Central Laser Facility
Science and Technology Facilities Council
Rutherford Appleton Laboratory
Harwell Science and Innovation Campus
Didcot
Oxfordshire
OX11 0QX, UK

T: +44 (0)1235 445603
F: +44 (0)1235 445888
E: clfenquiries@stfc.ac.uk
W: www.clf.stfc.ac.uk

www.stfc.ac.uk

EPSRC
The Engineering and Physical Sciences Research Council
Polaris House
North Star Avenue
Swindon
SN2 1ET, UK

T: +44 (0)1793 444000
W: www.epsrc.ac.uk

www.epsrc.ac.uk

EPSRC
Engineering and Physical Sciences
Research Council

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Lasers in our lives **50 years of impact**

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Lasers in our lives 50 years of impact

The information in this brochure is just a sample of the significant social and economic impact that lasers have had on our lives over the past 50 years.

Because of the collaborative nature of research many of the experiments, projects, R&D programmes, and applications that have led to the ubiquitous nature of lasers, have been joint efforts between research councils, academia and industry.

The Science and Technology Facilities Council (STFC), through its Central Laser Facility based at the Rutherford Appleton Laboratory (RAL), continues to play a leading role in the development of lasers and operation of high-power laser facilities.

The Engineering and Physical Sciences Research Council (EPSRC) is also a key funder of laser research and technology in the UK.

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Project Manager: Connor Curtis, STFC

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Introduction

What are lasers?

Light
Amplification by
Stimulated
Emission of
Radiation

Lasers are concentrated beams of electromagnetic radiation (light) travelling in a particular direction.

The defining properties of laser light are that the light waves are coherent (all travelling in harmony with one another) and that they are usually of one wavelength, or colour.

By harnessing these properties in a device that reflects light back and forth through a special material, it is possible to generate an amplified light source, or laser.

Such light can be concentrated in time and space to create truly extreme conditions, or be used to provide exquisite imaging and analysis capability across a wide range of applications.

A brief history

The conception of the laser traces back to a theory proposed by Albert Einstein in 1917.

It was Einstein's theoretical understanding of the interactions between light and matter that paved the way for the first laser. However, it was not until 1960 that the first working optical ruby laser was built by Theodore Maiman. Over the past 50 years, the laser has evolved considerably, and many new varieties have been developed. Due to their extreme versatility, lasers have become invaluable tools across a multitude of applications.

Where STFC fits into the picture

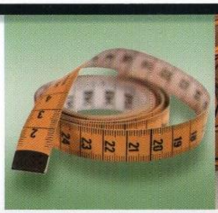
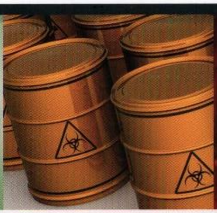
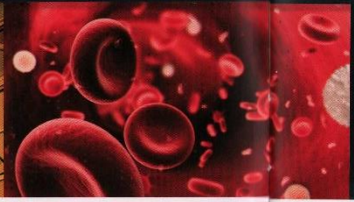
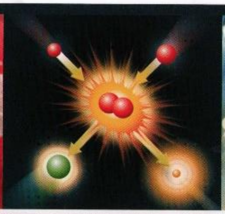
The UK excels in research using and creating high-power lasers.

STFC's Central Laser Facility (CLF), sited at the Rutherford Appleton Laboratory has been at the forefront of innovative laser technology and research for more than 30 years.

This brochure demonstrates the far reaching impacts that lasers have on our lives, and highlights some of the key contributions made by STFC in the field of laser research during the past 30 years.

Why do we care about lasers?

Today, lasers impact almost every aspect of life…


…from medicine to manufacturing, from communications to measurement, and from research and analysis to entertainment. This is ironic for a device that was initially described as a 'solution looking for a problem'. In fact, during its first 50 years, the laser has been nothing short of revolutionary! We can only wonder what the next 50 years will bring.

fact

Estimates suggest that the world market for lasers in 2007 alone was worth more than

£4Bn!

Measurement and analysis

Measurement and analysis have been transformed by the laser. Surveyors use lasers to mark out roads and construction sites, the military use them to determine the position of targets and even NASA has utilised lasers to measure the distance of the Moon from the Earth.

Laser analysis of chemical and physical structures has allowed factories to manage quality control efficiently. Laser techniques have been adopted by aluminium-manufacturing plants to monitor accurately the proportion of constituent metals in alloys. They also play a crucial role in the inspection of pharmaceuticals.

→ *SEE PAGE 4*

Defence and national security

The world is on high alert for potential terrorist attacks, and security is of high priority. Detecting explosives and biochemical hazards are just a few examples of how lasers can strengthen our national security.

→ *SEE PAGE 6*

fact

The total number of laser patents issued since its invention is well over 50,000

Medicine and health

Only one year after its invention, the laser was being applied in a medical procedure. This happened in December 1961 at the Columbia-Presbyterian Hospital, where a ruby laser was used to destroy an eye tumour. Today, lasers are commonly employed in most medical disciplines, including dermatology, dentistry, cardiology, neurosurgery and eye surgery, because of their ability to deliver high-precision treatments, whilst remaining minimally invasive. Laser-based therapies and diagnostic methods represent an area of huge future potential.

→ *SEE PAGE 8*

Energy

Lasers can generate extreme pressures and temperatures, and so can be used to ignite nuclear fusion – the same process that powers our Sun.

Research into laser-driven fusion is currently underway and promises to address our increasing demands for energy.

In addition, scientists are exploiting lasers in the development of solar cells.

