Welcome to the winter 2014/15 edition of *Fascination*.

2015 is the International Year of Light (pg 22) and here at STFC, we’re kicking the first half of the year off with some exciting new plans. Find out more about what we’re looking forward to on page 12.

Prepare for a visual feast, as we showcase the more artistic side of science with some amazing science photographs. The field of crystallography has inspired a whole exhibition from photographer Max Alexander – see some of our favourite images from Illuminating Atoms (some featuring the faces of STFC’s own scientists), on page 18. And on page 26, you can check out the behind-the-scenes snaps that won the STFC Photowalk Competition 2014.

Imagine if we could capture movies of chemical and biological processes as they happen, letting you see every little reaction in the chain as it happens. Thanks to an amazing breakthrough at our VELA facility, we now have the know-how to make it happen. Find out more on page 16.

This edition of *Fascination* comes with a special supplement dedicated to the world of CERN – including features on everything you need to know, from supersymmetry to dark matter.

Best wishes for 2015,
Your Fascination editorial team

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Our scientific research seeks to understand the Universe from the largest astronomical scales to the tiniest constituents of matter. Providing access to and managing a range of world-class research facilities, STFC delivers fundamental insight and scientific breakthroughs in areas ranging from particle and nuclear physics to space, laser and materials science. Through our UK operations and our involvement in major international collaborations, we generate outcomes that shape societies, strengthen economies, build industries, create jobs and transform lives.

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Don’t miss an issue

*Fascination* is STFC’s quarterly in-house magazine. We also produce ad-hoc themed editions throughout the year. To receive an electronic version straight into your inbox, please visit: www.stfc.ac.uk/fascination and subscribe.

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**ABOUT US**

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**CONTACT US**

We’d love to hear what you think.
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Cover: Venki Ramakrishnan
Structural Biologist, MRC Laboratory of Molecular Biology, University of Cambridge. Credit: Max Alexander
**NEWS**

**New technology to help diagnose AMD undergoes human trials**

Age-related Macular Degeneration (AMD) is the leading cause of sight loss in adults living in the developed world. It affects the macula, a small, specialised part of the retina at the back of the eye, which allows you to see fine detail and recognise colours. AMD leaves sufferers unable to see things that are directly in front of them, makes vision blurry and distorted, and over a period of time, can cause a black spot in the centre of vision. No bigger than a pin head, the macula is made up of photoreceptor cells called cone cells, which help us see in the daylight and provide the basis for colour vision. One of the earliest signs of AMD is a change in the way that these light-sensitive pigments regenerate after exposure to light.

Engineers at STFC’s UK Astronomy Technology Centre in Edinburgh are usually busy designing and building instruments that can detect faint light from distant galaxies and stars. But using this knowhow, in collaboration with scientists from Cardiff University’s School of Optometry and Vision Sciences, they have developed a prototype instrument called the ‘densitometer’, which can identify the earliest stages of AMD. The densitometer closely monitors minute changes in the amount of light reflected by the retina over time, and how the eye responds after exposure to light.

Funded by the National Institute for Health Research’s Invention for Innovation (i4i) programme and STFC, through our Commercial Proof of Concept Fund, the prototype was shipped from UK ATC to Cardiff University on 25 November 2014. There it will be used for realistic engineering tests involving human volunteers before further versions are deployed for clinical trials.

Dave Melotte leads the team as the densitometer is shipped. Credit: STFC

**STFC-funded animation wins a 2014 European Science TV and New Media Award**

An animated film by the Royal Institution (RI) and animation studio 12foot6, funded by STFC, has won an award for ‘The Best New Media Production’ at the 2014 European Science TV and New Media Festival. Narrated by structural biologist Stephen Curry ‘Celebrating Crystallography’ takes viewers on an animated journey through the past 100 years of crystallography, delving into the impactful field’s rich and varied history. Crystallography is used by scientists to find out how atoms are bonded together. It has broad applications and is used across various fields of science – from drug design and developing new materials through to mineralogy and space exploration.

The award winners were announced at a ceremony at Ciencia Viva in Lisbon on 28 November 2014, during the International Year of Crystallography.

You can watch the award-winning animation on the RI Channel: www.richannel.org

**STFC in new initiative to protect the UK and the USA from cyber-attacks**

In November 2014, members of STFC’s Futures team traveled to Washington, to take part in the launch of an important new cybersecurity initiative with the US Department of Homeland Security. The Collaboration on Resilience and Security (ColoRS) meeting was held to look at innovative ways to protect both the UK and the US infrastructure from the growing threat of cyber-attacks, and the emergency responses we need to put in place should one happen.

The meeting, the first of its kind, was attended by 35 multi-disciplinary academics and government officials. It was a huge success, and will culminate in novel research and a number of publications, including a book, to be published in 2015.

The ColoRS meeting gets underway. Credit: STFC
VELA helps test new travel security technologies

Rapiscan Systems have teamed up with University College London to use STFC’s Versatile Electron Linear Accelerator (VELA) for innovative testing to develop new travel security technologies.

Rapiscan Systems is a global provider of walk-through metal detectors and cargo-scanning X-ray machines, and as such is constantly investing in innovative new research and development to maintain its position at the forefront of innovative technological developments. In particular, Rapiscan was keenly interested in methods of generating three-dimensional X-ray images for more comprehensive cargo screening.

VELA, based at our Daresbury Laboratory, is a particle accelerator with high-energy and short pulse widths, and, combined with the expertise of engineers at our Accelerator Science and Technology Centre, made the ideal facility to perform Rapiscan’s proof-of-concept work. These experiments, which would not be possible on any other accelerator in the UK, involved scattering X-ray photons off a series of objects.

