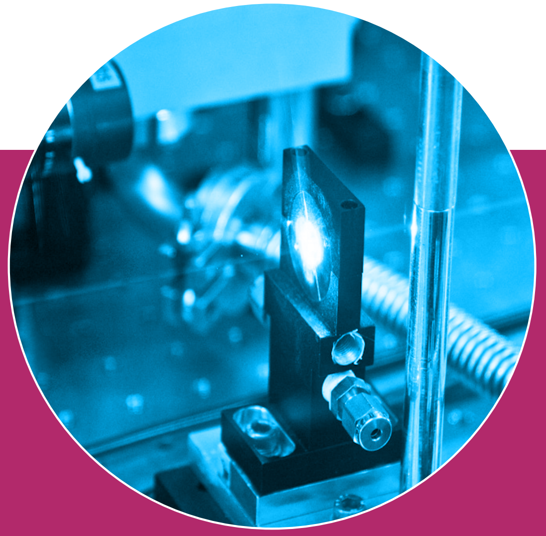
Changing lives

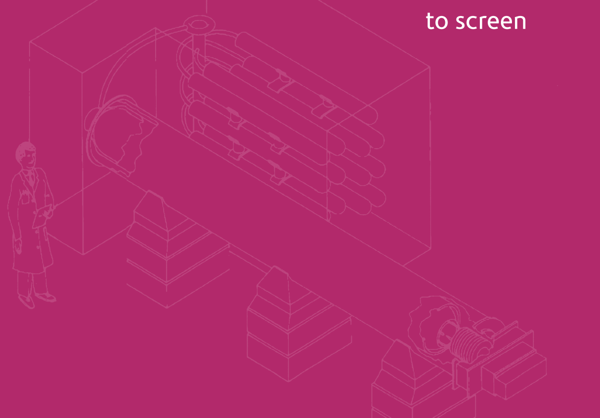


CLF has a strong history of translating the science inside its labs to technologies that improve our world. Its many spin-out companies and specialist applications are aiding technological advances in many walks of life.

In the 1980s, the CLF developed concepts, which demonstrated the fundamental role that lasers could play in corrective eye surgery, making a tangible difference to people's quality of life. In 2000 Summit Technologies Ltd, the company formed to develop and commercialise the technique, was sold for $893 million.

The Spatially Offset Raman Spectroscopy (SORS) technique developed in the CLF allows 'seeing' through barriers. Analysing the scatter of a laser beam shone on them allows identification of materials behind surfaces in a non-invasive manner. This revolutionary technique is now used for applications ranging from detecting original artwork beneath famous paintings to screening liquids passing through airport security and quality assurance in the pharmaceutical industry.

The CLF spin-out company Cobalt Light Systems specialises in finding new applications for SORS. The products that use this technology are being used in airports around the world to screen liquids, allowing passengers to travel with essentials like baby food; in future this may enable airports to relax the existing hand-luggage liquid limit. To date, this company has filed eight patents and won numerous awards, including the prestigious 2014 MacRobert Award for engineering innovation. Cobalt Light Systems are currently exploring SORS technology for diagnosing bone diseases and breast cancer.



CLF plays a major role in the development of novel plasma accelerators that may enable compact, cost-effective accelerator technology for applications ranging from medicine to security. With the UK's Defence Science and Technology Laboratory (DSTL), the CLF has patented a laser-based X-ray radar technique for security inspections enabling non-invasive detection of buried objects such as landmines. Once developed, these techniques will protect our armed forces.

CLF continues to convert the world-class science it does into spin-out companies creating products that are used across many areas of industry and have a wide range of applications. These range from micro-machining and making bespoke micro-targets for high-energy photon-science experiments to image grabbing and analysis, and sensor development.

Looking forwards

In 2017, the CLF celebrates 40 years of world class. world-leading research – but is not resting on its past achievements. It continues to drive innovation around the world through use of its existing lasers and the technology it develops. Scientific progress requires strong commitment and resources to develop technological solutions for our modern world. Therefore, the CLF must demand more from its instruments, and think creatively about how to apply them.

The CLF's Centre for Advanced Laser Technology and Applications (CALTA) has gone from strength to strength and works to develop new laser technology, responding to the needs of the scientists and researchers who use the CLF.

Its next-generation lasers are already being used at some of the world's leading facilities. A DiPOLE 10-joule 'head' was installed at the ELI Beamlines facility (Prague) in 2014, while the DiPOLE100 laser is also in use at the HiLASE facility(Dolní Břežany). DiPOLE100 is currently in production for delivery to the European XFEL in 2018 to generate extreme states of matter, mimicking astrophysical scenarios, for the FEL beamline to probe.