→ *SEE PAGE 10*

Communications

Long-distance telecommunications and broadband internet both depend on the transmission of light pulses along optical fibres. These light pulses are both generated and relayed via lasers. This revolutionary method of communication is replacing less efficient copper wire-based networks and is the foundation of the internet and information age.

→ *SEE PAGE 12*

Environment and climate

Climate change is one of our most immediate challenges. Deforestation and the burning of fossil fuels are the likely causes for the increased concentrations of greenhouse gases in the Earth's atmosphere.

Lasers can be used to analyse the concentrations of these gases and even to monitor their effects on ecosystems.

→ *SEE PAGE 14*

Manufacturing

Lasers are employed across the manufacturing industry as tools capable of delivering intense cutting or welding power with high precision. Their ability to manipulate and transform materials makes them ideal for the automobile, computer and clothing industries – to name but a few. In fact, it is difficult to find a modern consumer product that has not seen a laser during its manufacturing.

→ *SEE PAGE 16*

Measurement and analysis

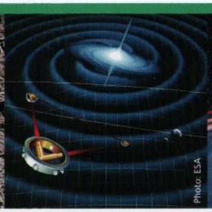


Photo: ESA

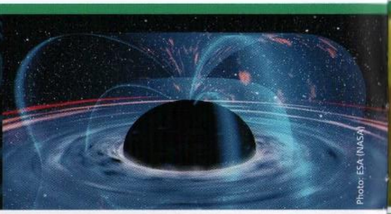
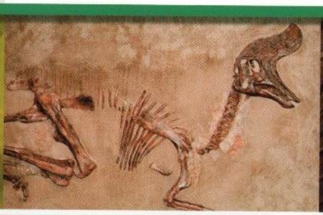
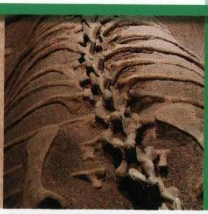


Photo: ESA (NASA)





Measuring the distance to the Moon

Thanks to special mirrors left behind by Apollo astronauts, the distance from the Earth to the Moon is known with a precision of millimetres!

Laser light fired from the Earth is reflected back by these mirrors (lunar retro-reflectors) and by accurately recording the time the light takes to travel, the distance to the Moon can be determined.

Do lasers hold the key to unlocking the secrets of the Universe?

The very fabric of space and time continually undergoes subtle 'ripples' that carry messages of astronomical events. These include the mergers of massive black holes, neutron stars and even the aftermath of the Big Bang.

The 'ripples', or gravitational waves, were predicted almost a century ago by Einstein's General Theory of Relativity. Detecting and studying them will provide an entirely new way to observe and understand the Universe.

The Laser Interferometer Space Antenna (LISA) experiment aims to do just that. An ESA/NASA joint venture, LISA will consist of three separate, identical spacecraft flying in an equilateral triangle arrangement, with 'laser arms' about 5 million kilometres long. Tiny changes in the relative length of these arms caused by gravity waves will be measured by precisely monitoring the separation between each spacecraft. From studying the shape and timing of these waves, the LISA research team will be able to infer information about the astronomical systems that emitted them, such as their nature and evolution.

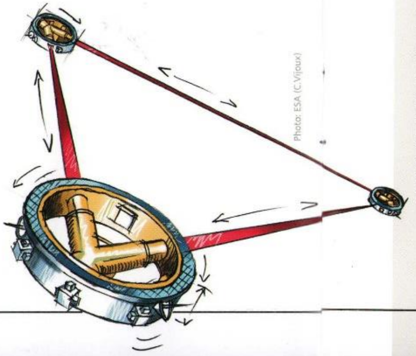


Photo: ESA (C.Vijoux)

Using lasers to measure gravity

As well as being able to generate extremely high temperatures, lasers can also be used to cool down atoms to temperatures close to absolute zero (-273°C).

When laser cooling is combined with another technique called magneto-optical trapping, it is possible to produce samples of trapped, slow-moving, neutral atoms that are close to absolute zero.

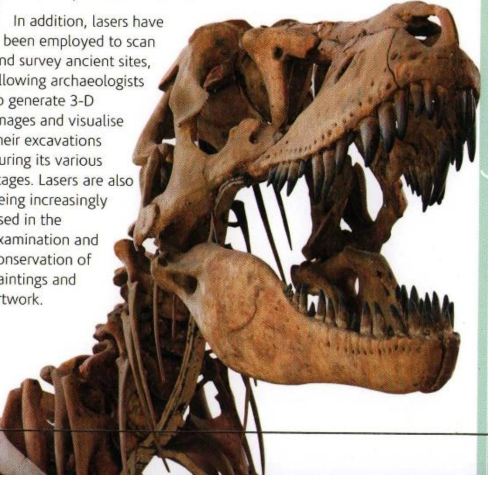
Following research carried out by US physicists, scientists at STFC are now working on a device that incorporates a magneto-optical trap into a system capable of measuring gravity to high accuracy. By 'dropping' these cold atoms down a vertical vacuum tube, precise gravitational measurements can be made. Such devices have potential applications in geophysics and in oil exploration.

