Foreword

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In its 45-year history, the Central Laser Facility (CLF) has never experienced such a challenging time as during 2020/21, with the COVID-19 pandemic that swept the world. Despite most staff and users being prevented from coming to site, and operations being severely curtailed, we still managed to maintain an active community, and deliver scientific output and technical development of the highest order. Moreover, the Lasers for Science division introduced a Rapid Access mechanism to grant facility access for R&D related to the fight against COVID-19, enabling users in academia and industry to take early action in a time of need and demonstrating how the CLF is able to respond quickly to new challenges.

Based at the STFC Rutherford Appleton Laboratory in Oxfordshire, our laser facilities – **Vulcan, Gemini, Artemis, Ultra** and **Octopus** – are amongst the most advanced in the world. They enable research across a broad range of science areas, spanning physics, chemistry and biology, that is contributing to international efforts to solve major scientific, economic and societal challenges. Our suite of facilities is underpinned by considerable expertise and enabling capabilities, including computational **plasma physics**, **target micro-fabrication** and **engineering**, that help our users to push the boundaries of science and research.

In the near future, our new **Extreme Photonics Applications Centre (EPAC)** will open its doors to users. An exciting partnership between UKRI, MoD, academia and industry, we expect this new facility to deliver scientific breakthroughs and new solutions to challenging problems. In the last year, considerable progress has been made and the building itself has started to take shape. **EPIC**, the joint innovation centre with India, also continued to play a major role in developing ancillary technology solutions for our high power laser facilities and EPAC.

In addition to its user facilities, the CLF is home to the **Centre for Advanced Laser Technology and Applications (CALTA)**. A key success has been the development of a proprietary technology, DiPOLE, capable of delivering high energy pulses at high repetition rate for applications including advanced imaging, materials processing, non-destructive testing and fundamental science. This technology will be the laser pump source for EPAC. CALTA and the CLF's **Industry Partnerships and Innovation (IPI) group** also work with industrial partners to facilitate solutions to real-world problems by exploiting the CLF's extensive technological capability developed by our experts over many years

This annual report for the CLF offers an insight into some of the scientific and technical research that has been carried out by users of the CLF and its staff over the financial year 2020/21. I do hope that you enjoy reading this selection of abstracts, and feel inspired by the achievements of all those involved.

Professor John Collier FLSW
Director, Central Laser Facility

Highlights of 2020/21 include:

A collaboration between the CLF and the Chinese Academy of Sciences used **Vulcan** Target Area West to produce a terawatt of terahertz. High power and spectrally tunable driver light pulses are required for an ever-increasing number of strong-field applications, such as ultrafast coherent control over matter and light.

An international group of researchers used the CLF's **Gemini** Laser to implement AI in order to optimise a new type of particle accelerator. The study highlighted the possibility of exploiting machine learning techniques to produce a fully automated plasma accelerator, whilst synchronously uncovering never-before-seen insights into the fundamental physics of the machine.

An international collaboration involving the **Artemis** Laser Facility looked at an intriguing 2D material. 2D materials have the potential to result in devices that are smaller, run faster, and consume less power, as well as offering a wealth of other potentials such as foldable, flexible, transparent electronics, and perhaps even self-charging solar powered devices.

Octopus took delivery of a MINFLUX microscope that aims to bridge the resolution gap between light and electron microscopy, with the ultimate goal of structure determination in the cell. Its scanning Stimulated Emission Depletion (STED) super-resolution microscope was also upgraded, and has resulted in a number of high impact publications from the user community in areas including antimicrobial resistance and immunology.

Research began to develop the technology to study ultrafast details of reactions in chemistry, with **Ultra** at the hub. Work with UEA and the wider CLF aims to improve understanding of, and potentially control, photochemistry and photobiology to maximise efficiency yield, with many possible applications including the potential for improving the efficiency of man-made solar energy.

CALTA's DiPOLE laser was used in the first ever demonstration of laser shock peening (LSP) of Tungsten. A Proof of Concept award was announced to take the DiPOLE laser shock peening programme forward.

In **EPIC**, team members were recruited for targetry, engineering and detector work packages and the preliminary designs for some of the technical solutions got underway. The control system group became fully functional, working hand-in-hand with the CLF team, delivering several modules.

Our scientists continued to be creative and drive forward the **IPI Group's** innovation portfolio. An additional four proof-of-concept projects were introduced and the CLF filed two new patent families this year, giving a current total of 23 active patent families.

The **Plasma Physics Group** has continued to provide CLF users with theory and simulation support, including access to the PRISM suite and help with use of the CLF's SCARF resources.

The CLF's **Target Fabrication Group** successfully fielded its high rep-rate tape drive system in the Gemini target area. After two days of dedicated facility time to enable some de-bugging and modifications, it was used successfully on a commercial access run.

The design of a new building for **CLF Engineering** was commissioned. This building will allow us to bring all of the engineering lab spaces together into a central hub.

CLF technicians worked with colleagues across STFC to provide much needed ventilators for the NHS.