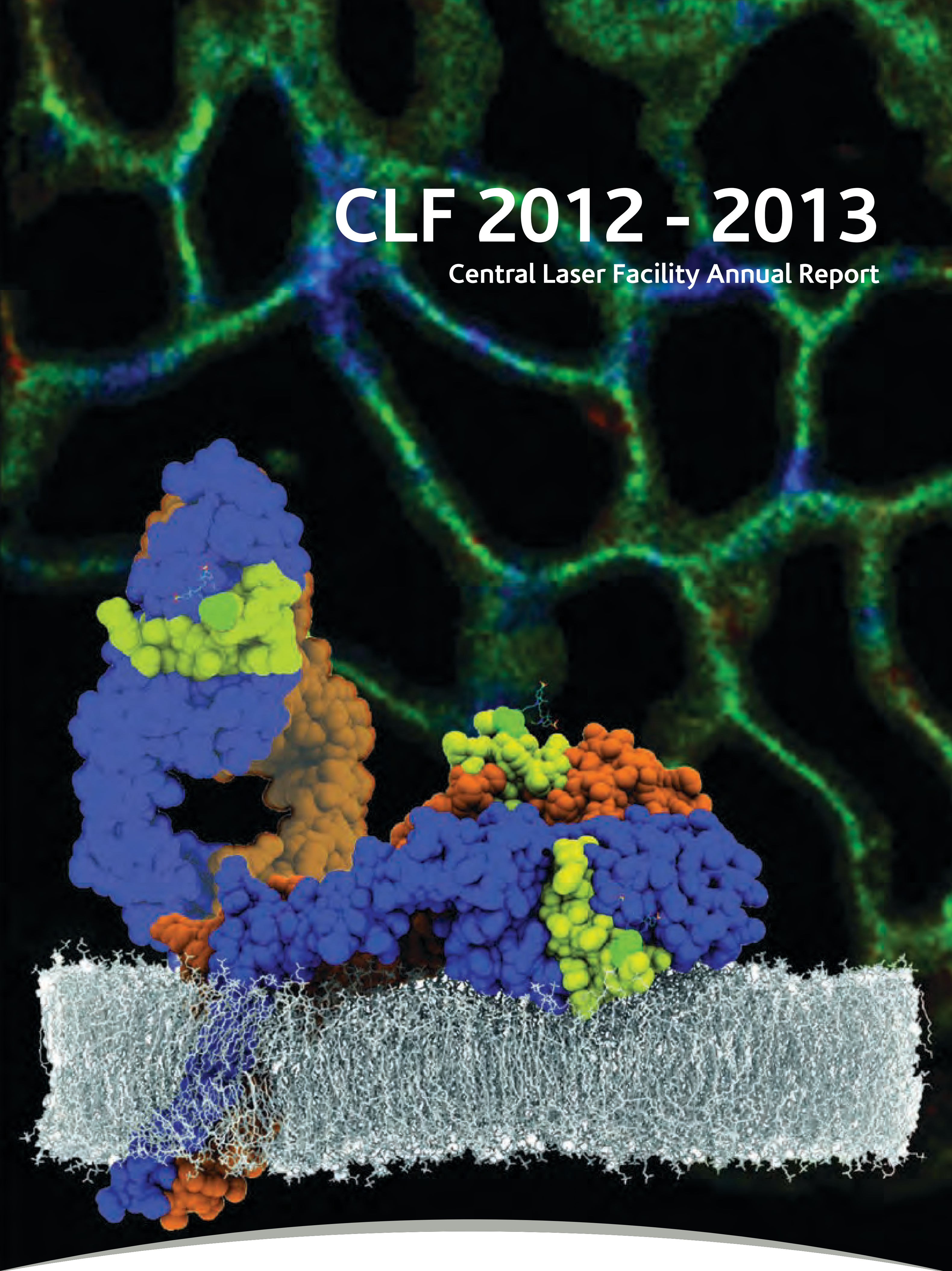
CLF 2012 - 2013

Central Laser Facility Annual Report



Science & Technology Facilities Council

CLF 2012 - 2013

Central Laser Facility Annual Report

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The front cover image has two parts. The background is an image of human epithelial cells showing the variation in fluorescence lifetime of a Förster resonance energy transfer (FRET) donor probe bound to epidermal growth factor receptor (EGFR) in an acceptor-labeled plasma membrane. FRET efficiency is used to determine the distance between the cell membrane and the ligand binding site of EGFR. The foreground is a model of human EGFR derived from FRET data and molecular dynamics simulations showing a conformation in which EGFR is flat on the membrane and another in which it is standing upright. The flat conformation shares key features with the structure of Drosophila EGFR, suggesting that the structural basis for negative cooperativeness is conserved from invertebrates to humans.

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Thanks to all the above for their contribution towards producing this report and of course to all the authors for their submissions.

Contents

Foreword

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This annual report for the Central Laser Facility (CLF) at the STFC Rutherford Appleton Laboratory provides highlights of the scientific and technical research which has been carried out by users of the Facility and its staff over the financial year 2012-13.

Despite its ongoing operation within the constrained environment set by the Large Facilities Funding Model (LFFM), the CLF and its community have continued to deliver scientific output and technical development of the highest order. This period has again seen considerable change and improvement in the programme delivery:

- **Vulcan** – the successful switch to shorter 5 week experiments has continued enabling more experiments to be conducted within the same overall constrained envelope. The sub-aperture laser diagnostics suite for the Vulcan TAP beamline have been commissioned and demonstrated improved reliability in comparison to the full-aperture diagnostics. The dielectric grating and other compressor optics for the high energy Vulcan TAW beam were replaced and the focal spot quality of both CPA beams considerably improved.
- **Gemini** - has seen several improvements in its laser and experimental areas during this period. To attempt to address very high levels of demand, the mothballed Astra Target Area 2 was re-opened for user access with updated infrastructure and delivered its first successful experiment. A new gas system was successfully commissioned in the Gemini Target Area, enabling fully remote user control of target parameters for gas-based experiments further driving our experimental efficiency.
- **Artemis** - A significant development for the Artemis facility over this year has been the implementation of long-wavelength pumping (up to 8 micron) for time-resolved photoemission measurements. This enables the photon energy to be tuned to cross band gaps, for example, and change excitation mechanisms in samples. This has been successfully used in experiments on graphene and on liquid jet targets.
- **Ultra** - Active feedback control on the pointing of the front end lasers and facility stations has reduced warm up time and increased stability of pump probe spectrometers in all Ultra stations. In particular this benefits the 2DIR photon echo spectroscopy facilities. Further improvements to the 2DIR facility include upgrade in infrared pulse energy for improved sensitivity and development of faster reliable analysis procedures.
- **Octopus** - A major development for Octopus was the award of £1.7M from the Medical Research Council through its Next Generation Optical Microscopy Initiative. The funds will allow the introduction of three new super-resolution microscopes to Octopus, including a new technique to achieve 3D imaging in real time at 20 nm resolution, developed in collaboration with STFC's UK Astronomy Technology Centre. The award will greatly increase the involvement of the biomedical research community at the CLF, and establishes links with the MRC unit on the Harwell Oxford campus.

The CLF has continued to work on essential technology for the 10 PW upgrade to Vulcan. Even though the availability of capital to enable this project to proceed still remains elusive, the CLF is determined to remain in a position to be able to start construction immediately should it appear. Over the year, CLF developments have seen improvements in the performance of key components such as gratings, crystals and mirrors thereby enabling us to contemplate an expected performance that exceeds the 20 PW level when this project eventually proceeds.

The CLF have a strong and impressive background in Economic Impact, providing solutions to industry and making a positive difference to society. This year three new SME's representing the environmental and health sectors engaged with CLF through the STFC CR+D programme, facilitating the opportunity to build new relationships and continue work programmes through direct commercial funding. Three inventions were put forward for patent analysis and funding secured to develop a prototype universal motor controller providing new opportunities for income via licence agreements. There has been a significant up-lift in the engagement during the year with Technology Strategy Board, BIS, UKTI and trade associations such as AILU and JEMI, as well as other agencies of Government. Maintaining and building these relationships is very important in terms of inward investment and support for UK industry and for the leveraging of external funds to CLF.

CLF's spinout company Cobalt Light Systems has successfully tested its non-invasive bottled liquid screener Insight100 at a large number of European airports for possible deployment ahead of changes to the security screening requirements in Europe in January 2014. It also achieved the highest level of certification for its product by the European Regulatory Committee for Civil Aviation Security. The INSIGHT100 may now be deployed in European Airports for screening of liquids, aerosols and gels without any modifications. The CLF spinout Scitech Precision Ltd continued to grow sales of microtargets into an expanding international customer base.

CLF's recently formed Centre for Advanced Lasers and Applications (CALTA) has won its first major contract, from ELI in the Czech Republic, to supply a laser head and pumping diodes for a duplicate of CALTA's DiPOLE 10J 10 Hz laser system. Early deliverables have all been made on time and to budget. Building on this success, CALTA has also won a major £10.4M contract to build a 100J version of DiPOLE for the HiLASE project, also based in Prague. This places us in an excellent position to win further major international contracts and to start realizing the impact that the DiPOLE technology can bring both nationally and internationally. Following the successful completion of the EU-funded HiPER project we are taking steps to ensure that UK leadership is maintained as the international laser fusion effort moves forward.

The communication of our work and its impact to non-scientific audiences is an increasing priority. A highlight of the year was having our work on breast cancer screening with SORS picked up by both the Daily Mail and the Telegraph. Over 1200 people toured the CLF this year, and we have opened a dedicated Visitors Centre to host them. Our outreach activities now include a laser-plasma research group based in a local school.

Finally, the close partnership the CLF has with its User community has been central to our past success, and as we look forward, it is imperative that we collectively draw on that partnership to promote our collective success that is, in part, represented in this publication.

I hope that you enjoy reading it!

Professor John Collier
Director, Central Laser Facility

Overview of the Central Laser Facility (CLF)

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The CLF is a world leading centre for research using lasers in a wide range of scientific disciplines. This section provides an overview of the capabilities offered to our international academic and industrial community.

Vulcan

Vulcan is a highly versatile 8 beam Nd:glass laser facility that operates to two independent target areas. The 8 beams can be configured in a number of combinations of long (>500ps) and short (<30ps) pulse arrangements. The maximum energy that can be delivered is 2.5kJ when all 8 beams are configured for long pulse operation. Temporal pulse shaping is available for long pulse operation and there are a number of focusing, beam smoothing, probe beam and harmonic conversion options. Target Area Petawatt is Vulcan's highest intensity area it is capable of 500J/500fs pulses focused to 10^{21} W/cm^2. The PS OPCPA front end ensures that the ASE contrast of the PW system is better than 10^{10} at 1ns. To compliment the short pulse beamline is an additional 250J long pulse beam line as well as a variety of possible probe beams that can be configured in the area.

Target Area West is Vulcan's most flexible target area offering up to 8 long pulse beams or 2 short and 6 long pulse beams. The two short pulse beams operate independently and can be configured so that one operates at 80-100 J / 1 ps (10^{20} W/cm^2) and the other one either at 80-100 J / 1 ps or at 300 J / 10 ps in flexible geometries. This year several large optics, including one of the di-electric compressor grating were replaced to restore the energy of the high energy CPA beamline to 300J at 10ps. In addition work was conducted to improve the focal spot quality for the CPA beam lines and this has resulted in much improved focal spots that are ~1.5 times diffraction limited.

Astra Gemini

This high rep-rate Petawatt laser based on Ti:Sapphire technology has a unique capability to offer 2 synchronised beams, each with a power of 0.5 PW and a repetition rate of one shot every 20 seconds. The facility will enable interaction studies up to 10^{22} W/cm^2. F/20 and F/2 beam focusing options are available, with a built-in plasma mirror set-up in one beam line for high contrast pulse delivery. In recent years the contrast of the compressed pulses from Gemini has been improved to the point where it is good enough for all but the most sensitive experiments, and for those the dual plasma mirror system is available. Over the past year the laser development activity has concentrated on improving focal spot quality, this has been achieved by the use of an adaptive mirror in the Gemini target chamber on several experiments. Two different adaptive mirrors have been used: one is a commercial device, and the other is a 250mm diameter gold-coated mirror that was made in-house.