Lasers in archaeometry and art

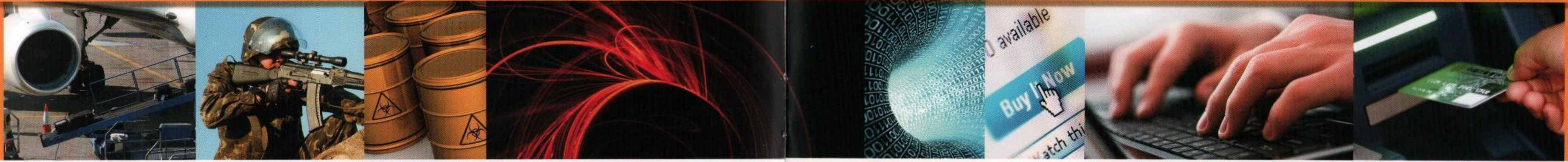
Non-invasive laser diagnostic techniques have been used to identify, date and analyse ancient artefacts, rocks and dinosaur fossils.

Archaeologists have also applied laser-scanning techniques to sites such as Stonehenge (Wiltshire, UK), leading to the discovery of lost ancient art.

In addition, lasers have been employed to scan and survey ancient sites, allowing archaeologists to generate 3-D images and visualise their excavations during its various stages. Lasers are also being increasingly used in the examination and conservation of paintings and artwork.



Defence and national security

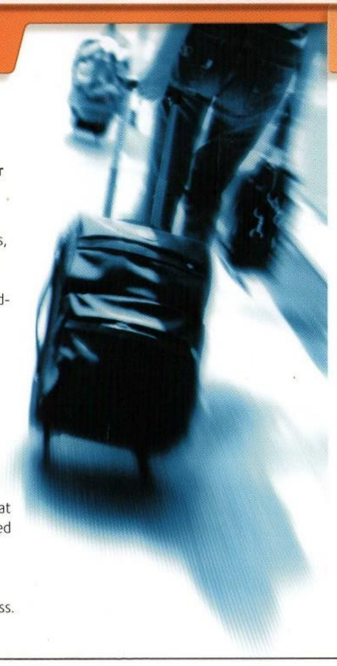


Detecting chemicals before it's too late

A system capable of remotely identifying, quantifying and locating the release of volatile chemicals would be invaluable for security applications.

Gas-phase chemicals, like the volatiles often emitted by explosives, possess unique spectral fingerprints that allow remote detection using optical techniques. A real-time stand-off detection system that exploits these fingerprints could provide improved security at airports and other civil infrastructures, and even on the battlefield.

STFC scientists and partners are currently investigating novel laser-based technologies for stand-off detection. Using continuous frequency-tuneable laser sources that are extremely compact and optimised for chemical detection, the team is developing novel instruments with unprecedented spatial resolution, chemical selectivity and compactness.



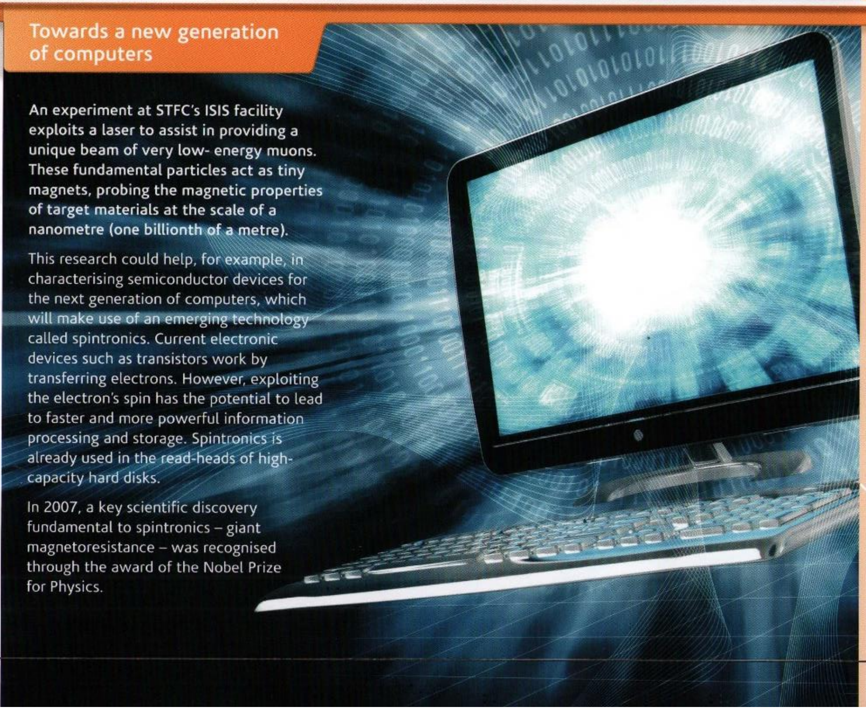
Seeing through opaque bottles

Spatially Offset Raman Spectroscopy (SORS), is a new non-invasive spectroscopy technique developed at STFC's ultrafast laser facility. It can determine the composition of materials hidden behind or within other layers, such as a liquid concealed in an opaque bottle or container.

The technique has been patented and developed via a spin-out company called Cobalt Light Systems, which seeks to exploit the technique's wide-ranging potential applications. These include a new capability for detecting hidden explosives and illicit drugs, as well as assessing the quality and authenticity of medicines, and potentially diagnosing bone diseases and cancer non-invasively.