Dr Edward Morton, Chief Technical Officer of Rapiscan Systems, said: “Rapiscan Systems is committed to creating a secure future for the travelling public and the development of new and innovative imaging techniques is key to achieving this goal. VELA was ideal for this project, which will help to establish the potential for the use of high-energy backscatter imaging in non-invasive inspection of large vehicles and cargo.”

Encouraging results from the proof-of-concept experiments carried out using VELA have prompted Rapiscan to continue long-term investment in this strategic product development programme.

The further the concept is developed, the more likely it will result in a breakthrough product that would return economic benefits for both the company and the UK in general, as well as protecting lasting job creation for skilled technical staff in the UK.

Read more about the latest developments on VELA on page 16.

First human trials show non-invasive diagnoses of bone disease possible

New research announced in November could lead to the early diagnosis and treatment of chronic, debilitating conditions such as ‘brittle bones’ and osteoporosis, and help improve the lives of tens of thousands of sufferers in the UK alone.

The researchers, from STFC, University College London (UCL), and the Royal National Orthopaedic Hospital, have used a technique known as spatially offset Raman spectroscopy (SORS) to test for the condition. The technique, originally developed at our Central Laser Facility, involves shining a laser through the skin to analyse the underlying chemistry of the bone, and can reveal differences between healthy and diseased bone.

This research has, for the first time, enabled detection of a genetic brittle bone disease known as osteogenesis imperfecta (OI), by simply scanning a patient’s limbs.

Until now, bone diseases have been diagnosed through X-rays, history of fractures and other clinical symptoms and, in the case of OI, genetic testing. The new technique could enable doctors to identify the bone diseases without having to use invasive diagnostic methods, or expose patients to radiation associated with the usual X-ray techniques.

“Presently, the range of clinical tools for early detection of these diseases is limited”, said UCL’s Dr Jemma Kerns, a researcher and clinical study manager for the project. “In the case of osteoporosis, people at higher risk of a fracture are identified using an association with bone density. However, the successful diagnosis of fracture risk in an individual is currently quite low. The SORS method could improve that rate and pave the way for studies of other bone diseases that have a large societal and economic impact.”

The research was funded by a £1.7 million grant from the Engineering and Physical Sciences Research Council, with facility time and other support coming from STFC. Control bone samples were provided by the Vesalius Clinical Training Centre, Bristol.

In December 2014, the same research team announced that they have successfully demonstrated this technique to test for rickets in human remains found on the Mary Rose. This will help historians understand the prevalence of such diseases at the time, but also inform our modern understanding of such metabolic bone diseases. For more information, see: www.stfc.ac.uk/3455

Stop press

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UK particle physics community welcomes first female Director-General of CERN

STFC receives Investors in People Gold award

UK now boasts more than 100 spectacular stargazing sites
Rosetta’s Philae lands successfully on comet 67P and casts some doubt on theories about how life on Earth began

After a nail-biting wait, on 12 November 2014, scenes of jubilation erupted in Darmstadt, Germany, as the European Space Agency (ESA) mission control received confirmation that Rosetta’s Philae lander had successfully touched down on comet 67P/Churyumov-Gerasimenko. The journey was eagerly followed by many, including the Prime Minister:

"It was great to gain some external recognition on behalf of the whole team, and it also proved to be a fantastic opportunity to talk to a wider audience about the work STFC and RAL Space do."

UrtheCast streaming is not yet available but will be rolled out in the coming months. Check the UrtheCast website for details: www.urthecast.com

Find out more about our graduate and wider recruitment schemes: www.stfc.ac.uk/1895

RAL Space engineer, Mike Salter, wins prestigious NI Award

Just two years after his graduation, RAL Space engineer, Mike Salter, has won a prestigious National Instruments (NI) Engineering Impact Award in the Electronics and Test Measurement category.

Mike won the award for his work on two advanced Earth-imaging cameras which were installed in the International Space Station (ISS) in 2013. The cameras were developed for UrtheCast, a project that will give anyone with an internet connection access to near-live Ultra-HD video footage of our planet from space. Footage will be streamed from the cameras aboard the ISS to the UrtheCast interactive web platform, allowing subscribers to explore virtually any part of the world from their computer or smart device, watching it change and evolve as time goes by.

Mike was involved in the project from day one, and played a major role in the development, building and testing of the award-winning cameras. Talking about his award, he said:

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Find out more about our graduate and wider recruitment schemes: www.stfc.ac.uk/1895

Joint Astronomy Centre telescopes in new transfers

Joint Astronomy Centre (JAC) has historically operated two telescopes on the summit of Mauna Kea: the James Clerk Maxwell Telescope (JCMT) and the United Kingdom Infrared Telescope (UKIRT).

The JCMT was transferred to the University of Hawaii (UH) on 31st October 2014, and is now operated by a new partnership between the University of Arizona and the Lockheed Martin Advanced Technology Center.

A process is in place for transferring the JCMT to UH ownership on 31st January 2015. It will then be operated by a new entity called the East Asian Observatory, supported by astronomical research institutes in Taiwan, China, South Korea and Japan, in collaboration with UK and Canadian universities.

Over their history these two telescopes have been a pinnacle of great science, and we wish them every success in the future to continue with their high-quality astronomical research.
Hello 2015!

AAAS
The American Association for the Advancement of Science (AAAS) annual meeting is a chance for scientists and organisations from all over the world to come together and share thoughts and ideas about pressing scientific matters. This year, the theme for the meeting is ‘Innovations, Information and Imaging’, and it will be held from 12 – 16 February in San Jose, California. STFC and the Biotechnology and Biological Sciences Research Council will be representing the UK, giving joint presentations on the UK’s approach to big data. There will also be presentations on how the Square Kilometre Array (SKA) is harnessing big astronomy data. Visit www.aaas.org for further information.

