ laser warning receivers or smoke screens to evade laser designation.
- Line-of-Sight Requirement:
  Laser designation requires a clear path between the designator and the target.
7. Modern Developments and Future Trends
- Integration with UAVs:
  Unmanned Aerial Vehicles can serve as persistent laser designators over extended periods.
- Multi-Spectral Designation:
  Using multiple laser wavelengths to overcome countermeasures and enhance target discrimination.
- Autonomous Targeting:
  Combining laser designation with advanced targeting algorithms and AI for rapid engagement.
Laser targeting and designation are vital for modern precision-guided weapon systems, enhancing operational effectiveness and reducing collateral damage. As technology advances, these systems are becoming more sophisticated, integrated, and adaptable to complex battlefield environments.

59. Look through the text and say what it is about. Give its brief contents.

Laser rangefinders play a crucial role in geodesy, providing precise distance measurements essential for various applications such as surveying, mapping, and construction. These devices have transformed how geodetic professionals gather data, enhancing both the accuracy and efficiency of their work.
The fundamental working principle of a laser rangefinder is based on the time-of-flight method. The device emits a laser pulse that travels to the target and reflects back to the receiver. By measuring the time it takes for the pulse to return, the rangefinder calculates the distance to the object using the

formula
= · 2, where is the distance, is the speed of light, and is the total time of travel. This method enables accurate measurements up to several kilometers with precision often within a few millimeters.
Modern laser rangefinders offer real-time data processing capabilities, greatly simplifying the tasks of surveyors and geographers. Many of these devices integrate GPS and other positioning systems, allowing for efficient mapping and the management of large projects. This technological integration enhances the utility of laser rangefinders in developing detailed geographic information systems (GIS).
Another significant advantage is the speed of measurement. Laser rangefinders can acquire multiple readings per second, drastically reducing the time required for data collection. This high rate of measurement is particularly beneficial in dynamic environments, such as construction sites, where quick and accurate data are critical.
Furthermore, laser rangefinders support advanced applications like 3D modeling and terrain scanning. These capabilities open new possibilities for architects and engineers, enabling them to create precise models and conduct thorough analyses of landscapes. The use of laser scanning in geodesy has also augmented the ability to document and restore historical sites, providing detailed models for preservation efforts.
However, despite their advantages, laser rangefinders have limitations. One primary concern is their sensitivity to atmospheric conditions. Factors like rain, fog, and dust can significantly affect measurement accuracy. In challenging environments, additional terrestrial stations or complementary measurement techniques may be necessary to ensure the reliability of the data collected.
Additionally, the cost of advanced laser ranging technology can be a barrier for small projects or individual professionals. While prices have been decreasing due to advances in technology and manufacturing processes, high-quality laser rangefinders may still represent a significant investment for some users.
In conclusion, laser rangefinders are an indispensable tool in modern geodesy. Their exceptional accuracy, rapid measurement capabilities, and integration with other technologies make them vital for contemporary geospatial surveys. As technology evolves and becomes even more accessible, it is expected that laser rangefinders will continue to strengthen their position in the geodetic landscape, driving innovation and improving the quality of geospatial data collection and analysis.

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Lasers play a pivotal role in Earth remote sensing, offering innovative methods for observing and analyzing our planet's surface and atmosphere. This technology has revolutionized various fields, including environmental monitoring, disaster management, agriculture, and forestry, providing high-resolution data for better decision-making.

The primary laser technology used in remote sensing is LiDAR (Light Detection and Ranging). LiDAR systems emit rapid laser pulses towards the Earth and measure the time it takes for the pulses to reflect back to the sensor. This time-of-flight principle enables the calculation of distances with remarkable precision, generating detailed three-dimensional models of the terrain. LiDAR can measure heights, canopy structures, and ground elevations, making it invaluable in topographic mapping and forestry applications.

One of the most significant advantages of laser remote sensing is its ability to penetrate vegetation. Traditional optical sensors often struggle to acquire accurate ground data in densely vegetated areas. In contrast, LiDAR can capture the height of tree canopies and the underlying ground surface, facilitating improved analyses of forest structures and biomass estimation. This application is crucial for understanding carbon storage, biodiversity, and ecosystem health.

Moreover, lasers in remote sensing are effective for monitoring atmospheric gases and pollutants. Techniques such as Differential Absorption Lidar (DIAL) utilize specific wavelengths of laser light to detect trace gases like ozone and carbon dioxide. By measuring the absorption of laser light at

these wavelengths, scientists can gather crucial information about air quality and climate change dynamics, contributing to more informed policy decisions for environmental protection.

Another promising application of laser remote sensing is in disaster management. By using laser technology to quickly assess areas affected by natural disasters such as floods, earthquakes, or wildfires, emergency response teams can swiftly identify damage and allocate resources effectively. This rapid assessment capability can significantly improve response times and enhance recovery efforts, ultimately saving lives and reducing economic losses.

Additionally, laser remote sensing contributes to precision agriculture by providing farmers with detailed information about field conditions, crop health, and soil properties. By integrating LiDAR data with other remote sensing technologies, farmers can optimize irrigation, monitor crop growth, and manage resources more effectively. This approach promotes sustainable farming practices and increases agricultural productivity.

Despite these advantages, challenges remain in the widespread adoption of laser remote sensing technologies. The cost of LiDAR systems and operational complexities can limit their use, especially in developing regions. Furthermore, data processing and analysis require specialized skills and software, which can be a barrier for smaller organizations or less-equipped research teams.

In conclusion, lasers in Earth remote sensing represent a transformative force in our ability to monitor and understand the planet. Their precision and versatility facilitate a wide range of applications, from environmental monitoring to agriculture. As technology continues to advance and costs are reduced, the potential for laser remote sensing will grow, offering invaluable insights into Earth's systems and aiding in the efforts to address global challenges such as climate change, deforestation, and resource management.