cobalt LIGHT SYSTEMS

Towards a new generation of computers

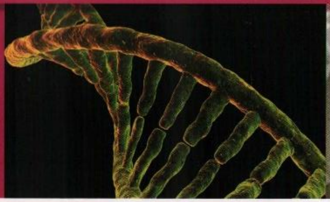


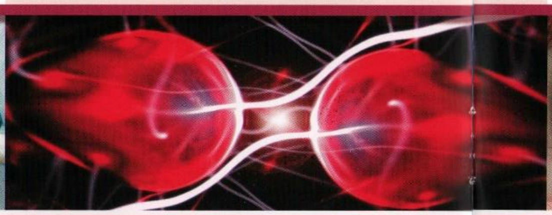
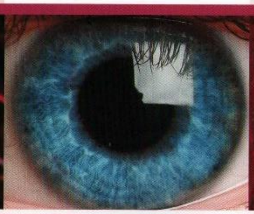
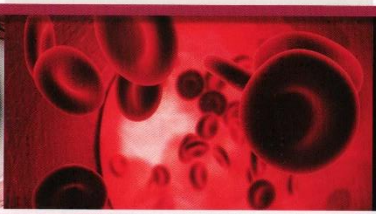
An experiment at STFC's ISIS facility exploits a laser to assist in providing a unique beam of very low- energy muons. These fundamental particles act as tiny magnets, probing the magnetic properties of target materials at the scale of a nanometre (one billionth of a metre).

This research could help, for example, in characterising semiconductor devices for the next generation of computers, which will make use of an emerging technology called spintronics. Current electronic devices such as transistors work by transferring electrons. However, exploiting the electron's spin has the potential to lead to faster and more powerful information processing and storage. Spintronics is already used in the read-heads of high-capacity hard disks.

In 2007, a key scientific discovery fundamental to spintronics – giant magnetoresistance – was recognised through the award of the Nobel Prize for Physics.

Medicine and health




How laser imaging can help diagnose cancer

Imagine a world in which doctors can prescribe medication that is specifically tailored to a person's DNA fingerprint. It is guaranteed to be effective against an individual's cancer, with minimal side-effects.

Scientists working at STFC's Lasers for Science Facility are at the forefront of research aimed at tackling diseases such as lung and breast cancer. A technique that colour-codes 'misbehaving' protein molecules with a fluorescent dye and then uses lasers to illuminate these molecules, causing them to glow, provides an insight into their behaviour during the onset of disease. Researchers can then use sophisticated computer methods to build up a detailed 3-D picture that reveals the underlying bio-molecular interactions leading to disease.

The information obtained from this novel use of lasers will be a crucial step towards a future of personalised medicine.

Shrinking accelerators

By smashing together beams of high-energy elementary particles in accelerators and observing the debris, researchers can better understand the structure of matter and the forces of nature at a fundamental level. In addition, beams of energetic particles are useful tools for biological, nanotechnology and chemistry research.

STFC scientists are involved in investigating and developing a new generation of radiation sources that aim to accelerate particles using lasers. This technology has the potential to reduce the size of conventional accelerators to fit on a laboratory bench-top, resulting in significantly reduced costs.

These potentially portable machines would also offer a host of medical, industrial and security applications, including cancer therapy, the rapid detection of hidden explosives and improved quality control in the fabrication of semiconductors.

Detecting eye disease

By scanning laser light back and forth across the retina, high-resolution, cross-sectional images can be taken, which can be combined into a 3-D picture of the retina.

This novel technique – optical coherence tomography (OCT) – can help ophthalmologists to detect the subtle changes that occur in retinal disease.

fact

More than 100,000 laser procedures to correct vision are performed annually in the UK – a figure that is on the increase!

Cholesterol testing

Using technology developed at STFC's Daresbury Laboratory in Cheshire, the company L3 Technology has used lasers to develop and patent a highly accurate cholesterol test that is more precise and cost-effective than other similar testing kits currently available.

Current 'over-the-counter' cholesterol test-kits do not distinguish between the different types of cholesterol considered 'good' or 'bad' from a health point of view. Existing laboratory tests take a minimum of three days to generate adequate results.

The L3 Technology test works by tagging compounds with a fluorescent marker that is subsequently illuminated with an intense light source. The intensity of fluorescence quantifies the type and amount of cholesterol that is present in the sample.

The company's ultimate goal is to produce a range of tests that will be conveniently available at your GP's surgery, saving both time and money.

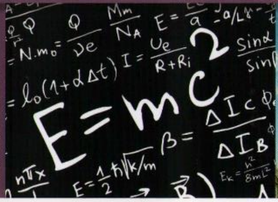
L3 Technology

Tattoo removal

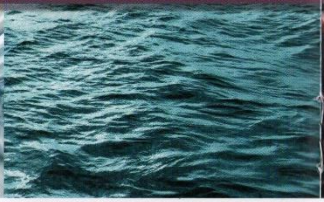
Tattoos consist of large clumps of pigment scattered through the lower layer of skin. Because of their size the body is unable to remove these clumps, so instead, seals them off with a protective fibrous barrier.

Laser therapy works by breaking down this fibrous barrier, allowing the pigment to disperse into smaller pieces, which the body's natural defences can slowly remove.

Energy







$E = mc^2$

Einstein's famous equation, $E = mc^2$, tells us that energy and matter are interchangeable, such that even a small amount of matter can potentially be converted into a large amount of energy.

Nuclear fusion is Nature's way of releasing some of this energy and is the process that drives the Sun and other stars. Here on Earth, atomic nuclei such as those of hydrogen isotopes, deuterium and tritium, can be fused into heavier nuclei such as helium, releasing a huge amount of energy in the process. Fusion has the potential to address our increasing energy needs, providing a safe and effectively inexhaustible energy supply, in an environmentally sustainable manner.

Benefits of laser fusion

Plentiful fuel
Laser-driven fusion could supply the world with an abundant, effectively limitless fuel supply.