SuperSTEM 3 launch
In February, the Engineering and Physical Sciences Research Council (EPSRC) will launch the SuperSTEM3 microscope at our Daresbury Laboratory, marking another world first for the SuperSTEM Laboratory. This amazing microscope will boast the world’s highest energy resolution (10meV) and the world’s highest spatial resolution for a microscope operating in this energy range (0.1nm at 60KV, 0.8nm at 100kV). The SuperSTEM facility allows scientists to see the properties of materials at the atomic level, and SuperSTEM 3 has the potential to shift electron microscopy to a whole new level – giving scientists access to an unprecedented amount of detail. SuperSTEM3 will be the first instrument of its kind fully available to the UK and worldwide scientific community, as part of the open-access user facility funded by EPSRC. The new installation will strengthen the SuperSTEM Laboratory’s status as one of the premier centres for electron microscopy and spectroscopy in the world.

British Science Week 2015
This year, British Science Week (formerly National Science and Engineering Week) will take place 13 – 22 March, and will involve a huge, eclectic mix of fun events taking place up and down the country to celebrate all things science. As usual, STFC will be joining in with our own programme. Please visit our website and keep an eye on our social media channels to find out more nearer the time!

BBC Stargazing Live 2015
The ever-popular BBC Stargazing Live is back from 18 – 20 March 2015 for more sky-watching fun. This year, Stargazing Live has been planned to coincide with the next visible solar eclipse on 20 March, and we are currently working on an exciting line-up of supporting activities. Keep your eyes peeled to our website and social media channels for more information.

Training new medical physicists with the NHS
On 2 February 2015, we celebrated the opening of the brand new Medical Teaching Research Laboratory (MTRL), based at our Daresbury site in Cheshire. The MTRL is a unique facility in the UK. It houses a used SPECT/CT scanner which is dedicated to teaching and research. MTRL is a partnership between the University of Liverpool Physics Department, the Royal Liverpool University Hospital and STFC. It was born out of the need to provide hands-on training for students from the NHS Scientist Training Programme MSc course in Clinical Science (Medical Physics) taught by University of Liverpool.

Talking Science: The Light Fantastic
In celebration of the International Year of Light, join us on 20 March 2015 for a talk with experts from the Diamond Light Source, RAL Space and RAL’s Central Laser Facility, when we will discover some of the ways in which we explore our world using light. For more information or to book tickets, visit www.stfc.ac.uk/2840
Laser scientists’ new research could improve the treatment of the five million asthma sufferers in the UK

UK scientists have used a laser beam trap to examine how drug particles from asthma inhalers behave as they are projected through the air. Their findings could improve the effectiveness of inhalers for the more than five million people in the UK suffering from asthma.

How was it done?
Dr Andy Ward from the CLF explains: “We captured each particle by trapping it between two focused laser beams, and then tested its behaviour in different temperatures and levels of humidity. Our tests show how water is adsorbed by following changes in chemical bond vibrations. Usually such tests are done on a glass slide so this is the first time the particles have been tested while airborne, as they would be when travelling through the respiratory tract.” The term ‘adsorbed’ refers to the binding of molecules or particles to a surface – which is different from absorption, the filling of pores in a solid.

We would not have been able to do this work without the unique capability of these lasers to capture and levitate particles.

“A research team, made up of scientists from the Universities of Birmingham and Cambridge, Imperial College London and from STFC, used the Octopus laser imaging facility at our Central Laser Facility (CLF), Oxfordshire, to trap individual solid particles of the drug salbutamol sulphate. They then suspended them in air to test how the particles behave in conditions that simulate the human respiratory system. Funded by STFC, the Natural Environment Research Council and the European Research Council, this is the first time tests on microscopic particles have been carried out in an environment that mimics their journey from inhaler to lung.

The human respiratory tract is anatomically evolved to prevent particles being inhaled”, says Dr Peter Seville from the University of Birmingham’s School of Clinical and Experimental Medicine, one of the researchers on the project.

“To overcome the natural defence mechanisms of the body, complex delivery devices and extremely small drug particles are required. These particles are typically 2-5 micron in diameter, making them approximately a tenth of the width of a human hair. Any moisture that clings to the particles as they travel from inhaler to lung is likely to increase the particles’ size, and this may affect the site of particle deposition within the lung. It can result in the drug being deposited in a non-ideal site, giving rise to less effective treatment and potentially an increase in side-effects.”

Using raman spectroscopy techniques to measure the vibration and wavelength of light from molecules, the research team was able to provide a new method of studying the salbutamol sulphate as it exited from a commercially-available inhaler.

They discharged the inhaler into the optical laser trap, and without changing the drug’s physical and chemical properties, captured a microscopic particle in air. They then recorded its size, shape and chemical signature to show evidence of any water adsorption. This all happened within a matter of seconds, closely replicating the time, relative humidity and trajectory of the particle in the lung.

Improving asthma treatments
Over 73 million inhalers are used every year in the UK. By studying how the expelled drug particles might behave as they enter the human respiratory tract and travel into the lungs, this new research could lead to an improvement in the formulation of these drug delivery systems, increasing their effectiveness whilst reducing negative side-effects. Lead investigator, Dr Francis Pope from the University of Birmingham, says: “This research could lead to more efficient inhalers to deliver drugs for respiratory problems. Our results will also inform pharmaceutical companies who may be looking to improve the chemical structure of the drug, increasing effectiveness whilst reducing negative side-effects. We would not have been able to do this work without the unique capability of these lasers to capture and levitate particles, providing a new way to test the performance of the inhalers.”

More information about the CLF can be found at www.stfc.ac.uk/clf

© Jason Stitt | Dreamstime.com
Our Versatile Electron Linear Accelerator (VELA) facility’s amazing new imaging capability takes biological and materials research beyond the limits of what is currently possible in the UK and is a step towards making ‘molecular movies’.