Artemis

Artemis is an ultrafast laser and XUV science facility, offering high repetition-rate, ultrashort pulses spanning the spectral range from the far-infrared to the XUV. The facility is configured flexibly for pump-probe experiments. Tuneable or few-cycle, carrier-envelope phase-stabilised pulses can be used to generate ultrafast, coherent XUV pulses through harmonic generation or used as pump and probe pulses. Two XUV beamlines lead to end-stations for atomic and molecular physics and condensed matter physics.

The condensed matter physics station enables time-and angle-resolved photoemission spectroscopy (ARPES) with XUV pulses, and is equipped with hemispherical electron analyser, five-axis manipulator with cooling to 14K and a sample preparation chamber. Artemis has two experimental chambers for studies of gas-phase atomic and molecular targets. The atomic and molecular physics end-station contains a velocity map imaging detector and gas source, and has been used for photoelectron spectroscopy with XUV probes, coulomb explosion imaging of clusters and time-resolved studies of autoionisation. The flat-field spectrometer is used for high harmonic generation (HHG) spectroscopy and for HHG optimisation experiments.

In this reporting year, the CLF has recruited an additional link scientist for gas-phase experiments. The Artemis laser system has been upgraded with new pump lasers, with increased long-term reliability. This enables the laser to be run continuously from Mondays to Fridays, substantially increasing availability and productivity.

Lasers for Science Facility (LSF)

The CLF operates two facilities in the Research Complex at Harwell, Ultra, for ultrafast molecular dynamics measurements in chemistry and biology, and Octopus, a cluster of advanced laser microscopes for life science research.

In the dynamics area Ultra offers a state-of-the-art high power 10 kilohertz fsec / psec system combined with OPAs to generate pulses for a range of unique pump and probe spectroscopy techniques. It provides spectral coverage from 200-12000 nm and temporal resolution down to 50fs. This is used in the investigations of fast photodynamic processes in solids, solutions and gases. Its time resolved resonance Raman (TR^3) capability enables highly fluorescent samples to be studied using a 4ps optical Kerr shutter. The Time-Resolved Multiple-Probe Spectroscopy (TRMPS) facility links Ultra with a 1 kHz ultrafast laser spectroscopy system, giving a femtosecond to millisecond pump-multiple probe spectrometer.

In the imaging area, the Octopus cluster offers a range of microscopy stations linked to a central core of pulsed and CW lasers offering "tailor-made" illumination for imaging. Microscopy techniques offered include total internal reflection (TIRF) and multi-wavelength single-molecule imaging, confocal microscopy (including multiphoton), fluorescence energy transfer (FRET) and fluorescence lifetime imaging (FLIM), and single molecule Alternating Laser Excitation (ALEX) in both confocal and TIRF modes. 2D Stochastic Optical Reconstruction Microscopy (STORM) with adaptive optics is also available. Additional super-resolution capability in the form of Structured Illumination Microscopy (SIM) and Photoactivated Localization Microscopy (PALM) will be added to Octopus in late 2013 as part of a programme funded by MRC. Laser tweezers are available for combined manipulation/trapping and imaging with other Octopus stations, and can also be used to study Raman spectra and pico-Newton forces between particles in solution for bioscience and environmental research.

Chemistry, biology, and spectroscopy laboratories support the laser facilities, and the CLF offers access to a multidisciplinary team providing advice to users on all aspects of imaging and spectroscopy, including specialised biological sample preparation, data acquisition, and advanced data analysis techniques. Access is also available to shared facilities in the Research Complex, including cell culture, scanning and transmission electron microscopy, NMR, and x-ray diffraction.

Laser Loan Pool

Commercial laser systems are available from the EPSRC Laser Loan Pool for periods of up to 6 months at the user's home laboratory. A wide range of ancillary and diagnostic equipment is also available to support user experiments.

Engineering Services

Mechanical, electrical and computing support is provided for the operation of the laser facilities at the CLF, for the experimental programmes on these facilities and for the CLF's research and development activities. Mechanical and electrical CAD tools and workshop facilities enable a rapid response.

Theory and Modelling

The CLF will offer to support scheduled experiments throughout the design, analysis and interpretation phases, if required and within the resources available. We offer hydrodynamic, particle-in-cell, hybrid and Vlasov-Fokker-Planck modelling capabilities and access to large-scale computing. New 1D and multi-dimensional radiation-hydrodynamic and atomic physics tools have been renewed for a further year, as endorsed by the CLF User Forum. Student training in computational methods and opportunities for networking with colleagues will continue to be provided. Extended collaborative placements within the group are particularly encouraged.

Target Fabrication

A high quality target fabrication facility is operated within the CLF offering integrated microassembly, thin film coating and characterisation areas. A dedicated chemistry laboratory has recently been commissioned. The facility is equipped with a wide range of complementary target production and characterisation equipment including evaporation and sputter coating plants, interference microscopy, SEM, AFM and surface profiling. Many microcomponents are produced in collaboration with the STFC micromachining and MEMS facilities. Target Fabrication is ISO9001 accredited. Commercial access to target fabrication capabilities is available to external laboratories and experimentalists via the spin-out company Scitech Precision Ltd. This year a Diamond Like Carbon (DLC) coating capability has been made available to the user community with high quality films in the range of a few nm to several hundred nm.

Centre for Advanced Laser Technology and Applications (CALTA)

CALTA is a new STFC/CLF Centre that is charged with driving forward next generation laser technology that is principally focussed on the industrial and commercial application of high power lasers and the by-products interactions (e.g super bright, high energy photons, electrons, ions etc). At its heart is a campaign to develop advanced, proprietary diode pumped laser technology (DiPOLE) and associated multi-PW component technology that has been pioneered with in the CLF in recent years.

