Foreword

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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 2017-18.

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

Vulcan – has started on the design of a new short-pulse beamline for the Vulcan TAP area. This will be based on the OPCPA technique that the CLF has pioneered and will deliver a PW level pulse (30J in 30fs) in addition to the existing PW (500J, 500fs) and long pulse (250J) capabilities. This will enable new areas of imaging and combined proton/ electron interactions to take place.

Gemini – has maintained its pre-eminent stature as a driver for secondary sources for applications as well as fundamental science, yielding several high-impact papers this year. Highlights include demonstration of radiation reaction — where the radiation emitted by a near-light speed electron beam in presence of an intense field exerts a back action on the electron itself, slowing it down — which was published in Physical Review X.

Artemis – will be moving 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 purchase with Ultra. The laboratories will hold three dedicated XUV beamlines for imaging, photoemission from condensed matter, and gas-phase photoelectron spectroscopy. This year saw detailed planning for the upgraded labs, which will re-open in 2019.

Target Fabrication – has continued to deliver high specification targets to the internal user programme, including development of novel microcone targets for electron guiding. In addition, investment in x-ray CT for characterisation and single point diamond turning for precision machining has expanded the capabilities of the group with world leading technologies. Scitech Precision Limited (the spin out from CLF Target Fabrication) 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 continued to improve its provision of codes, cluster resources, and direct user support. The group has recently installed a new 1500 core cluster resource, with commissioning taking place in the 2017/18 period.

The CLF's facilities in the Research Complex at Harwell, *Ultra* and *Octopus*, 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 four weeks to industrial users. The facility continues to develop capability and scientific applications of its non-linear vibrational spectroscopic techniques, for example the use of the surface sensitive technique on studies of earth abundant metal catalyst surface and hybrid Raman-IR 2DIR techniques applied to drug discovery. A new programme was awarded,

titled "Time and length scale correlations in biomolecular dynamics", that will provide insights into protein dynamics and advance the facility through the introduction of time resolved 2DIR capability.

Octopus – continues to deliver 100 user weeks per year to the user community. This includes 10 weeks of proof of concept access where prospective users can make short visits for feasibility studies. In addition there has been an increase in access to the facility by industrial users, particularly through the Bridging for Innovators (B4I) programme. A new microscope offering super-resolution microscopy at cryogenic temperatures is now available for users and has already been accessed by a number of groups. Correlative microscopy has continued to be a focus for development, in collaboration with Diamond, eBIC, and the Rosalind Franklin Institute.

The **CLF's Centre for Advanced Laser Technology and Applications (CALTA**) was established in 2012 to develop a new class of lasers capable of delivering high energy, high peak power pulses at high repetition rate and high efficiency to drive new applications in advanced imaging, materials processing, non-destructive testing and fundamental science. Based on laser diode pumped Ytterbium-YAG in the form of a transparent ceramic, CALTA's DiPOLE Diode Pumped Solid State Laser (DPSSL) architecture has demonstrated stable 1 kW operation for extended periods in 100 J, 10 ns pulses delivered at 10 Hz. With an overall optical efficiency of >20%, DiPOLE systems have the potential to transform single shot demonstrations of effects into real world applications.

Following delivery of the first 1 kW DiPOLE system to the HiLASE Centre in Dolní Břežany, Czech Republic, work is well advanced on the construction of a second system destined for the European XFEL in Hamburg. Funded through a joint STFC / EPSRC research grant, the "DiPOLE 100" will be used to drive materials to high energy density 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 energetic states 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 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 10J laser, increasing the pulse energy of the DiPOLE architecture and developing efficient second and third harmonic generation at 10Hz. This will extend STFC's lead at the forefront of DPSSL technology.

Economic Impact – continues to increase, with the CLF building strong relationships with industry. Six new commercial contracts were established with companies this year to gain access to our facilities (Ultra, Octopus and Gemini). Additionally the CLF is building industry partnerships to help solve industrial challenges, and a pilot innovation project between the CLF and India's Tata Institute of Fundamental Research is underway.

In summer 2017, the CLF/STFC spinout company Cobalt Light Systems Ltd was acquired by Agilent Technologies for £40M. The company is based around CLF's patented technology developed at its Ultra facility.
Company products include airport security scanners used at over 75 airports worldwide. Agilent will now develop their global centre for Raman spectroscopy at the Harwell Campus.

Despite an uplift in funding and consequently an uplift in the volume of user access we are able to offer, demand for access to the CLF both from UK and international scientists continues greatly to exceed the time available for the scheduling of experiments. It is not surprising then that the standard of the research presented in this report is excellent, demonstrating once again the internationally leading position of the CLF and our user community. The close partnership we have with our user community remains central to our success, together with the ability and dedication of our staff.

I 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!

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