What is ultra-fast electron diffraction?
Diffraction imaging itself is not new and has already led to the development of new drugs and understanding of viruses such as HIV and foot and mouth disease. However, these discoveries have relied on high-intensity X-rays that can change or destroy the tiny and fragile samples of materials before valuable information is gained. Ultra-fast electron diffraction imaging, which uses short, fast pulses of electrons, causes little damage to these samples and can therefore take biological research beyond what is possible with X-rays on third generation light sources.

How can we use it?
Ultra-fast electron diffraction is exciting news, particularly for the drug discovery sector, because it means that UK researchers will now be able to look at protein membranes in a way that they have not been able to before. There are thousands of protein molecules within the protein membrane of one single human cell. These proteins control the movement of substances into and out of the cell, and send signals from the outside of the cell to the interior. They are the key targets of drugs, and over half of the drugs on the market today work by interacting with proteins in the cell membrane. The fragility of these proteins limits what we can find out about them by X-ray, but ultra-fast electron diffraction removes this risk.

Talking about the discovery, Minister for Universities, Science and Cities Greg Clark, said: “This visionary breakthrough at Daresbury Laboratory is a further demonstration of how British expertise is pushing the boundaries of science. Not only will this development mean that the scientific community can work more efficiently, but it could help pave the way for new treatments to use in the fight against viruses and diseases”.

What is a ‘molecular movie’?
‘Molecular movies’ are a way to document chemical and biological processes, and are made up of lots of images taken very quickly as the processes take place – like a movie. This is made possible by the ultra-fast shutter speed achieved at VELA, and puts the UK well on track to being one of the only places in the world capable of making them.

STFC’s Dr Mark Surman led the experiment which achieved the ultra-fast images on samples of platinum, aluminium and gold. Dr Surman said: “The capability that we have achieved here provides a much lower cost alternative that can be used on smaller accelerators, which might only be a few meters in length. This is a major milestone for VELA and we are really looking forward to taking this capability to the next level, which is to make molecular movies that can be used by industry to develop new products.”

The result of a £2.5 million investment into Daresbury Laboratory for accelerator technology developments, VELA has been purpose-built to assist UK industry in bridging the gap between prototypes and market-ready products, by making this ultra-fast imaging technique available at a fraction of the cost and physical size of facilities using other methods.

For more information about VELA, visit: www.stfc.ac.uk/2617

STFC’s newest particle accelerator, VELA, has successfully taken images of the atomic structure of materials - at a shutter speed close to one ten-thousandth of a billionth of a second. Known as ‘ultra-fast electron diffraction’ the technique is a UK first, and a remarkable milestone for researchers at our Daresbury Laboratory in Cheshire, where VELA is based.

Electron diffraction from gold acquired with 1000 VELA shots in 100 seconds.
Max Alexander: Illuminating Atoms

Last year was the International Year of Crystallography. To celebrate, we co-sponsored Illuminating Atoms, a photographic exhibition by Max Alexander, held at the Royal Albert Hall in November 2014.

Crystallography reveals the atomic structure of materials, from minerals, to magnets, to viruses, and it underpins many of the biggest scientific discoveries of the past 100 years, including the chemical structures of antibiotics and DNA.

By exposing a crystal to a beam of X-rays, neutrons or electrons, it is possible to obtain the characteristic 'diffraction' pattern of a material and work out where the atoms are located inside the crystal. The technique of X-ray crystallography was first established in 1913 by William and Lawrence Bragg, a father and son team who were awarded the 1915 Nobel Prize for Physics for their work.

UK crystallographers have always led the world in chemical, physical and biological sciences, with significant contributions in studies of disease, catalysts, batteries and climate change. Women scientists are also strongly represented with Rosalind Franklin and Dorothy Hodgkin amongst many successful British female crystallographers.

To celebrate the International Year of Crystallography, STFC, along with co-sponsors The Diamond Light Source Ltd, the Wellcome Trust, GlaxoSmithKline (GSK), Astra Zeneca and Pharmorphix, sponsored Illuminating Atoms, a selection of photographs by Max Alexander portraying the inspirational work of crystallographers. Through portrait and documentary photography, Max shows us the life of scientists at the cutting-edge of discovery, including some of the world-class facilities they use. This is Max Alexander’s second exhibition at the Royal Albert Hall, the first being Explorers of the Universe in 2009.

The full exhibition can be viewed on our website, at www.stfc.ac.uk/3388
Anna Warren
Macromolecular Crystallographer, Diamond Light Source, Didcot Credit: Max Alexander

Emma McCabe
Chemist, School of Physical Sciences, University of Kent Credit: Max Alexander

Sam Callear, Chemist, STFC ISIS Facility, Didcot. Credit: Max Alexander
INTERNATIONAL YEAR OF LIGHT 2015

STFC is celebrating the International Year of Light, a global celebration throughout 2015 that aims to highlight the amazing impact of light science and light-based technologies to the world. In this special feature, find out how scientists at STFC are using lasers to improve modern life.

You can’t go very far without encountering a laser these days. They’re used to read Blu-ray discs and DVDs, by laser printers and barcode scanners and for handy things like laser pointers. Lasers are used in surgery, for industrial cutting and welding, and even for entertaining light shows.

What are lasers?
The word ‘laser’ is an acronym for ‘Light Amplification by Stimulated Emission of Radiation’, and it’s used to describe coherent beams of light. Lasers can be tightly focused, enabling applications such as cutting and welding. Lasers can also have a very narrow spectrum of light, meaning they emit only one colour (wavelength), and can produce extremely short bursts of light that are a valuable research tool for scientists.