The main activity within DiPOLE is the development of a scalable diode pumped solid state laser (DPSSL) concept that is capable of delivering kJ-level pulses at a 10 Hz or above repetition rate. A conceptual design of a cryogenic Yb:YAG amplifier that can be scaled to kJ energy levels and beyond, owing to its geometry, unique laser design and cooling technique has been developed. To test this concept in the laboratory a lower-energy 10J prototype amplifier system has been built and is currently being refined and tested. This year CALTA secured a £10.3M contract to supply a 100J DiPOLE to the HiLASE project in the Czech Republic.

The CLF will continue to develop 10 PW technologies that are crucial to a future upgrade to the Vulcan high power laser to 10 Petawatt (PW). This includes developing dielectric Adaptive Optic mirror, ultra broadband optics such diffraction gratings and the realisation of specialised large aperture crystals required in multi Petawatt facilities. To test all these components a test component facility based on OPCPA is currently under construction to be able to amplify broad band pulses to 7J of energy.

Access to Facilities

Calls for access are made twice annually, with applications peer reviewed by external Facility Access Panels.

The CLF operates "free at the point of access", available to any UK academic or industrial group engaged in open scientific research, subject to external peer review. European collaboration is fully open for the high power lasers, whilst European and International collaborations are also encouraged across the CLF suite for significant fractions of the time. Dedicated access to CLF facilities is awarded to European researchers via the LaserLab-Europe initiative (www.laserlab-europe.net) funded by the European Commission.

Hiring of the facilities and access to CLF expertise is also available on a commercial basis for proprietary or urgent industrial research and development.

Economic impact

The CLF undertakes comprehensive world leading research programmes which significantly advances fundamental science whilst opening up potential for innovation, the exploitation of exciting new ideas in a timely and efficient manner. Novel technologies and processes developed in the course of our science programme are proactively assessed for their exploitation potential. The delivery of high Economic Impact (EI) forms an integral component of the CLF strategic objectives and the overall delivery plan. To deliver the most effective long term EI the CLF encourages, facilitates and actively promotes:

- Expanding our expertise via continued and enhanced support of the underpinning, fundamental science
- Attracting inward investment from global sources including the BRIC countries
- Training scientists, engineers and technicians to the highest standards
- Innovation - exploiting the right ideas at the right time with optimum efficiency
- Ensuring our intellectual property is protected and utilised to maximise return
- Supporting existing spin-out companies and forming new ones where appropriate
- Engaging with the public, in particular through outreach to schools and colleges
- Addressing the big challenges - Security, Energy, Environment and Healthcare
- Pro-actively seeking new partnerships and collaborations across industry and academia to enhance the Harwell and Daresbury Science and Innovation Campuses (HSIC and DSIC)

Please visit www.clf.stfc.ac.uk for more details on all aspects of the CLF.

Economic Impact

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Introduction

The CLF have a strong and impressive background in Economic Impact –providing solutions to industry and making a positive difference to society. The intention is to build on this platform and reach out further than before. This paper highlights some of the high impact activities for the 2012/13 period and sets out a new strategic plan to ensure the impact of our work at the CLF is maximised.

Industry Engagement

Three new SME's from the environmental and health sectors engaged with CLF through the STFC CR+D programme (funded to £110k) – with the experimental campaigns generating excellent results, realising the potential to continue work programmes through direct commercial funding.

There have been early stage discussions with a major bio-medical company, exploring the potential for a funded programme in in-vitro glucose detection. This work will continue to progress during FY 13/14.

There has been a significant up-lift in the engagement during the year with Technology Strategy Board, BIS, UKTI and trade associations such as AILU and JEMI. Maintaining and building these relationships is very important in terms of inward investment and support for UK industry and for the leveraging of external funds to CLF. Working closely with UKTI on the dissemination of opportunities created via the Extreme Light infrastructure programme is a good example of delivering real impact to the UK economy.

A programme of engagement with a large number of companies and institutes has been initiated covering the defence, automotive, medical and manufacturing industrial sectors. It is envisaged that a number of new commercial contracts will be won during FY13/14 as a result and that the programme will continue to evolve and grow.

Technology Transfer

Spin Outs

Cobalt Light Systems Ltd has continued to grow and expand its range of products. They now employ over 20 staff and to date it has received around £3M of funding. New products launched during FY 12/13 include:

- INSIGHT100 - A revolutionary non-invasive scanner for the detection of liquid explosives concealed in bottles in aviation security and will be ready for deployment at airports by January 2014 in line with regulatory change in scanning at EU airports – the first purchases by airports anticipated in autumn/winter 2013.
- RapID - A novel device for the identification of incoming raw materials in pharmaceutical manufacturing through unopened packaging – a step change in the verification process permitting to replace previous invasive methods.

Scitech Precision Ltd combines expertise in micro-assembly and micro-engineering with extensive insight into the physics behind high power laser science. Over the last year Scitech has completed over 30 contracts with facilities in the US, Europe, Japan and India. This work has supported experiments and has led to a number of publications for the UK HPL user community. Targets delivered include complex 3D assemblies, multi-layer foils and dot targets.

In the last reporting year Scitech Precision employed 2 members of staff. It has continued to develop its portfolio with a significant capability in MEMS production that has led to numerous high value contracts being placed for the 2013-2014 financial year. It has also extended the range of facilities that it supplies to and is bringing in a significant amount of revenue from outside the high power laser community.

Colsicoat Ltd. re-located to laboratory space within the CLF temporarily – in order to facilitate a move to be incorporated with Scitech Precision. This is currently in the final stages of negotiation. Colsicoat will bring new skills in coating technology to Scitech and grow its existing product and service offering.

Intellectual Property and Know-How

Three new inventions were put forward for patenting during FY12/13; a stress free coating method for adaptive optics, pulse contrast enhancement using transmission gratings and electron probes for non-destructive testing. Unfortunately a comprehensive prior art search prevented the adaptive optics patent from being taken forward. However, the other two inventions have passed the initial prior art search and are in the process of writing up in preparation for filing later in FY 13/14.