The scientists who use the facility drive the CLF to upgrade its instruments – creating more powerful, efficient, and versatile lasers – so it can continue to push the boundaries of what is possible in laser science.

One of the scientific problems CLF aims to tackle next is the challenge of how lasers can be used to create mass from light. This is theoretically possible – but it will require an extremely powerful laser. Using techniques pioneered by the CLF in 1996, Vulcan could be upgraded to make it 20-times more powerful than it is today, enabling this ground-breaking research.

To develop and demonstrate applications of laser-based accelerators in medicine, aerospace, nuclear, security and defence sectors, the CLF's DiPOLE technology can also be used to upgrade the Gemini laser to deliver ultra-short, high-intensity pulses at ten-times a second – a key enabler for technology transfer of the laser accelerator concept into industry.

In order to tackle the grand challenge of 'making the molecular movie' by probing vibrational and electronic dynamics in molecules and on surfaces, the Ultra and Artemis systems have the potential to jointly upgrade to next-generation Optical Parametric Chirped-Pulse Amplification laser technology.

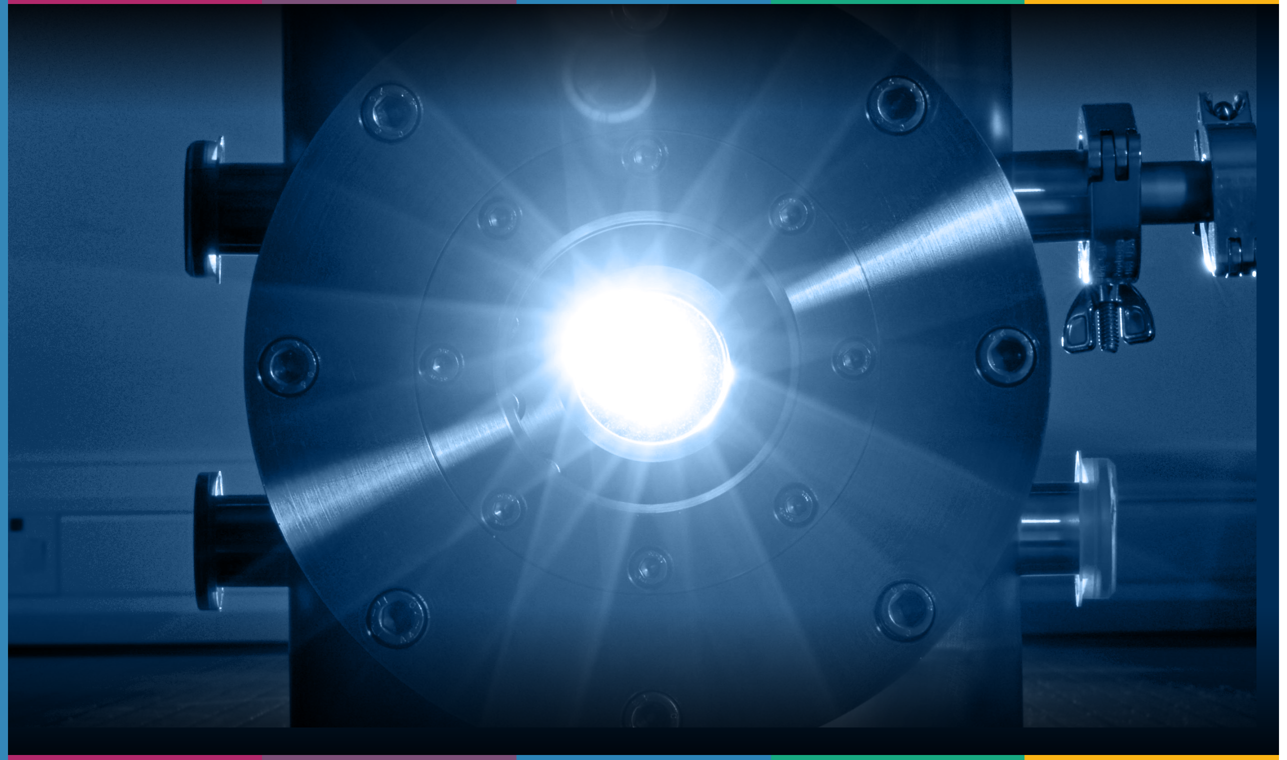
Further upgrades will bring together different imaging approaches simultaneously, to provide deeper insights into biological, medical and materials science, working closely with other imaging facilities on the campus. The CLF will work in partnership with the Research Complex at Harwell, Diamond Light Source Ltd., and The Rosalind Franklin Institute to make the Harwell Campus a world-leading centre for multimodal imaging.