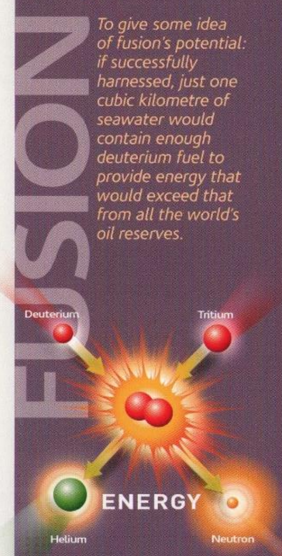
Energy security
The required fuel is readily available in seawater.

Clean energy
Laser-driven fusion produces no greenhouse gas emissions and thus has a low environmental impact. Also, unlike nuclear power stations, there is no long-lived radioactivity, thereby reducing health risks.

Creation of jobs
The progression of laser-driven fusion, from proof-of-principle to commercial exploitation, will require a combination of specialised facilities and considerable scientific expertise. The construction of HiPER, the proposed European High Power laser Energy Research facility to demonstrate the feasibility of laser-driven fusion, would generate huge economic benefits both domestically and beyond. These include job creation and the capitalisation of emerging spin-off technologies.

Did you know?

To give some idea of fusion's potential: if successfully harnessed, just one cubic kilometre of seawater would contain enough deuterium fuel to provide energy that would exceed that from all the world's oil reserves.



National Ignition Facility (NIF)

NIF, situated at the Lawrence Livermore National Laboratory in California in the US, hosts the world's largest laser system.

One of its missions is to investigate the feasibility of nuclear fusion. NIF aims to produce more energy from a fusion reaction than is used to initiate the reaction. This would be a landmark demonstration of the principles of laser fusion.

If successful, NIF ignition will be the launch-pad for the next generation of laser-fusion facilities such as HiPER.

High Power laser Energy Research facility (HiPER)

The next step towards fusion

HiPER is a European collaborative project that represents the next step in the development of laser fusion as an energy source. It aims to bridge the gap between fusion research and harnessing fusion energy on an industrial scale. Operating rather like a car engine, the fuel will be injected, then compressed and ignited via controlled laser pulses, creating the extreme conditions necessary for fusion. Unlike NIF, HiPER will integrate highrepetition rate technology and will be capable of repeating the ignition process an estimated five times per second.

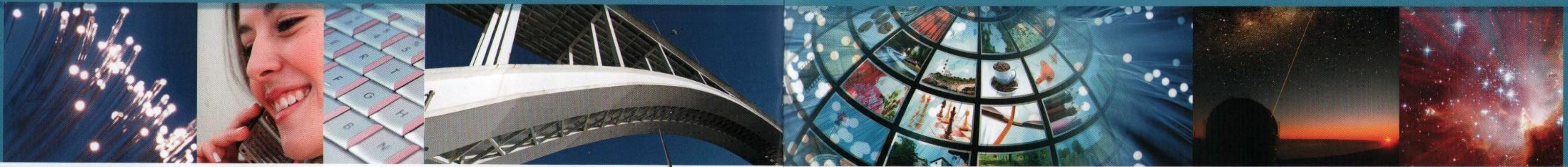
HiPER aims to demonstrate the full laser-fusion cycle, to provide the basis on which a new generation of electricity power stations could be built.

Harvesting sunshine

Living organisms depend on complex and often extremely efficient biochemical processes to harness, store and transport energy. By understanding the underlying mechanisms of the light-capturing processes and energy transport involved in photosynthesis, for example, researchers aim to develop similar systems that could be employed in the next generation of solar cells.

Laser studies of how light triggers the movement of electrons through photosensitive biological structures are contributing to the scientific understanding of solar-energy conversion at the molecular level. STFC scientists, in collaboration with partners, have performed experiments to measure the speed of electron transfer through these molecular structures. They involve firing a short laser pulse at a sample to stimulate the electron-transfer process, and then using a tuneable infrared laser to monitor how the system evolves in real time.

Communications



Fibre optics

Lasers have revolutionised the way in which we communicate and are largely responsible for the advent of the information age.

Central to this new age of information transfer is the network of fibre optics that comprise the core of long-distance telephone communications and the internet. These networks rely on transmitting information through glass or plastic fibres via pulses of laser light. The light pulses are converted at their destination into electrical signals that provide the information.

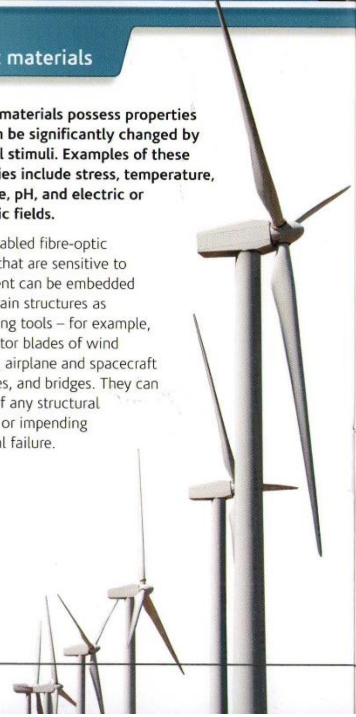
Fibre optical systems are rapidly replacing the pre-existing copper-wire networks. Their flexibility, lower cost, higher efficiency, clearer signal and increased capacity (to carry thousands of times the amount of information that copper wires can), make them a superior option for the telecommunications industry.

A new type of laser actually based on specialised optical fibres is expected to have a range of important applications including biomedical microscopy and analysis, and quantum-information processing.

Smart materials

'Smart' materials possess properties that can be significantly changed by external stimuli. Examples of these properties include stress, temperature, moisture, pH, and electric or magnetic fields.