New Products and Materials

Work conducted in collaboration with Sheffield and Durham Universities on platinum complexes has resulted in the molecules now being offered for sale in the Sigma Aldrich catalogue with 30% of income generated from each sale coming to the CLF. This is a significant result for the three parties involved and represents an important commercial step for the department.

CLF won STFC Proof of Concept funding to develop a Universal Motor Controller. The project progressed well and the prototype has been delivered. The optimum exploitation route is currently being established. Ideally the product will be licensed for manufacture to a main stream electronics company and be included in mainstream electronic catalogues for general sale. The CLF itself will be an early adopter and a number of facilities across the globe have already expressed interest e.g. the Extreme Light Infrastructure partners in Czech Republic, Hungary and Romania.

Forward Plan

Key elements of the forward plan for economic impact are illustrated in the diagram below.

Demonstrate Capability

In order to generate interest and excitement and build our credibility with industry we have to be able to demonstrate our capability. To some extent this can be achieved via the facilities we operate but in order to exploit new technology that is developed within CALTA and CLF it is proposed that we set up the following:

(a) A materials interaction facility for the new DiPOLE laser technology.
(b) A demonstration facility/area for our technology developments.

Industry Engagement

Work to:
(a) Build strategic partnerships with large organisations in the aerospace, automotive and health sectors. 2-3 year programmes with scheduled access throughout the year.
(b) Keep a keen eye on short term opportunities with SMEs – this is particularly relevant to the Ultra and Octopus facilities where fast turnaround and flexible scheduling fit to the SME business model.
(c) Maximise our IP potential – scan for new patent opportunities, ensure IP is protected where relevant, review and modify our IP strategy as required to ensure we achieve the best possible return on our inventions and ideas.
(d) Exploit our IP – through license agreements and formation of Spin-out companies where appropriate.

International Engagement

Work to:
(a) Further strengthen relationships with UKTI, BIS, British Embassy and FCO – with a BRIC + US focus.
(b) Raise the global profile of CLF and CALTA through attending and presenting at international conferences and exhibitions.

Leadership and Networks

Generate new contacts and commercial opportunities by:
(a) Participating in and inputting to groups such as the Photonics Leadership Group (UK) and Photonics21 (EU).
(b) Engaging with Catapults, KTNs, Fraunhofer UK, AILU and relevant trade associations in electronics, advanced manufacturing etc.

Leveraging External Funds

Increase CLF and CALTA income by:
(a) Actively seeking participation in TSB and EU funded CR+D programmes either as partners or sub-contractors.
(b) Winning commercial contracts with non-UK based companies and institutions.

Conclusions

Careful planning and implementation of this plan will result in increased impact for the benefit of the CLF, STFC and UK. Key to our success will be in maintaining a balance between academic and commercial activities ensuring a robust and healthy innovation pipeline.

Communication and outreach activities within the CLF

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Introduction

Public engagement encompasses outreach activities that inspire the next generation and raise the profile of our world-class research as well as communication activities that offer a platform on which to demonstrate the high-impact (and awesome) science that the Central Laser Facility (CLF) delivers. This year has seen a burst of life in the CLF communication and outreach activities, in order to increase the visibility of the facility's role, science and impact to the public, as well as to STFC staff. Various platforms have been used to achieve this, including the CLF and STFC websites, the newly established CLF visitor centre (see below) as well as the innovative ways in which CLF staff are engaging with the public (see 'Inspiring the next generation' and 'Engaging with the public').

Figure 1: The entrance of the new CLF visitor centre

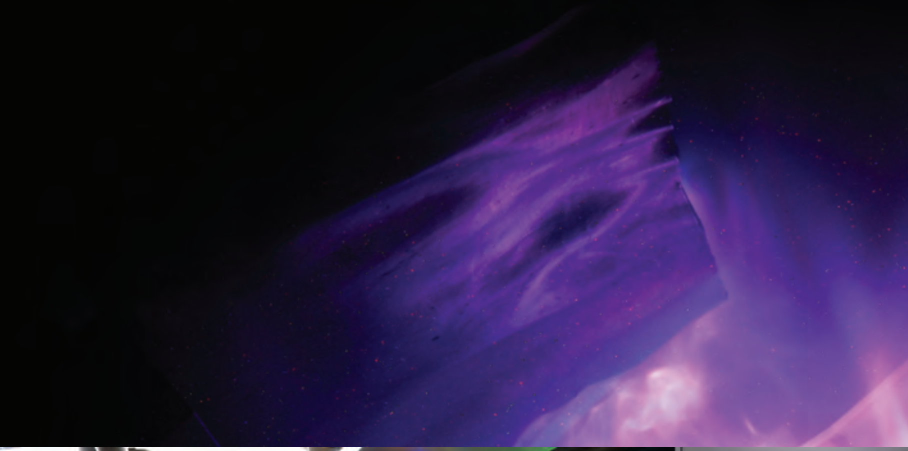

Figure 2: Panoramic view of the CLF visitor centre

New CLF Visitor Centre now open

A considerable effort has been made this year in the construction of the CLF's visitor centre. CLF staff wrote all of the content for the centre's panels, ensuring that we cover the breath of science that we do and that we also incorporate inspiring examples of current work. The centre is an excellent tool for educating our visitors about the CLF and is kitted out with display cabinets, demonstrations and animations on the display screens to help with this, including a laser air breakdown demonstration as well as a new, true-to-life Vulcan laser flythrough animation to celebrate the 10th anniversary of Vulcan Petawatt (see figure 3 below). In thanking all contributors, John Collier points out that "we have done our department proud and set a new bar for promoting the importance, wonder and impact of our, and STFC, science".

Figure 3: The new CLF visitor centre global challenges' wall

Figure 4: Robert Buckland MP in the Vulcan control room (above) and Trevor Winstone showing STFC council chair Prof. Sir Michael Stirling the Vulcan fly-through animation in the new CLF visitor centre (below).