The CLF works as part of a global scientific community. Its facilities serve not only UK researchers, but those from all over the world. By continuing to partner with international players, contribute to world-leading projects, and work to meet the needs of the scientific community and society, the CLF will continue to deliver excellence in the field of laser science.

Science & Technology Facilities Council

Cover image: The record-breaking DiPOLE laser.
All image credits: STFC.

LIGHTING THE WAY



Leading laser science for academia, industry and society into the future:

The United Kingdom's Central Laser Facility (CLF)

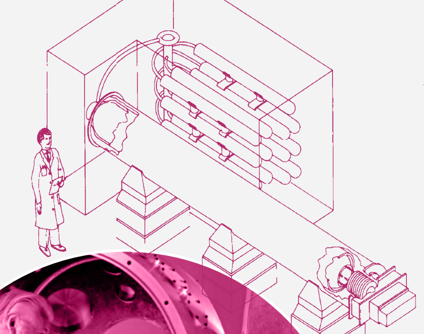
Science & Technology Facilities Council

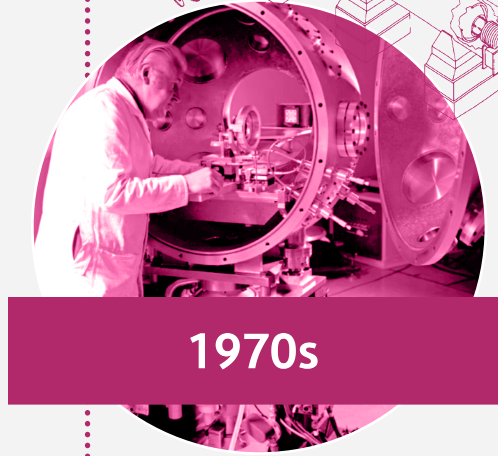
Forty years of excellence

For 40 years, the United Kingdom's CLF has been at the cutting edge of laser science, discovering and developing new technologies. From humble beginnings with just a single laser, the facility now has a large suite of instruments, and works with and for researchers and organisations around the world.

1970s

1975 The CLF project is announced, with a mission to "provide high-power laser facilities for UK universities".





1977 The Vulcan laser begins operations. This two-beam, 0.5-terawatt laser, emits an optical pulse. Each short laser pulse is as powerful as the total energy produced by all of the world's wind turbines today. Its first experiment investigates whether lasers can be used to develop fusion as a clean, limitless supply of energy.

1977 The CLF builds its first micro-structure target for use in high-power laser experiments. These were typically tiny glass spheres – no bigger than 100µm – filled with inert gasses like argon or neon.

1979 Electron-beam Laser Facility (ELF) – the first pulsed-power excimer laser in the world – is commissioned. It can be used to energise gaseous media and generate short (UV) laser wavelengths that can be use for heating and compressing matter as inertial-fusion drivers.

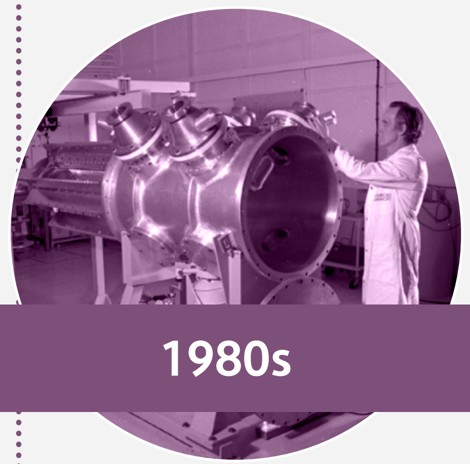
1980s

1980 Vulcan is upgraded to deliver up to six beams on to targets for exploring heating and compression of matter for fusion applications. This provides a world-leading facility that underpins the global research effort for laser-driven fusion as a future energy source.

1981 To optimise the design of Sprite, a krypton fluoride (KrF) laser, a computer model is developed and runs on the IBM 360 computer.

1981 Construction and testing begins on Sprite, a krypton fluoride (KrF) laser. Sprite is the highest-powered laser of its kind and is used to develop the next generation gas-laser technology and bright X-ray sources.