STFC’s Central Laser Facility (CLF)
The CLF, based at our Rutherford Appleton Laboratory, is one of the world’s leading laser facilities, providing scientists from the UK and Europe with an unparalleled range of state-of-the-art technology. Headed up by Professor John Collier, CLF is home to some very special lasers that are allowing our scientists to make interesting discoveries in chemistry, physics and biology. They help us understand more about our environment, diagnose and treat diseases, produce potential new energy sources and even prevent terrorism.

Lasers for health
The Octopus facility at CLF has a central core of around 20 lasers, coupled with high-powered microscopes. The Octopus team, led by Dr Marisa Martin-Fernandez, is at the forefront of research into using lasers for the diagnosis and treatment of diseases, such as lung and breast cancer.

By tagging ‘misbehaving’ proteins in a patient’s cells and using lasers to illuminate the molecules, our scientists can build up a complex picture of the exact molecular interactions that lead to disease. This picture, unique to every patient, will enable doctors to tailor medication to a patient’s DNA fingerprint, to target the exact disease pattern with minimal side-effects.

Laser science is also involved in a new generation of therapeutic radiation sources that could be small enough to be placed in hospitals and used for cancer detection and therapy. These compact sources use high-power laser pulses to accelerate charged particles, producing beams of high-energy particles as well as very short bursts of X-rays that could be used in imaging and radiation therapy.

Lasers for security
Explosives emit a cocktail of volatile chemicals and the combination of these creates a unique fingerprint. When you ‘read’ this fingerprint, it is possible to detect a number of dangerous substances, and this is just one of the ways that laser research is being applied to the field of security.

Scientists at STFC spin-out company, Cobalt Light Systems, have used a laser spectroscopy technique to create a detection system that could identify liquid explosives, even when concealed in an opaque bottle. This laser-based technology is also under investigation for the detection of counterfeit and illicit drugs, and biological and chemical warfare agents.

When a high-power laser is driven into a foil target, it produces an intense burst of gamma rays. The team at the Central Laser Facility Centre for Advanced Laser Technology and Applications (CALTA) is hoping to use this technology for advanced imaging to screen large mobile container crates at ports, for instance.

Lasers for environment
Laser beam ‘tweezers’ are helping scientists gain an insight into climate change – one of the most important environmental issues on our planet.

The tweezers are made from two beams of laser light and can be used to hold the individual micro-droplets that make up clouds. Clouds absorb and reflect heat and are thought to have a substantial impact on climate change. But pollutants, produced by burning fossil fuels, can affect the formation and growth of water droplets in the clouds. By studying the droplets, and mimicking their behaviour in controlled laboratory conditions, scientists can then reveal some of the complex chemistry behind climate change.

Observing and capturing microscopic objects using specialist laser techniques at the CLF is allowing us to understand more about our environment. But laser tweezers are also being used to identify and study individual microbes that are good at eating certain types of pollution, as well as manipulating structures inside plant cells to watch and understand how plants transport nutrients during growth.

Did you know?
Once up and running, the CLF’s upgraded Vulcan 10 PW will be the most powerful laser in the world.
Lasers for understanding space

Supernova explosions, triggered when the fuel within a star reignites or its core collapses, launch a detonation shock wave that sweeps through several light years of space from the exploding star in just a few hundred years. But not all such explosions are alike and some, such as Cassiopeia A, which is 11,000 light years from the Earth, show puzzling irregular shapes made of knots and twists.

An international team, led by Professor Gianluca Gregori from the University of Oxford, used the Vulcan laser to recreate a supernova explosion in the laboratory, to investigate what might cause these peculiar shapes.

The team focused three laser beams onto a carbon rod target, not much thicker than a strand of hair, in a low density gas-filled chamber. The enormous amount of heat generated by the laser - more than a few million degrees Celsius - caused the rod to explode, creating a blast that expanded out through the low density gas. The dense gas clumps or gas clouds that surround an exploding star were simulated by introducing a plastic grid to disturb and introduce turbulence into the expanding blast wave. The experiment demonstrated that, as the blast of the explosion passes through the grid, it becomes irregular and turbulent, just like the images from Cassiopeia.

Lasers for life

It’s been nearly fifty-five years since the invention of the first laser, but it has already revolutionised both science and the way we live. The next fifty years could be equally impressive. The facilities at CLF maintain their international competitiveness through a vigorous development programme and deliver world-class laser systems to its users.

A new technology platform, called DIPOLe, is being developed to enable pioneering and exciting new applications of laser technology. DIPOLe is focused on delivering a high average power laser system, capable of firing pulses ten times a second. As well as bringing major benefits to the science world, DIPOLe will have a positive impact on sectors including security, energy, space, defence, manufacturing and health.

Laser technology is innovative, diverse and life-changing. The future looks brighter already.

Get involved

For more on the International Year of Light, follow: @IYL2015, search #IYL2015 or visit www.Light2015.org

For further information about STFC’s lasers, visit www.stfc.ac.uk/light

How much impact did our work have in the last year?

Find out in our brand new STFC Impact Report 2014.

Our vision is to maximise the impact of our knowledge, skills, facilities and resources for the benefit of the United Kingdom and its people. The STFC Impact Report 2014 illustrates the extraordinary breadth and depth of the economic and societal impact we achieve, with quantitative data and case studies. In this edition of the report, we showcase how STFC has played a key role in delivering impact from CERN, as the facility celebrates its 60th anniversary.

Some highlights from this year's report include:

World-class research

- Our research remains amongst the best in the world, as measured by citation impact in astronomy, nuclear physics and particle physics. STFC also consistently outperforms the other areas of physical sciences in the UK in terms of research quality.
- The Rosetta spacecraft has manoeuvred beside a comet and landed a probe on the surface of the comet, thanks to significant UK academic and industrial involvement. The spacecraft has delivered several firsts in space exploration, making it one of the most complex and ambitious missions ever undertaken.
- Our research has been applied to detect the earliest stages of eye disease, made a breakthrough in the race to solve antibiotic resistance and is supporting carbon capture and storage to help the UK meet its greenhouse gas emissions target.

