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 research which has been carried out by users of the Facility and its staff over the financial year 2007-08.

2007 marked the 30th anniversary of the official launch of the CLF, captured in the pictures below. Funding approval was actually granted in 1975, and the first shots fired in December 1976. The first 2-beam implosions were performed by April 1977, with over 1000 shots fired in the subsequent 12 months, including studies of fusion neutron production! Over the subsequent years, laser development continued on three fronts: high energy glass (Vulcan), KrF (ELF, Sprite, Titania), and table-top lasers (the Lasers for Science Facility – LSF), which launched the current Astra Ti:Sapphire system. The science performed on these systems has been consistently reported in these Annual Reports – which are now archived online on the CLF website.

It is fitting that in this year of celebration – which includes the laboratory's 50th anniversary – a number of major steps have been taken to help ensure the CLF will maintain its strong international position for many years to come.

In November 2007, the Minister of State for Science and Innovation (Ian Pearson MP) officially opened the Astra-Gemini laser facility. This laser is set to enhance the peak intensity available at the CLF by a factor of ten (to 10^{22} W/cm^2), and marks a step-change in petawatt laser capability – moving from one shot every 30 minutes to one shot every 20 seconds! The LIBRA Basic Technology project – led by Queen's University Belfast, with significant involvement from the CLF – is designed to develop the associated diagnostic and target handling technology to take full advantage of this new source capability. I believe these changes will transform the field over the next few years, and pave the way for many future applications of high power laser science.

This year also saw significant progress with the Ultra and Artemis facility development projects – designed to take vibrational spectroscopy and ultrafast science into new regimes for our user comminity. We also initiated the New Light Source project, which is exploring the potential for next-generation photon sources to probe the dynamics of matter on femtosecond timescales by combining conventional lasers with Free Electron Laser technology. This project will present its science case in October 2008, and a facility proposal the following year.

Top: Official Launch party in June 1977, with Alan Gibson (first head of the CLF), Dan Bradley (leading academic), Sir Sam Edwards (Chair, SRC) and Godfrey Stafford (Director of the Rutherford Laboratory).

Bottom: Godfrey Stafford, Mike Dunne and Malcolm Haines at the 30th birthday celebrations.

A significant review of STFC was undertaken over the past year, in which its entire science portfolio was assessed and prioritised. The outcome provided solid backing for our high power laser facilities and reinforced the need for significant investment in ongoing facility development, for example the proposed 10 Petawatt upgrade to Vulcan. It also recommended a focusing of the Lasers for Science Facility (LSF) to ensure full advantage is taken of opportunities for longer term strategic programme development associated with the LSF's relocation into the Research Complex at Harwell, which is now under construction (next door to Diamond). As part of this process, we will be integrating STFC's single molecule imaging facilities within the LSF. This move from the Daresbury Laboratory will take place in 2009.

The CLF has invested in an expansion of its target fabrication and mechanical engineering support laboratories, which underpin our successful operation as a full service facility. We also undertook a significant upgrade to the Vulcan TA-West facility to provide a dual CPA capability combined with the existing long pulse beamlines. This will ensure a significant medium-term niche role for Vulcan in the fields of inertial fusion energy and related high energy density science at a time when major facilities are coming online in the USA and Pacific Asia.

I am particularly pleased to say that the CLF has led the European HiPER laser fusion project to the stage where substantial funding has been obtained for the critical 3-year Preparatory Phase. Along with the European ELI project, this is intended to secure a strong future for the science of truly extreme conditions, whilst addressing some of society's most compelling priorities.

The high level of 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 first rate, demonstrating once again the internationally leading position of the CLF and its user community. It is important to remember also that the science performed at the CLF maps strongly onto real world problems that concern us all. The table below lists some examples of the experimental and theoretical research now underway that is of direct relevance to the societal priorities identified by our parent Government department – Department for Innovation, Universities & Skills (DIUS).

Finally, I would once again like to record my sincere appreciation to the CLF staff for their outstanding effort, enthusiasm and commitment over the past year.

Mike Dunne

Energy	• novel photovoltaic materials development and understanding • pursuit of abundant clean energy via laser fusion
Living with Environmental Change	• understanding the chemistry of our atmosphere at the molecular level (e.g. aerosol behaviour in the upper atmosphere) • study of fundamental atmospheric physics to help computer modeling development (e.g. molecular clusters, droplet and snowflake formation)
Global Threats to Security	• detection of counterfeit drugs, concealed liquid and powder explosives and illicit drugs using laser spectroscopy techniques (with CLF's spin-out company LiteThru Ltd) • detection of explosives and nuclear materials using high power lasers • biological agent studies
Ageing: life long health and wellbeing	• development of techniques to understand from a systems biology viewpoint, the function of drugs at the molecular level in diseases like cancer, osteoporosis and neurological disorders • studies to understand the structural dynamics of protein folding in Alzheimer's and motor neurone disease • understanding the molecular function of drugs (e.g. Rapamycin, Herceptin) and their variations in populations • development of 2-photon photo-dynamic therapy • non-invasive diagnostics for osteoporosis, breast cancer, serotonin levels, etc • imaging techniques to facilitate stem cell research • development of novel drug delivery techniques • laser driven ion sources that offer the potential for high quality, lower cost oncology treatment
Digital Economy	• development of ideas for ultra-high density data storage devices
NanoScience through Engineering to Application	• nanoprobes with unsurpassed force resolution (pN) for medical and material science studies • new sub diffraction-limit spectroscopic imaging techniques • in situ nano-machine fabrication and micro-fluidics for sorting particles and cells • populating structured biomaterials with stem cells

Examples of experimental and theoretical research and their societal applications