Laser-enabled fibre-optic sensors that are sensitive to movement can be embedded into certain structures as monitoring tools – for example, in the rotor blades of wind turbines, airplane and spacecraft structures, and bridges. They can inform of any structural changes or impending structural failure.



Information and communications technology

Because they can carry large volumes of information as pulses, lasers have been exploited extensively across the ICT industry. Examples of areas where lasers are employed include:

Optical storage

Lasers read and write information encoded as microscopic 'pits' on CDs, DVDs, Blu-Ray and other storage media.

Communication

Laser-diode coupled fibre optics are being rolled out as the backbone of the high-speed internet, transforming the way in which we interact with each other and access high volume media such as movies, games and business information.

Increasing microprocessor speed

Micro-lasers could provide a high-speed alternative to transistors. Optical signals can be used to connect integrated circuits at light speed, as well as providing the basis for a new generation of holographic memory.

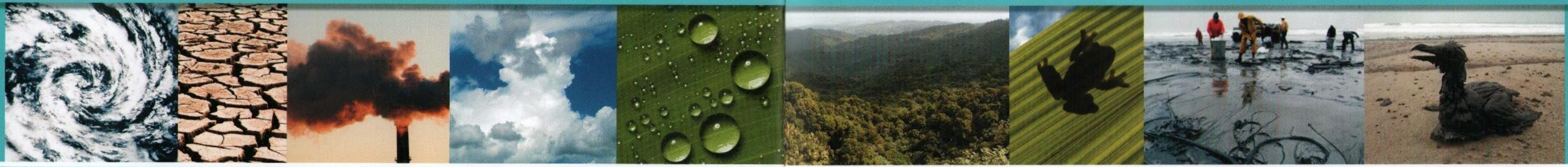
Seeing stars more clearly

As light from distant stars and galaxies passes through the earth's turbulent atmospheric layers, it becomes distorted. Astronomers have long sought to diminish these atmospheric effects so that ground-based observations can become clearer and more precise.

One solution, which is becoming increasingly employed by astronomers, is to create an artificial guide star by shining a laser into the atmosphere. Atmospheric turbulence and changes in temperature cause the image of this laser on the sky to distort in a random fashion, it is also what makes stars appear to twinkle in the night sky. Astronomers can utilise a system of adaptive optics to measure the distortions of this laser image and correct for any aberrations or deviations. By rapidly changing the surface of a deformable mirror via a computer system, these deviations can be compensated for, resulting in clearer astronomical images. Many of the world's largest telescopes now use an artificial guide star in the form of a laser, which can be conveniently directed up into the sky.

The same adaptive optics technology is also applied to laser communication systems, such as the fibre optics network, to improve performance and efficiency.

Environment and climate



Lasers to monitor and understand climate change

Climate change and poor air quality are major challenges in a world of increasing industrialisation and urbanisation. Understanding and monitoring the Earth's atmosphere is of crucial importance.

Observing the atmosphere from space can provide a global view of atmospheric composition and processes. An innovative research project, funded by the Natural Environment Research Council, called the Laser Heterodyne Radiometer (LHR) has involved the development of a prototype instrument that could potentially be the forerunner of a new generation of satellite-based infrared monitoring instruments. The LHR has been developed to provide a unique combination of high spatial resolution (to locate gaseous emission sources and observe between clouds), high spectral resolution (to discriminate between types of gases), and high sensitivity to detect the tiniest concentrations of atmospheric constituents.

Developed for Earth observation by a team of STFC scientists in collaboration with partners, a prototype LHR instrument has recently been successfully demonstrated at 'the Rutherford Appleton Laboratory' through ground-based measurements of atmospheric ozone, and is now being developed to monitor other key atmospheric trace gases.

Global cooling

Clouds are considered to have a substantial impact on climate change because of their role in both absorbing and reflecting heat transferred through the atmosphere.

Pollutants such as the organic compounds produced when fossil fuels are burnt, are believed to affect the formation and growth of water droplets in clouds.

Scientists working at STFC have been able to gain an insight into chemical reactions occurring on the surfaces of cloud droplets in the atmosphere. Typical experiments involve spraying a mist of particles into a model 'cloud chamber' and using a microscope to focus a laser beam into it. One of the droplets eventually finds its way into the centre of the laser beam and is held in position via the intense light-field pressure of the laser, which acts like 'optical tweezers'. Analysis of laser light scattered by the droplet underpins the development of complex computer models of the atmosphere and contributes to improving our understanding of climate change.

Monitoring forests with lasers

Important properties of ecosystems such as those found in tropical forests can be measured using a system of lasers attached to the underside of aircraft. Often covered with dense vegetation, these forests tend to be difficult to study on the ground or even with satellites.

A combination of advanced spectroscopic imaging and laser remote-sensing technologies can measure differences in ground elevation to an accuracy of within a few inches. This technology can provide insights into how changes in climate and land use can affect the structure, composition and functioning of ecosystems.

Using lasers to tackle oil spills

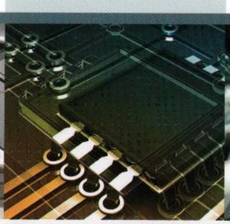
Oil spills represent a major environmental risk, often taking many years to clean up. But, for some bacteria, oil is the perfect meal! By introducing colonies of hydrocarbon-digesting bacteria, it may be possible to lessen the impact of oil spills and clean them more efficiently.

