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 2014-15.

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. User volume has increased again despite the financial constraint and the CLF's facilities remain heavily oversubscribed.

- **Vulcan** – This year saw one of the Vulcan Target Area West experiments enter into the Institute of Physics Physics World Top 10 achievements of 2014. The experiment, led by Professor Gianluca Gregori from Oxford University was designed to investigate magnetic field generation within supernova remnants. The group collided high-turbulence plasmas driven by the long pulse beamlines and was originally published in Nature Physics.
- **Gemini** – Gemini continued to prove its unique capability as a driver for secondary sources for applications. Scientific highlights include two high impact results that appeared in Physical Review Letters. In one of them an international team used the Gemini laser pulses to accelerate a dense relativistic electron sheet formed between two few-atoms thick foils. The coherent motion of this sheet gives rise to a bright, isolated half-cycle pulse in the XUV. In another, a Queen's University Belfast-led team produced gamma-ray beams in the multi-MeV range with highest peak brilliance ever generated in a laboratory - three orders of magnitude higher than conventional bremsstrahlung x-ray sources – using nonlinear-Thompson scattering of one beam of Gemini off a 0.5 GeV electron beam produced by the other.
- **Artemis** - Artemis continued its successful string of experiments looking at electron dynamics in graphene, with high–impact publications in Physical Review Letters and Nano Letters, including investigations of how graphene can be tailored to potentially act as a semiconductor and as a more efficient solar cell. A collaboration using an Artemis end-station at Diamond Light Source achieved a first with measurements of time-, spin- and angle-resolved photoemission. Artemis can now offer shorter pulses to users, and this year measured sub-10 fs electron dynamics combined with sub-eV energy resolution, and developed a source of few-cycle pulses in the infrared.

The CLF's facilities in the Research Complex at Harwell, Ultra and Octopus were strengthened with the addition of new capabilities funded by the BBSRC in partnership with STFC.

- **Ultra** - The "LIFEtime" instrument on Ultra uses new laser technology to extend the Time-Resolved Multiple Probe spectroscopy idea first developed on Ultra, to enable the monitoring of processes on timescales from femtoseconds to milliseconds in the same experiment.
- **Octopus** – Octopus benefited from the addition of a new super-resolution microscope, that offers Stimulated Emission Depletion (STED) Microscopy, capable of a spatial resolution of 50 nm. This complements the MRC-funded super-resolution microscope that was commissioned for users early in the year.

Science highlights included work on polymer–fullerene heterojunctions, from a team using Ultra involving the University of Cyprus, Imperial College, the University of Montreal and the CLF, published in Nature Communications.

Some of the CLF's spectroscopy techniques found unusual applications, with Spatially Offset Raman Spectroscopy being used to investigate evidence for bone diseases in the

remains of Henry VIII's sailors from the Mary Rose. Raman spectroscopy techniques were also used in a collaboration between Durham University and the CLF, investigating medieval manuscripts at Durham's World Heritage Site in Palace Green Library, Durham Cathedral. The aim of the project was to identify the pigments used in a range of manuscript books of Northumbrian origin or provenance, dating from the 6th to 12th century. Non-destructive spectroscopy techniques are ideal for studying these delicate, precious samples.

The CLF has continued to work on essential technology for the 20 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. CLF has also continued to invest in next generation laser, target and diagnostic technology as well as continuing its development of large scale computing in support of its programmes.

In terms of economic impact, this has been a very successful year with a number of high impact activities. In particular the ground-breaking experimental run in Vulcan TAW demonstrated the capabilities of Laser Driven Sources for imaging of industrially relevant complex samples, engaging with companies from Aerospace, Energy, Security & Defence and Advanced Manufacturing sectors. The work provides a platform to build a solid case for future funding to fully develop this key area of impact for CLF. New contracts with industry have been won this year enabling access to Vulcan and Ultra, providing industry with the opportunity to access state-of-the-art laser systems to develop their own products, processes and technologies whilst generating additional income for the department. On the IP front several new ideas are in the early evaluation stage, including a new device for short pulse diagnostics, a novel alignment process for high power laser systems and new methods for nuclear waste imaging.

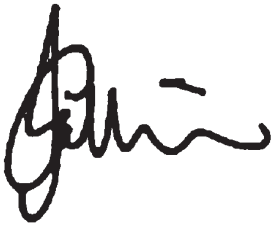
CLF's spinout company Cobalt Light Systems has continued to grow and expand its range of products. They have recently won a number of awards including the prestigious Royal Academy of Engineering MacRobert Award and the Queen's Award for Enterprise. Cobalt also recently topped the Sunday Times BT Business SME Export Track 100. CLF spinout Scitech Precision Ltd combines expertise in micro-assembly and micro-engineering with extensive insight into the physics behind high power laser science. New opportunities exist for high repetition rate target positioning and target supply. Plans to ensure Scitech continues to grow and flourish will be stepped up in 2015.

The CLF's Centre for Advanced Lasers and Applications (CALTA) has successfully completed seven milestone deliverables for the D-100 laser (1032nm, 100J, 2-10ns, 10Hz) due for delivery to the Czech Republic "HiLASE" facility in Dolni Brezany during 2015. The milestones completed include; demonstration of the main pre-amplifier (1032nm, 7J, 10ns, 10Hz) for a period of forty eight hours, high efficiency (>75%) frequency conversion (SHG) of the output of the main pre-amplifier and demonstration of the 100J power amplifier laser diode pump system. The successful delivery of these milestones has significantly increased the profile of the CLF as a leader in this "ground breaking" DPSSL technology.

The communication of our work and its impact to non-scientific audiences is an increasing priority and the public profile of CLF continues to grow with a number of impact stories featuring in the mass media.

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

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