Visits and tours

The CLF continues to welcome visitors and host tours around the facility. Over the last year, 1246 people have visited the CLF, an increase of more than 20 % over last year's total.

A wide range of people have passed through our doors, including many VIP guests, industry representatives, secondary school students and undergraduates. The CLF was delighted to host the STFC Council meeting lunch as the first event in the visitor centre in March 2013. Council members and Executive Board members were fascinated to see and hear all about laser technology in more detail and its many applications. As part of Tony Parker's involvement in the Royal Society MP pairing scheme, we also welcomed Rob Buckland MP to the facility, during which PhD students and facility staff were on hand to describe how they use CLF in their research. We also continue to support the STFC public and education access days that occur several times throughout the academic calendar, during which up to 100 young people are shown around the facility and entertained with talks and demonstrations by CLF staff. Feedback from these tours has been very positive, with the top two responses being 'interesting' and 'enjoyable'; most likely a result, as one teacher noted, of the tours being conducted by 'very passionate and highly educated people'.

Hitting the headlines

Press releases are a great tool for communicating CLF science as, if they are successfully picked up by news media, they can reach large audiences very quickly. An example of the top CLF press releases we've generated this year include the announcement of CALTA gaining large European contracts to deliver DiPOLE's high average power laser technology, the start of a research program to look at using CLF patented SORS technology for non-destructive breast cancer diagnosis as well as the announcement of a collaborative STFC-MRC grant to use the CLF Octopus system for cancer treatment research.

Establishing a close working relationship with the RAL press officers has been key to getting these press releases as accurate and clear as possible. Their advice to us and the wider CLF user community is that aligning the date of the press release with a paper publication or grant announcement is absolutely crucial to attract high impact coverage, so we would like to encourage our users to let us know as early as possible if your CLF-related work could be press release material. Contact ceri.brenner@stfc.ac.uk for any enquiries or further information.

Working together to improve CLF communications

An improvement in the dissemination of information between the CLF and the STFC communications and outreach team has resulted in increased coverage of CLF science and news on internal staff outlets, such as the newsletter, as well as in externally facing articles that appear on the STFC website and in publications such as STFC's Fascination magazine. A good record of participating in the STFC staff 'other people's business' scheme of short talks has also helped to increase our visibility to those outside of the department, who are then able to communicate our role to others.

A significant amount of time has been dedicated this year to updating and adding new pages to the CLF website. We understand that our website is a key communication asset, as it often acts as the facility's 'shop window' for the public to learn about our capability. We have added new page content and photos to the Engineering section, the Gemini laser section, the Science section, the Facilities section and to keep up with regular contributions to the News feed. Work is still on-going to improve it further.

The STFC corporate website has also recently been upgraded and as part of this process the CLF contributed a large amount of content not only to the Lasers & Plasmas heading of the Our Research tab, but also in Energy, Environment, Medicine, Health & Biosciences, Chemistry, Physics & Materials Science and Engineering. This is a great demonstration of how many aspects of STFC work are contributed to by the CLF. Two CLF-based web articles have also been chosen to appear on the STFC homepage, including an entertaining piece entitled 'Lasers for Life'.

Inspiring the next generation

Work experience is a very effective way in which the CLF is able to reach out to young people interested in science and engineering. Normally occurring over the summer, sixth-form and undergraduate students are matched with a CLF supervisor to carry out a project lasting up to 6 weeks. It is often the case that the students make a real contribution to the CLF, for example Steph Tomlinson's students designed a diagnostic shutter and portable fluorometer that have both been put to use. Over the last year, the CLF has been able to host almost 20 students in the facility through either the RAL or Nuffield placement schemes.

The CLF also participates in the Engineering Education Scheme, run by the UK's Engineering Development Trust, which introduces sixth formers to the world of engineering via a programme of joint projects between participating schools and institutions. Darren Neville regularly volunteers to mentor a group through this scheme and this year David Haddock also hosted a project from within the target fabrication group with a group from a local school, who designed and built a container to slowly remove a thin film from a slide onto water (see figure 5).

There still remains much participation by CLF staff in the STEM ambassador scheme, which has included visits to local schools and hosting laser activity sessions for school groups in collaboration with the University of Oxford Education department. CLF staff have also contributed their time to talk about their careers in STEM to young people, including Graeme Wiggins who attended a school careers fair day as well as Jamie Pinnel and Ceri Brenner who were invited to speak about life in the CLF during the Oxfordshire Young Scientist of the Year event held in the Oxford history museum. CLF career profiles now feature on the RCUK website and in the special careers edition of the STFC Fascination magazine.

In a bid to encourage more young women to consider STEM qualifications and perhaps even STEM careers, Ceri Brenner, along with other STFC staff, has been involved in activities such as the IOP's 'Girls into Physics' school workshops as well as joining the ScienceGrrl campaign and featuring in their calendar as a CLF physicist, an initiative which aims to increase the exposure of female scientists to demonstrate that 'science is for everyone'. She also took part in interviews with BBC Radio Oxford, BBC Radio Berkshire and BBC Radio 5Live as a CLF and RAL physicist to contribute towards a 'Girls in Physics' discussion live on air. Steph Tomlinson is an active member of the RAL 'Women in STEM' group, participated in Diamond Light Source's 'Science your future' day event and has received a staff recognition award from corporate services for public engagement activities.

Figure 5: David Haddock (front row left) with the group he worked with through the Engineering Education scheme receiving their STFC awards.

An interesting outreach opportunity has been established by Peter Norreys and Raoul Trines, who have instigated the 'λaser πlasma research group': an opportunity for school students to help solve the energy crisis by working on physics relevant to the global Inertial Fusion Energy project. The first of these research groups, planned for summer 2013, will see them learning how to run computer simulations of laser-plasma interactions.Peter Norrey's explains why he supports such engagement: "I think it is very important to get the younger generation involved in cutting-edge science at an early stage. In my own experience, I have found that encouraging younger students to help carry out research open their horizons and gets them excited about exploring the natural world".