1981 The plasma theory group solve a complicated, but key, equation describing the heat flow in laser compression of fusion targets.



1982 The Ultra-Violet Radiation Facility (UVRF) begins operations undertaking a full programme of photochemistry, photobiology, physics, and micromachining. It becomes the Laser Support Facility in 1985.

1982 The first photobiology experiment uses UV spectroscopy to obtain structural information of biological molecules (proteins and enzymes) in solution.

1984 Sprite is used to calibrate the dust sensor for the Giotto space probe mission to Halley's comet.

1984 The CLF establishes spin-out company Exitech, which manufactures specialised laser micromachining systems. The company quickly grew to supply high quality systems to global brands like Sony.

1985 The CLF further develops its excimer laser technology and associated applications, including the addition of a new pre-amplifier named Goblin and demonstrations of lithography and micro-machining for circuit boards.

1985 The Laser Loan Pool begins lending lasers to UK universities to use at their home institutions, underpinned by scientific and technical support, to enable new research.

1987 The CLF launches the Lasers for Science cluster, which pushes medical boundaries, enhances our biological knowledge, and furthers chemistry research.

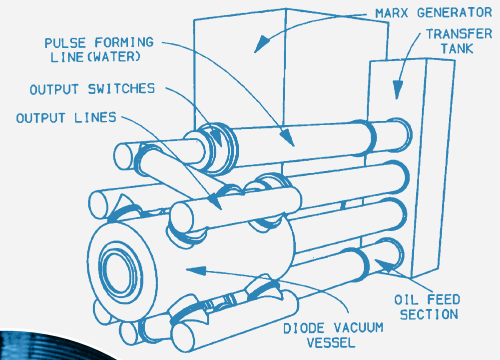
1990s

1990 The CLF develops new laser systems which reinforce its leadership in UV and X-ray laser science.

1996 The CLF develops the pioneering technique of Optical Parametric Chirped-Pulse Amplification (OPCPA), which enables high-power lasers to break the one-petawatt ceiling limit and reach new, higher power levels.

1996 The Titania excimer laser opens, providing a new and more powerful beam than the existing Sprite system.

1997 The Astra high-power laser opens for exploring intense laser matter interactions and the physics of extreme energy densities.



1999 Researchers use the Vulcan laser to demonstrate that high-power lasers striking matter can be used to generate highly energetic and directional gamma beams that can image through very dense objects with high resolution, opening up a new application for high power lasers in security and nuclear imaging.

1999 The Pirate laser is funded by the Engineering and Physical Sciences Research Council to revolutionise tunable lasers for studying chemical and biological events on the picosecond timescale.

1999 The CLF establishes spin-out company LaserThor. In conjunction with the rail industry, LaserThor seeks to develop laser technology to clean railway tracks, addressing issues such as 'leaves on the line'.

2000s

2001 The CLF creates spin-out company L3 Technology Ltd, to develop medical applications for an optical spectroscopy technique that can be used to tell good cholesterol from bad.

2002 Vulcan is upgraded to a petawatt beam, 10,000 times more powerful than the UK's national grid. It emits a very short pulse that lasts for up to a picosecond, a trillionth of a second.

2003 The CLF establishes spin-out company Colsicoat Ltd, which specialises in optical coatings for microtargets for high-powered laser experiments.

2004 Using the Astra laser, UK researchers demonstrate the world's first high-quality, high-energy electron beams by driving the laser into a puff of supersonic gas. This makes the front cover of the scientific journal *Nature*, which dubs Astra the 'dream beam' and is currently the facility's most highly cited paper.

2007 The Astra laser is upgraded to become the Gemini laser, making the CLF the first facility in the world to provide a dual-beam system of high-power, super-intense light.

2008 The CLF establishes spin-out company Cobalt Light Systems, which specialises in finding new applications for SORS. The company develops scanners that can detect explosives in airports, keeping people safer, as well as a product line that supplies the pharmaceutical industry, and inspection tools for front-line services such as firefighters.

2008 The Artemis system opens, providing ultrashort, coherent pulses in the extreme UV. This allows researchers to create movies of electrons moving within molecules and 2D materials such as graphene.

2005 The CLF scientists develop and patent a technique called Spatially Offset Raman Spectroscopy (SORS), which allows researchers to look beneath an object's surface without cutting it open or damaging it.

2005 The Guinness Book of World Records certifies Vulcan as the world's most intense laser.

2009 The Ultra laser system, which can capture the dynamics of molecules with ultra-short pulses, opens for users. This system can freeze-frame chemical and biological reactions.