World-class innovation

- Our campuses host over 230 enterprises and support more than 5,000 jobs. This year our tenant companies at Sci-Tech Daresbury created over 100 jobs, delivered £52 million in sales, attracted £97 million of investment and developed 97 new products.
- A new incubation facility, commemorating Peter Higgs, will exploit the UK Astronomy Technology Centre’s capabilities in instrumentation for space and big data. The £10.7 million Higgs Centre for Innovation will host 12 small businesses, bridging the gap between research and industry.

World-class skills

- We have invested £22.4 million in postgraduate training and fellowships in particle physics, nuclear physics and astronomy. Our current cohort of 766 PhD students are trained in the high-end scientific, analytical and technical skills which drive the knowledge economy.
- We play a key role in attracting young people to follow STEM (science, technology, engineering and mathematics) careers. In 2013, applications to study physics at university increased a further 7% from the year before. There has been an increase in applications of 64% between 2008 and 2013.
- STFC research inspires future generations to study STEM subjects. Between 2009 and 2014, we reached 84 million members of the public through four STFC mass media initiatives.

Get involved

For more on the International Year of Light, follow: @IYL2015, search #IYL2015 or visit www.Light2015.org

For further information about STFC’s lasers, visit www.stfc.ac.uk/light
STFC Photowalk Competition: 2014

Between June and July 2014, we staged our third STFC Photowalk Competition, providing 204 photographers with ‘behind-the-scenes’ access to world-leading facilities at each of the main STFC science sites within the UK. Competition was fierce, but in November 2014, the judges chose the lucky winners. And here they are…

1st

The National Winner
Photographer: John Willoughby
The Polref instrument in ISIS Target Station 2 takes centre stage. The photographer captures some of the multitude of cables and pipes needed to operate the instrument. (Credit: STFC/John Willoughby)

Online Winner
Photographer: Mike Tyldesley
At one with the machines - ASTeC employee, Oleg Malshev, working in the Vacuum laboratory at the Cockcroft Institute. (Credit: STFC/Mike Tyldesley)

Highly Commended
Photographer: Katharine Barnes
The access service tunnel running underneath the Chilbolton Observatory in Hampshire. (Credit: STFC/Katharine Barnes)

Regional Winner
Chilbolton, Hampshire
Photographer: Mervyn Edwards
The 6.1m antenna scans the sky at the Chilbolton Observatory. (Credit: STFC/Mervyn Edwards)

Regional Winner
Daresbury Laboratory, Cheshire
Photographer: Paul Worpole
A vacuum vessel with glass viewing port. (Credit: STFC/Paul Worpole)

Regional Winner
UK Astronomy Technology Centre (UK ATC), Edinburgh
Photographer: Eric Begbie
“Lines made with light” - diffraction gratings at the UK ATC. (Credit: STFC/Eric Begbie)
Big data; big impact: how the UK is leading the world in data-intensive science

Big data is helping us to learn more about the Universe we live in, and to answer some fundamental questions. But reaping all of the benefits that big data offers us means constant innovation in computing and communications – and the UK is leading the way.

Transforming UK business

STFC's Hartree Centre at Daresbury Laboratory, Cheshire, is an industrial gateway to world-class high-performance computing and simulation technology. Home to the UK's most powerful supercomputer dedicated to the development, deployment and demonstration of new software, it enables new high-performance computing collaborations that promote UK economic growth.

In the Autumn Statement on 3 December 2014, the Government announced an investment of £113 million into Hartree's high-performance computing capabilities – a move which is expected to give UK business a two-year head start over international competitors, transform the way we do business, and the way we do science.

At present, our many existing data sets are so large that even the data experts find it difficult to extract much insight from them. The new two-year Government investment signals an enhanced collaboration with IBM to improve and substantially expand the data-intensive research capabilities of the Hartree Centre. Cognitive computing systems ‘learn’ in similar ways to human development, and the goal is to enable not only scientists, but doctors, bankers, retailers and others to extract the full value of their data and thus make better, more accurate and more timely decisions and discoveries.

Universities, Science and Cities Minister Greg Clark said: “The Government’s investment will create an exciting innovation environment that will enable UK industry to exploit value from advanced computing and big data to create new and improved products, services and manufacturing processes.”

As well as creating the new structures, architectures and tools needed to help non-scientists take advantage of big data, the Hartree Centre will deliver computing capability to the international Square Kilometre Array (SKA) project through its headquarters at Jodrell Bank, and to a variety of national projects including the Turing Centre in London, and the new national materials institute in Manchester.

The advanced supercomputing facilities and highly-skilled scientists at the Hartree Centre, combined with IBM’s big data and analytics technology, is now enabling companies to quickly identify the value in their data and design their own big data technology system to meet their individual business needs. This could be anything, from developing new products more quickly and cheaply, to understanding disease and developing new drugs. Once a company has completed a successful ‘proof of concept’ of their system, the Hartree team will help them establish it, facilitating the journey from initial business objective through to a fully-operational system.

Lee Hannis, Business Development Manager at the Hartree Centre, says: “STFC’s Hartree Centre has a great track record of delivering high-performance computing services to industry and developing algorithms and complex models that are used to create new products faster and cheaper. This new collaboration in data analytics provides an obvious and exciting extension to open up our skills to a wider business audience. This unique toolset will allow any company to accelerate their understanding of data and its value within their business.”

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Delivering high-tech infrastructure

In general it is not public demand that drives computing advances, but the requirements of researchers to collect, store and manipulate increasingly large and complex datasets. Big science projects, such as those supported by STFC, have consistently pushed the boundaries of data volumes and complexity, serving as “stretch goals” that drive technical innovation.