CLF science has also reached post-18 students this year through target fabrication lectures delivered as part of the University of York's fusion Masters program and via an invited lecture on laser fusion for 2nd year physics undergraduates at Queen Mary's University, London.

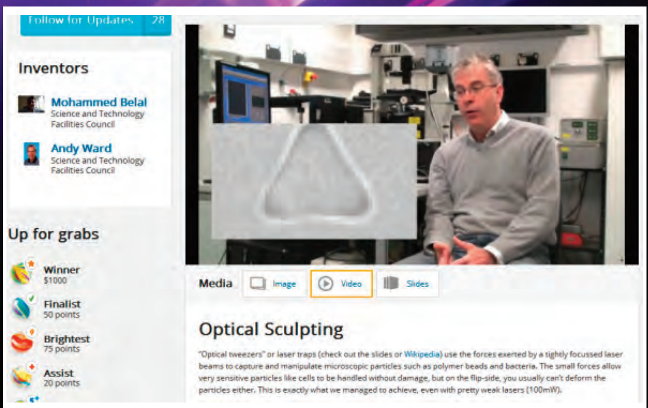

Figure 6: (Above) Peta Foster's 'Gravity Experiment' on the STFC Backstage Science youtube series has over 25'000 views and (below) Andy Ward describes the laser tweezer technique to the online Marblar community

Figure 7: (The video answers the question: why build a sun on Earth? (Credit: Nik Morris and Vimeo)

Engaging the public

An impressive effort has been made by CLF staff in volunteering their time to carry out outreach and communication activities related not only to CLF but also to STFC science in general, both on-and off-site. Andy Ward contributed to the Marblar online forum with a video explaining the CLF's laser tweezers system, while Peta Foster presented the 'feather and weight in a vacuum' demonstration for the STFC Backstage Science youtube series (see figure 6).

Our communication activities have also reached out to people who do not normally come across laser science; CLF communicators took the time to help out at the very popular BBC stargazing event hosted at RAL and Ceri Brenner gave a talk and co-hosted a laser fusion evening as part of the Super-Collider science weekend held at the trendy Kings Cross Filling Station in London.

Rutherford prize for the public understanding of plasma physics 2013

This annual prize of £500 seeks to recognize achievements made by PhD students in the communication of plasma physics to the general public. The 2013 prize was awarded to a team from the University of York consisting of Rachel McAdams, Tom Williams, Lee Morgan, Ben Moody, and Mohammed Shahzad. The York team produced a short animation film aimed at children aged 9-11 which explains why scientists are trying to build a 'mini-sun' on earth. The film also won first prize at Durham Energy Futures Film Festival 2012.

For more information on submissions for next year's prize, please contact Alex Robinson (alex.robinson@stfc.ac.uk).

Continuing the good work

We would like to thank all members of facility staff and the user community who participate in public engagement activities to help promote the laser science and engineering work of the CLF.

If you would like to work with us to promote your research or any aspect of CLF work, then please get in touch with Ceri Brenner (ceri.brenner@stfc.ac.uk). Whether it be through outreach events and activities, or via press releases and website content, we welcome collaboration on communicating CLF science.

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Vulcan flythrough: Cristina Hernandez-Gomez and Trevor Winstone

CLF website: Emma Springate, Ceri Brenner, Steph Tomlinson and Chris Hooker

CALTA – The Centre for Advanced Laser Technology and Applications

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Introduction

STFC has established CALTA at the CLF both to develop one specific new area of technology, and to encourage applications of all our technology in wider society. CALTA is thus all about Technology and Applications.

Technology

Our next-generation Technology development centres around a Diode-pumped solid-state laser called DiPOLE. Because diodes provide the power for the laser, such systems are much more efficient than the current competing technologies for ultra-high power (petawatt level) lasers. Using diodes as the laser pumping source brings excellent energy efficiency. That, together with their robust and compact nature, means that this technology could ultimately be made transportable for remote site operations. Another important feature of DiPOLE is that the basic design is in principle scalable to very high energy (~kJ) pulses. DiPOLE was described more fully in the 2011/2012 Annual Report. It currently produces 10J pulses and a 10Hz repetition rate, and we are working on the next generation which will produce 100J pulses at the same repetition rate.

In addition to DiPOLE, CALTA can access all of the technologies developed at CLF over many years in pursuit of its core scientific mission.

Collaboration with ELI

CALTA were delighted to announce in March 2013, the signing of a contract with the HiLASE project in the Czech Republic. The contract, worth approximately £10.2M, involves the supply of a 100J DiPOLE complete working system, in approximately two years. This is a follow-on from the existing contract with ELI-Beamlines project, also in the Czech Republic.

Application areas

With access to high-power lasers, including in due course DiPOLE, a raft of application areas opens up. The laser light can be applied directly, perhaps in areas such as laser materials processing. Or, with suitable targets and detectors, imaging techniques such as ultrafast X-ray imaging will become possible. CLF's background technology in areas such as simultaneous control of multiple motion systems, is also applicable in a range of settings.

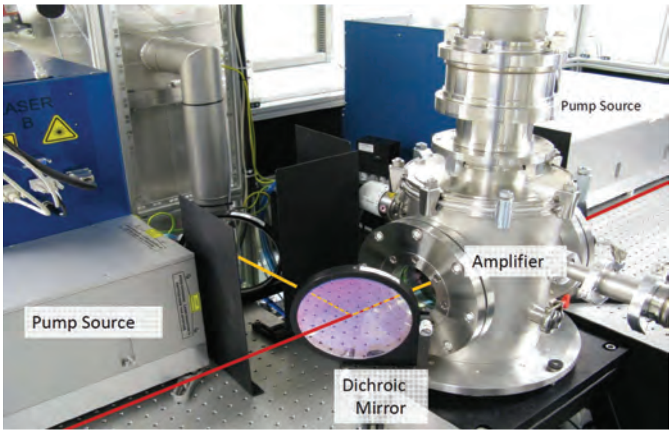

Figure 1: The DiPOLE amplifier head with light paths shown

Applying laser light

We expect that pulses of light at 100J with a repetition rate of 10Hz will find applications in traditional areas of laser materials processing such as shot peening, and also in new areas not currently accessible to lasers. Other possible applications include diverse fields such as communications, medical applications, and laser-driven fusion.