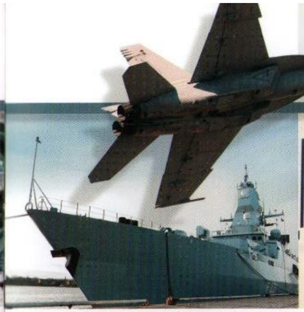
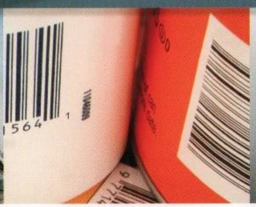
Researchers at STFC's 'Lasers for Science Facility', in collaboration with scientists from the Centre for Ecology and Hydrology, have been assessing the different types of bacteria that can digest hydrocarbons. By capturing individual bacteria in laser optical tweezers and analysing their spectra, scientists can establish whether the bacteria have broken down particular chemicals.

Potential future applications of this research range from cleaning oil spills at sea, to the contaminated land under petrol stations.

Manufacturing





How are lasers used in manufacturing?

- Laser cutting
- Laser marking and engraving
- Laser welding
- Laser drilling
- Laser melting
- Laser heat treating
- Laser micromachining
- Laser soldering
- Laser surface treatment

Building a car with lasers

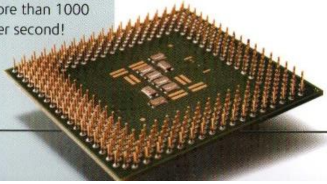
Innovative, high-power lasers have been utilised by the automotive industry since the early 1980s.

Today, almost every modern vehicle will have had various encounters with lasers during its manufacturing – from cutting the airbag cloth, door lining and keys to welding the body shell, annealing door springs and marking tyres; lasers are absolutely essential tools in modern automobile production.

Lasers and semiconductors

The manufacturing of semiconductors requires the rapid, clean cutting of composite materials. Lasers fit this role perfectly. Their ability to cut irregular shapes to high precision, whilst minimising surface roughness, makes them ideal cutting tools.

Lasers are also used extensively to mark metals, polymers, silicon wafers and printed circuit boards, aiding their traceability during the manufacturing process. These miniature, machine-readable identification marks can be inscribed at speeds of more than 1000 characters per second!



Lasers and packaging

Scribing, perforating and marking represent areas where lasers are employed in the packaging industry.

Some specific uses include the selective weakening of individual packaging layers, providing an 'easy to open' solution, and the puncturing of tiny holes such as those found in bags of vegetables on supermarket shelves. These help to create ideal atmospheric conditions within the product, allowing perishable food to 'breathe' and last longer.

Paint stripping

Mobile, large-area laser beams can be deployed to remove paint and contaminants from objects such as aircraft and ships. These lasers are carefully tuned to maximise beam absorption by the contaminant or paint – to give a clean, stripped surface.

Because the laser beams have only a minimal impact on the subsurface (usually metal, plastic or ceramic), little residue is left behind. Laser stripping is often a cleaner, more efficient option to previous chemical removal techniques.

Laser coding

Industrial laser marking is used extensively across the food and beverage manufacturing industry for marking numerical codes, barcodes, logos and symbols onto materials including inked paper, glass, plastic and metals.

Intense laser beams can be deployed to remove small amounts of material from the surfaces of packaging and also to melt and modify such surfaces with speed and accuracy.

These techniques have numerous benefits, including faster production line speeds and high-quality marking with an enhanced resistance to extremes of temperature and humidity.

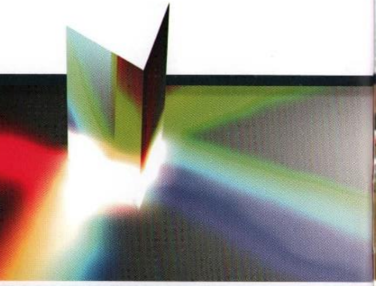
Quality control

By shining lasers beams onto ball bearings and measuring the dispersion of the laser light reflected back, their sphericity (or roundness) can be determined. This proves an efficient tool in managing quality control.

Consumer technologies

- Laser light shows
- Laser pointers
- Laser printers
- Laser tag
- Laser pocket projectors
- Games consoles
- Laser TVs
- CD players
- DVD players

Before the LASER…



…a story of light

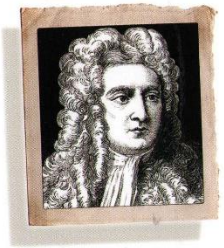
The science behind the laser started centuries earlier with scientists such as Isaac Newton, James Clerk Maxwell and Albert Einstein. Traditionally, the UK has played a major role in laser science and its applications.

Isaac Newton

Born: 4 January **1643**
Died: 31 March **1727**

Between 1670 and 1672, Isaac Newton investigated the refraction of light and showed that a prism could split white light into a spectrum of colours.

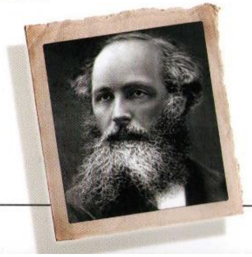
The same principle applies to water droplets, which can act as tiny prisms and refract the Sun's rays to form rainbows.



James Clerk Maxwell

Born: 13 June **1831**
Died: 5 November **1879**

Maxwell made remarkable contributions to physics by uniting what were previously unrelated experiments, equations, and observations of electricity, magnetism and optics into a consistent 'electromagnetic' theory. Maxwell demonstrated that electric and magnetic fields travel through space in the form of waves and at the speed of light. His equations laid the foundations for many of the scientific and technological advancements during the 20th century, including special relativity and quantum mechanics.