Housed at our Rutherford Appleton Laboratory, JASMIN is half supercomputer and half data centre, called a ‘super-data-cluster’. It delivers the high-tech infrastructure needed for environmental science research in the UK and Europe.

Educating Europe’s scientists in the research programmes of tomorrow

The ELIXIR project is a pan-European initiative that aims to develop a sustainable big data infrastructure for the life sciences, supported in the UK by the Medical Research Council (MRC), the European Molecular Biology Laboratory’s European Bioinformatics Institute (EMBL-EBI), the Natural Environment Research Council (NERC), the Biotechnology and Biological Sciences Research Council (BBSRC) and The Wellcome Trust. ELIXIR will provide researchers with easy access to biological data from all over Europe – supporting life science research in areas such as medicine, bioindustries, agriculture and society.

To transform big data captured by ELIXIR into meaningful results that lead to new life sciences breakthroughs and innovations, scientists require training and opportunities for interdisciplinary collaboration. ELIXIR UK is taking the European lead in training UK and European scientists in both academic and industrial arenas, working in collaboration with scientists, key organisations and specialised centres to develop a new big data training strategy.

These activities are coordinated at ELIXIR’s Central Hub, the nerve centre for bioinformatics in Europe, which is based on the Wellcome Trust Genome Campus in Hinxton, Cambridge. The Hub is positioned alongside EMBL-EBI, a world-leading centre for computational biology and long-time champion of open data in the life sciences.

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JASMIN’s high bandwidth networks link it to satellite installations at the Universities of Bristol, Leeds, Reading and Edinburgh as well as Plymouth Marine Labs and the Met Office, where data is collected. It is funded by the Natural Environment Research Council (NERC) and the UK Space Agency (UKSA) and delivered by STFC.

Professor Duncan Wingham, NERC’s chief executive, says: “JASMIN is a unique hybrid of high-performance computing, storage and networking, coupled with cloud hosting capabilities. It will make a significant contribution to one of NERC’s most strategically important challenges: the improvement of predictive environmental science.”

Professor Peter Jan van Leeuwen, acting director of the National Centre for Earth Observation, added “With JASMIN, the UK will be well-placed to exploit the wealth of Earth observation data coming from the European Space Agency and elsewhere over the next decade.”

Supporting big science

The Square Kilometre Array (SKA) will be the world’s largest and most sensitive radio telescope. Thousands of radio wave receptors (antennae) will combine to allow the SKA to see back into the early Universe, before the stars were formed. It will allow researchers to investigate a wide range of fundamental questions in physics, astronomy, cosmology and astrobiology, exploring distant parts of the Universe for the first time.

The SKA presents unprecedented big data challenges. It uses powerful supercomputers to digitally combine the signals from each antenna, providing a virtual telescope with a collecting area of a square kilometre. It will be 50 times more powerful than any existing radio telescope, and the data it will collect in just one day will be enough to fill 15 million 64 Gb mp3 players. In fact, it would take nearly two million years to play back on an iPod. The SKA central computer will need to have the processing power of over a 100 million PCs.

The UK is leading two consortia – Signal and Data Transport (SaDT) and Science Data Processor (SDP). The SDP consortium is focused on the technology needed to turn the data collected into useable science products, whilst the SaDT consortium is responsible for the design of the data transport networks that will have to handle the volume of data. Dr Keith Grainge, Deputy Lead of the SaDT consortium, says: “The SKA will be an extraordinary project. The flow of data we need to transport from the antennae to the processors is equivalent to the entire world’s internet traffic rate in 2011. In addition, we will need to synchronize the clocks at each antenna to a thousand-billionth (0.000,000,000,001) of a second. With the team of experts we have round the world, we are confident that we can meet these challenges and we are all looking forward to exploring some fascinating new areas of science with the telescope.”

Find out more about the Hartree Centre: www.stfc.ac.uk/hartree

UK companies keeping their fingers on the pulse at the Hartree Centre

Global healthcare company GSK is working with the Hartree Centre to develop clustering techniques, similar to that used on social networking sites, to enhance the understanding of diseases. ‘Disease mapping’ looks at a wide array of source data from various journals and other records to identify correlations between genes, biological processes and known diseases.

Democrata, a UK construction company, is using the powerful analytics at Hartree Centre to automate environmental impact assessments and predict risk better. Surveys are required to analyse a multitude of data sets, for example, to understand the impact of a high-speed rail link or a new road, and in the past this has been a slow and cumbersome task. Using the big data analytics, automated searches and queries on disparate data sets provided by Hartree gives way to faster and cheaper decision-making for large engineering and construction firms.

KnowNow Information, an IBM business partner, is helping local government emergency service providers improve their decision-making and resources planning. Using the Hartree Centre’s big data analytics technology and calling on the expertise of its data scientists, the emergency services provider can now see patterns of incidents across their territory, and the system can begin to predict where and when to allocate resources. This has the potential to save time and money for all emergency response teams.
Opening in 1964, the Atlas Computer Laboratory at RAL was one of the first purpose-built computing facilities in the world, and was home to the Ferranti Atlas 1 computer – one of the most powerful and innovative computers in the world at the time and the first general-purpose super-computer to be built in this country.

The world’s first computer animations were produced at the laboratory, and it has even helped win an Academy Award: the laboratory’s facilities were used to produce the 3D wire-frame model shown on the navigation monitors in the landing sequence of the Ridley Scott film ‘Alien’ - which won the 1979 Academy Award for best visual effects.

Instead of running a job on their local network or on a distributed computing grid as we do now, in the 1960s and 70s, universities and other research establishments that needed to use computing facilities had to put their program and data onto punch cards and post them to the Atlas Computing Laboratory, where their program would be run for them. The design of Atlas is incredibly important to modern computers, and led to many computing concepts we now take for granted, including multi-tasking operating systems, virtual memory and compiler techniques.