2009 The CLF establishes spin-out company Scitech Precision Ltd, which supplies bespoke microtargets for high-energy photon-science experiments worldwide.

2010s

2010 The state-of-the-art Research Complex at Harwell (RCaH) becomes the new home of the CLF's life sciences facilities – microscopy, spectroscopy and laser tweezers – creating a village atmosphere and encouraging cross-disciplinary collaboration between scientists.

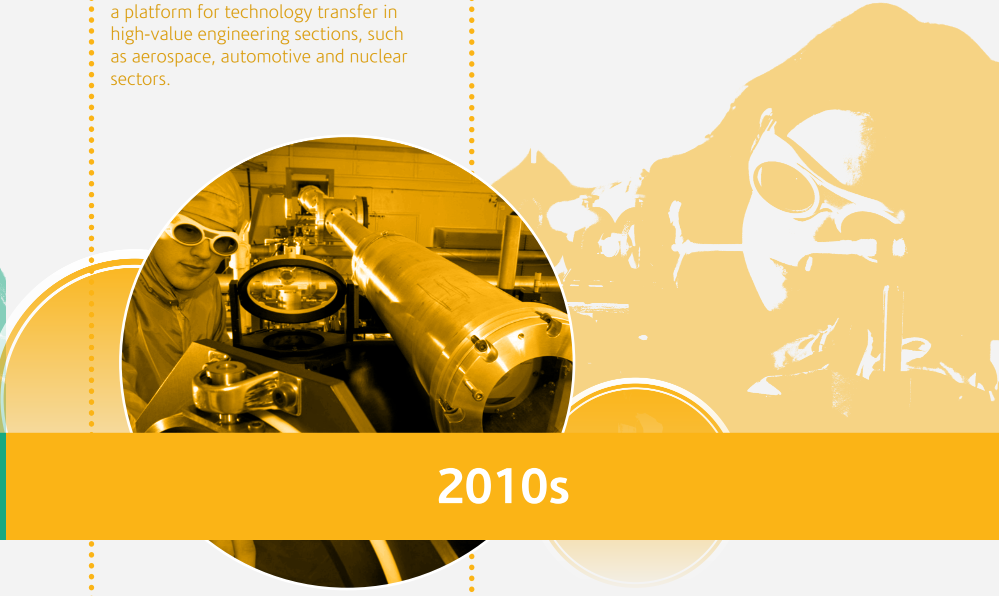
2011 Researchers use the recently opened Octopus system – a suite of laser microscopes that can see how molecules move within cells in real time – to make an important discovery in the field of cancer research by determining the precise shape of a molecule that instructs cells to grow and divide.

2011 Recognising how rapidly science and laser technology is advancing, the CLF sets up the Centre for Advanced Laser Technology and Applications (CALTA). Its main mission is to develop new laser technologies and provide a platform for technology transfer in high-value engineering sections, such as aerospace, automotive and nuclear sectors.

2014 The LIFEtime upgrade to Ultra gives the CLF a unique ability; it can explore the dynamics of chemical reactions and molecules across their whole lifetime, from femtoseconds up to milliseconds.

2014 Researchers use the Vulcan facility to create supernovas – tiny exploding stars – in the lab. This becomes one of Physics World's top 10 science breakthroughs of the year.

2014 A group of scientists use the Gemini laser to demonstrate an effect first hypothesised by Albert Einstein in 1905. He predicted that a reflection from a mirror moving close to the speed of light could generate bright light pulses with short wavelengths, and this was observed.



2012 CLF researchers develop and patent technology for the DiPOLE laser. This laser can fire ten-times a second, and is a key technology for commercial-scale laser accelerators and fusion drivers.

2013 The CLF partners with the UK's Defence Science and Technology Laboratory (DSTL) to work on the Gemini laser and patent. This laser-based X-ray radar technique could be used to detect landmines and other below-surface security inspections.

2016 DiPOLE 100, developed and built by the CLF, is delivered to the HiLASE facility in Czech Republic. This remarkable laser is the first of its class and can generate ten 100-joule pulses each second.

2017 The CLF moves to develop both Artemis and Ultra facilities using state-of-the-art mid-infrared OPCPA lasers, providing new opportunities for next generation facilities of the future.

Building on a history of scientific innovation and achievement, the future is looking bright for CLF...

Visit www.clf.stfc.ac.uk to find out what happens next.