Foreword

John Collier
Director, Central Laser Facility, STFC Rutherford Appleton Laboratory, Harwell Campus, Didcot, UK
Email address: **john.collier@stfc.ac.uk** Website: **www.clf.stfc.ac.uk**

This annual report for the Central Laser Facility (CLF) at the STFC Rutherford Appleton Laboratory provides highlights of scientific and technical research that has been carried out by users of the Facility and its staff over the financial year 2018-19.

The CLF and its community have continued to deliver scientific output and technical development of the highest order.

Vulcan – has progressed the design of a new short-pulse beamline for the Vulcan TAP (Target Area Petawatt) area. Based on the OPCPA technique that the CLF has pioneered, this will deliver a petawatt level pulse (30 J in 30 fs) in addition to the existing petawatt (500 J, 500 fs) and long pulse (250 J) capabilities. This beamline will enable new areas of imaging and combined proton/electron interactions to take place. Tenders for the main equipment have been started and work to transform the old Target Area East into the new laser area for the beamline is nearing completion.

Gemini – discovered a potential solution for one of the perennial problems with pointing jitter, affected by vibrations. This solution, based on stabilising a back-propagating beam from the focus, was successfully tested and put into effect in an experiment in Gemini. We also took a great stride towards implementing machine learning algorithms for plasma-based accelerators. An experiment in Gemini's Astra target area used a genetic algorithm to apply active feedback to optimise laser-driven electron acceleration, the results of which were published in Physical Review Accelerators and Beams.

Artemis – has moved across campus to the Research Complex at Harwell as part of a major upgrade. The upgraded Artemis will include a new laser system – a mid-IR system running at 100 kHz – which is a joint development with Ultra. This year saw the building and installation of new laboratories, which will re-open in 2020. These laboratories will hold three dedicated XUV beamlines for imaging, photoemission from condensed matter, and gas-phase photoelectron spectroscopy.

Target Fabrication – has maintained delivery of high specification targets to the internal user programme, including development of multi-element assemblies with high alignment tolerances and novel coil geometries for ion acceleration experiments. Target delivery has been achieved using the highly specialist equipment available within the CLF and more widely across STFC. The investments in x-ray computed tomography (CT) for characterisation have allowed Target Fabrication to provide user groups with increased data on targets, while the further development of single point diamond turning for precision machining has allowed new targets to be fielded. High repetition rate targetry developments include robotic assembly and tape targets. Scitech Precision Limited (the spin out from CLF Target Fabrication) has provided microtargets to many national and university laboratories across the world, in addition to supplying precision laser machining services to support the high-tech businesses on the wider campus.

Plasma Physics Group – has improved its provision of codes, cluster resources, and direct user support. The group is in the process of obtaining a replacement for the computer cluster SCARF-Lexicon-2, namely SCARF-DeMagnete, which will be of comparable specification.

The CLF's *Ultra* and *Octopus* facilities in the Research Complex at Harwell continue to serve a multidisciplinary community, with user programmes in areas ranging from fundamental chemistry and materials science to biomedical and environmental research.

Ultra – delivered 60 weeks of access to the academic community and two weeks to industrial users. The changes in the structure of proteins and DNA underpin their function in nature; to study the dynamics of these changes, Ultra has developed a unique two-dimensional infrared (2DIR) spectrometer with 1 ns high intensity laser that induces bimolecular change by creating temperature jumps in the sample. A new programme, "Structural dynamics and photoinduced electron transfer", will deliver new understanding on the mechanisms of electron transfer. This research will impact the development of photocatalysts and light energy harvesting and chemical synthesis.

Octopus – delivered 100 weeks of access to the user community. This included 10 weeks of proof of concept access, enabling prospective users to make short visits for feasibility studies. In addition to this, the facility has delivered industrial access to a number of companies, through paid access, collaboration with academia, and the Bridging for Innovators (B4I) funding programme. Development on correlative light and electron microscopy (CLEM) continues. The most recent development, funded jointly by BBSRC's 18ALERT scheme and the CLF, was the installation of a cryo focused ion-beam scanning electron microscope that will be used for both imaging and preparation of samples for transmission electron microscopy, as part of a CLEM workflow involving other Octopus microscopes.

Following delivery of the first 1 kW DiPOLE system to the HiLASE Centre in Dolní Břežany, Czech Republic, the CLF's Centre for Advanced Laser Technology and Applications (**CALTA**) has made significant progress on the construction of a second system destined for the European XFEL in Hamburg. Funded through a joint STFC / EPSRC research grant, this "DiPOLE 100" will be used to drive materials to high pressure states to be diagnosed using the XFEL x-ray beam. A unique temporal pulse shaping capability, developed specifically for the XFEL application, will enable precise control of the pressure produced, while the high repetition rate will enable rapid accumulation of data for improved measurement accuracy. The system build is nearing completion and commissioning of the first stage of amplification is underway.

Further development of the DiPOLE Diode Pumped Solid State Laser (DPSSL) technology is an essential element of a Widespread Teaming collaboration between STFC and the HiLASE Centre. The €50M project to establish HiLASE as a Centre of Excellence is jointly funded by the EC and the Czech Ministry of Science. STFC is assisting in the establishment of the Centre and is playing a leading role in the development of advanced DPSSL technology. This includes the design and construction of a 100 Hz version of the DiPOLE 10 J laser, increasing the pulse energy of the DiPOLE architecture and developing efficient second and third harmonic generation at 10 Hz. This will extend STFC's lead at the forefront of DPSSL technology.

Industry Partnerships and Innovation Group

has been established to build and manage the CLF's partnerships with industry, deliver contract access to our capabilities and expertise, and oversee the innovation activities within the department. The CLF continues to participate in the STFC Bridging For Innovators funding programme, which offers businesses access to STFC facilities for projects that fast-track solutions to industrial challenges. For example, OxSyBio, a University of Oxford spin out developing adipose models for testing new drugs, accessed microscopy techniques in Octopus to validate their 3D printed cell structures. "*It is a powerful platform for potentially identifying new therapeutic interventions for metabolic diseases. This achievement has only been possible through a multi-institutional collaboration between a broad range of specialists at OxSyBio, MRC Harwell Institute and the Central Laser Facility.*" Dr Alex Graham (MRC-Harwell).

Dr Chris Thornton at the CLF was successful in his application for a three-year UKRI-EPSRC Innovation Fellowship, in partnership with Johnson Matthey, the Manufacturing Technology Centre and Warwick Manufacturing Group. The Fellowship is hosted at the CLF and is focused on laser-driven x-ray techniques for advanced micro-CT imaging and x-ray absorption spectroscopy.

I do hope that you enjoy reading this selection of abstracts. Please visit the CLF website to access the full papers and find out more about the exciting times ahead at the CLF!

Professor John Collier FLSW
Director, Central Laser Facility