On 13 November, over 200 people came to RAL to help us celebrate the half-century milestone. We had a series of afternoon lectures on the past, present and future of supercomputing, with talks on visualisation, climate modelling and computing for the Large Hadron Collider, amongst others. The lectures were followed by a tour around our Atlas exhibition, where visitors could see the console from the original Atlas computer, together with memorabilia of the time.

We even managed some extra research: one of the life-size historical photos we used as part of the exhibition allowed a computing historian to determine, for the first time, the precise arrangement of Atlas circuit boards in a particular cabinet.

Celebrations continued on 14 November, as local primary school children came to the lab to learn about computer programming.

For more information about scientific computing at STFC, visit: www.stfc.ac.uk/920

Children show adults the future of learning in ‘FIRST LEGO League’ regional final

On 4 and 5 December 2014, Daresbury Laboratory hosted the FIRST LEGO League (FLL) regional final, where 17 teams of children from Manchester and Warrington gathered to compete in the regional heat of this year’s challenge.

Taking place worldwide, the annual FLL is a science and technology competition for students aged between 9-16. It aims to encourage students to be innovative with technology and develop the key skills they need for their future careers. Each year, FLL teams are set a ‘World Class Challenge’ to address, which for 2014, was to redefine how we learn in the future.

At the regional final, teams (whose members were aged between 9 – 14) were given a project to identify a problem related to the FLL World Class Challenge, conduct some research into the issue and propose their solution.

Teams were also encouraged to think like engineers and scientists as they built, programmed and tested Lego Mindstorm Robots to compete in robot table battles and a series of robot games, completing missions against the clock whilst trying to achieve the highest point scores. Between rounds, teams were able to modify and reprogram their robots to adapt to unexpected challenges.

Judges were not only looking for the teams’ ability to strategically design their robots and take part in the project task, but also how they demonstrated FIRST LEGO League ‘Core Values’ – ‘Gracious Professionalism’ and ‘Cooperation’, values set up by FLL to encourage children to show respect to one another, be kind, share their knowledge and work as a team.

As the competition wound to a close, the winners were announced in the Merrison Lecture Theatre with the Manga Masters from St. Thomas’ Church of England Primary School winning the first day and Withington Girls School winning the second. Both teams will now go through to compete in the national finals to be held later in the academic year.

The FLL event celebrated the achievements of the young contestants and most importantly, inspired them with science and technology. It was a fantastic experience for the young people involved, and a pleasure to see boys and girls in equal numbers getting excited about science and technology. Daresbury Laboratory will be looking forward to hosting the event again next year and hopefully for many years to come.
Science and Technology Facilities Council - Fascination

Winter 2014/15

STFC has welcomed the popular Talking Science lecture series back to Daresbury Laboratory and the Rutherford Appleton Laboratory. The first part of the programme has already been a roaring success with most of the lectures being fully booked, and we have a jam-packed schedule of exciting lectures lined up for 2015.

Lectures are free to attend and always have a brilliant turn-out, so why not come along and learn something new from one of our amazing speakers?

Upcoming lectures include:

**Indestructible Energy**, 20 February, Daresbury Laboratory, 13:00/19:00 – appropriate for ages 5/6+
Dr Jamie Gallagher, University of Glasgow
Petrol, ping pong balls, calories and cookies – what do they all have in common? Energy! FameLabber Jamie Gallagher burns food, bounces balls and generates electricity as he shows us what energy is and why we can’t create or destroy it. Take part in his energy swap shop game; explore how your body is like a combustion engine and why cars burn petrol instead of eating cookies!

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**Eat, Play, Collide!** 20 February, Rutherford Appleton Laboratory, 13:30/19:00
Dr. Suzie Sheehy, ASTeC, STFC
Crack open the food on your plate and find interesting science oozing out everywhere. In this fun demonstration-packed talk, we’ll tour through quantum physics, extreme states of matter and gigantic atom smashers all with the help of ingredients you might find in your lunch box. What is a calorie, really? How are sugar cubes connected to neutron science? What can grapes tell us about the next generation of particle accelerators? Once you’ve done with the entrée, move onto the main course and learn how to cook a frozen pizza with the Large Hadron Collider. You’ll never look at your lunch in quite the same way again.

**Gamma-rays: Imaging the invisible**, 27 March 2015, Daresbury Laboratory, 19:00 – appropriate for ages 14+
Dr Laura Harkness-Brennan, University of Liverpool
This lecture will outline the latest research being carried out by the University of Liverpool to revolutionise gamma-ray imaging. Nuclear imaging plays a key role in medicine, the energy industry, security and environmental monitoring. New areas of application include monitoring radiation uptake of plants, which is important in fallout areas such as near Fukushima.

**The Light Fantastic**, Friday 20 March 13:30/19:00, Rutherford Appleton Laboratory
(Doors open 13 Feb)
Diamond Light Source, RAL Space and the Central Laser Facility
Light helps us to make sense of the world, we can use it to look at the smallest creatures or investigate the furthest galaxies. Light itself is made up of more than just the colours of the rainbow; it is the heat that comes off a roaring fire, or the X-ray that sees a broken bone.

All of these types of light tell us more about how the Universe works, heat from distant galaxies shows us where new stars are born, and X-rays can probe into the very heart of materials to show us why a diamond is the same as a lump of coal.

In celebration of the International Year of Light, join us for a talk with the Diamond Light Source, RAL Space and RAL’s Central Laser Facility, where we will discover some of the ways in which we explore our world using light.

Lectures need to be booked in advance

To see the full programme of events and for booking information about lectures at RAL, please visit: www.stfc.ac.uk/2480
To see the full programme of events and for booking information about lectures at Daresbury Laboratory, please visit: www.stfc.ac.uk/2454

Booking and more information
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