Lasers as radiation sources: X-ray imaging and more

The advent of Pettawatt (PW) class lasers brings with it the possibility to generate a variety of different types of radiation. For example, x-rays can be generated for use in imaging applications. The pulse of radiation is very short (of order of Picoseconds, ps) which means that motion in the image is "frozen". It is very small (sub-mm), which minimises the need for collimation. Finally it is bright enough that a single ~ps pulse can form an image of a large object. This raises the possibility of being able to image, for example, the blades of a gas turbine in an X-ray image taken while it is running. And the fact that DiPOLE runs at 10Hz raises the possibility of X-ray movies. Early in the year we carried out a very successful run on Vulcan demonstrating with a conventional laser what will be possible with DiPOLE.

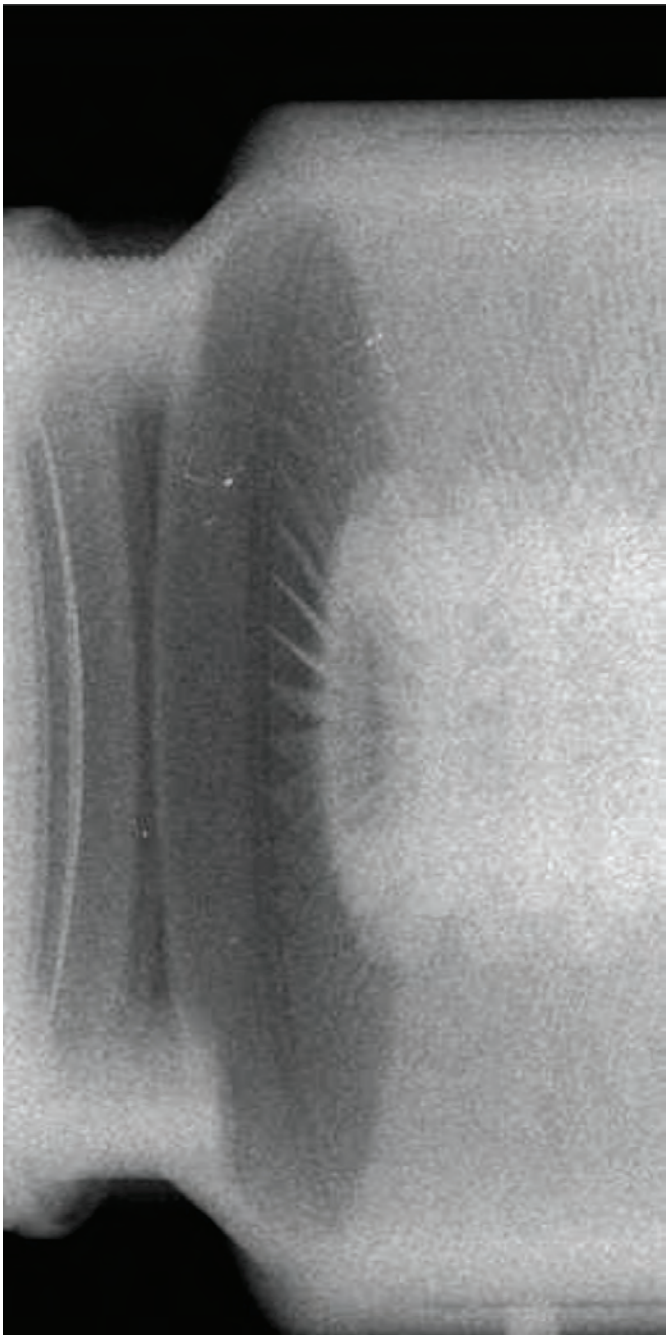

Figure 2: An ultra short (5 ps) laser driven X-ray flash radiograph of a Oerlikon Leybold turbo pump rotating at 42000 rpm, demonstrating the capabilities for the X-ray beam to freeze the motion and obtain clear images from which dynamic positions and displacements can be obtained.

Applying other high power laser technology

CALTA has access to a wealth of technology developed in CLF over the years.

A beam stabilization system has been developed to handle multiple interacting control demands. The most obvious application is to stabilise very large laser systems but other complex equipment with multiple controls can also benefit from this technology.

Our engineers have produced a simple, elegant safety interlock system with a unified interface which works across all our laser systems. While the most obvious application is to other major laser systems, any facility which needs controlled access with multiple points of entry can benefit from this technology.

With many motorised systems to control for beam shutters and so on, we faced the problem of interfacing their multiple manufacturer's interfaces to our own unified system. We have developed a "universal" motor controller card, and an intuitive user interface, to allow simple control of a large number of motorised functions across different platforms. This could readily be applied in other major facilities but also in any setting where multiple motorised systems need to be managed.

We have developed advanced adaptive optics systems to keep our various laser beams stable as thermal gradients in the optics and the air tend to distort them. In order to provide Chirped-Pulse Amplification (CPA) with high-power lasers, we have developed diffraction gratings capable of withstanding very high energy pulses. We are working to refine optical parametric amplifiers which use non-linear crystals to add pump energy to a seed laser, and we are working on beam combination to allow the beams from two lasers to be added coherently to act a single laser of double the power.

CALTA securities

There are a host of potential applications of CALTA technologies to defence, such as the detection of land mines and screening of goods as part of border control. We are working with the security community to push forward these areas, exploiting the fact that we can trial applications using spare capacity on CLF's laser suite. This allows us to establish strategic partnerships at an early stage and so guide other activities in order to ensure that CALTA's effectiveness is as high as it can be.

Conclusion

All of CLF's technology, and the development of DiPOLE, puts CALTA in a good position to generate real societal impact and we are now steadily following CALTA's business plan with major contract wins from the Czech Republic and developments in other areas.

References

1. The CALTA website: http://stfc.ac.uk/calta/
2. The ELI Beamlines website: http://www.eli-beams.eu/