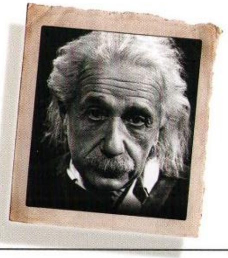


Albert Einstein

Born: 14 March **1879**
Died: 18 April **1955**

A paper written by Einstein in 1905, proposed that light consists of quantised particles (later called photons). This inspired the quantum mechanical concept that light can exist in both a wave and a particle form.

Just over a decade later, in 1917, Einstein established the theory of stimulated emission of radiation, setting the scientific foundations for the subsequent discovery of the LASER.



Where STFC fits into the picture

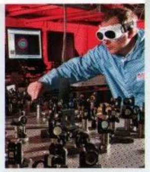
The UK carries out leading research using and creating high-power, ultrafast and high-sensitivity laser systems.

STFC's Central Laser Facility (CLF), provides an internationally leading range of laser systems for research by academia and industry.

Science & Technology
Facilities Council

Vulcan HIGHEST POWER OF ALL

Vulcan is one of the most powerful and versatile laser systems in the world. This unique facility delivers a focused beam – which for 1 picosecond (0.000000000001 seconds) is 10,000 times more powerful than the output of the National Grid – to support a wide-ranging research programme in fundamental physics and advanced applications relevant to clean energy and medicine.



Astra Gemini HIGH REPETITION RATE

Astra Gemini delivers laser pulses at the petawatt (a million billion watts) scale, with unsurpassed intensity and in an entirely new 'high-repetition rate' regime. Its two beams can provide one pulse every 20 seconds (compared to once every 20 minutes for conventional systems such as Vulcan). This makes it extremely useful for the detailed study of laser-driven particle acceleration, opening up a transformation in accelerator science and technology.

Lasers for Science Facility HIGH VERSATILITY AND SENSITIVITY

The Lasers for Science Facility (LSF) offers one of the most concentrated and versatile arrays of laser systems and expertise in the world. The facility is divided into three sections: the Molecular Structure and Dynamics Group, the Functional Biosystems Imaging Group and the EPSRC-funded Laser Loan Pool.

50 years of lasers timeline

1958

Concept of the laser

The concept of the laser is introduced by Charles H. Townes and Arthur L. Schawlow.

1959

The term 'LASER' is coined

The term 'LASER', which stands for Light Amplification by Stimulated Emission of Radiation, is introduced by Gordon Gould.

1960

First operational laser

16 May: The first working laser is developed at the Hughes Research Labs by Theodore Maiman, C.K. Asawa, and I.J. D'Haenens. It consists of a synthetic ruby crystal encased by a flash lamp.

1962

Diode lasers

The first semi-conductor diode lasers are invented. These proved to be an important progression towards the development of optical communication, and are nowadays used in a very wide range of industrial and scientific applications.

1965

First CD player

The laser compact disk (CD player) is invented by James Russell. Years later, in 1982, Billy Joel's *52nd Street* is the first album to be released on CD.

1968

Laser in space

The first laser-equipped satellite is launched by NASA.

1970

Laser lighthouse

Australia's Point Danger accommodates the world's first laser-driven lighthouse.

This proves to be an effective aid to short-range navigation.

1970

Successful fibre optic test

The first batch of optical fibre is produced by scientists at the Corning Glass Works. Despite being hundreds of yards long, they are able to communicate over the fibre, via pulses of laser light, with astonishing clarity.

1974

Barcode scanner

26 June: The first product to be scanned and logged by a barcode scanner is a 10-pack of Wrigley's *Juicy Fruit* chewing gum.

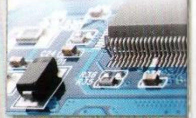
Today, barcode scanners are ubiquitous across the retail sector.

1982

Lithography

The first paper on Excimer laser lithography is published by Kanti Jain.

Today, laser lithography is employed extensively to produce microchips for the computer and electronics industry.



1987

Laser eye surgery

The first laser eye surgery using an Excimer laser is performed in 1987, by ophthalmologist Steven Trokel. Today, millions undergo eye surgery every year.

1992

Magneto-optic data storage

A magneto-optic data storage technique is developed which utilises a laser and a magnet to write information to a disk. It is capable of compacting one billion bits of data into a square-centimetre of disk space.

STFC 2005

Vulcan Petawatt laser

Vulcan becomes the highest-intensity focused laser in the world. It is used to investigate fundamental interactions between light and matter, and to carry out laser-driven fusion experiments.

STFC 2007

Astra Gemini laser

Astra Gemini is completed. This laser system can deliver very intense, focused pulses with a high repetition rate, and provides the capability to study matter under extreme physical conditions analogous to the pressures and temperatures inside stars.

2009

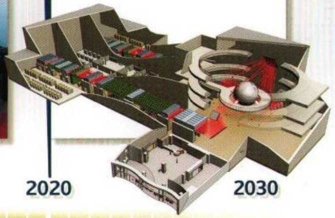
NIF

The National Ignition Facility (US) completes construction, with the aim of demonstrating nuclear fusion using powerful lasers. NIF intends to produce more energy from a reaction than was required to initiate it.

STFC 2020s

HiPER

The construction of the European collaborative High Power laser Energy Research facility should be complete. HiPER will be a test facility for prototype systems, components and materials that will directly enable the subsequent construction of a demonstration electricity generating plant.



1960 1970 1980 1990 2000 2010 2020 2030

KEY:

- 🟥 *New type of laser/facility*
- 🟧 *Commercial product/medical application*
- 🟩 *Interesting fact*
- ● *Nobel prize (for laser-related research)*