Artemis

Velocity map imaging spectrometer for the study of atomic and molecular physics in the gas phase

63

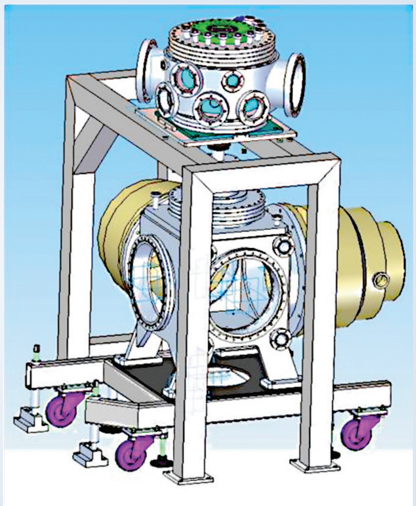
R. Minns, E. Springate, C. Cacho, E. Turcu, S. Spurdle
(STFC, Rutherford Appleton Laboratory, UK)

M. Siano, S. Weber, C. Hutchison, M. Oppermann, T. Siegel
(Imperial College, UK)

J. Underwood
(University College London, UK)

E.Springate
emma.springate@stfc.ac.uk

Imaging techniques now dominate the study of excited state molecular dynamics and strong field physics. The ability to angle and energy resolve fragments produced via laser induced processes can provide a new viewpoint for the study of molecular fragmentation, strong field ionization and dissociation and Coulomb explosion processes, among others. To this end a new velocity map imaging (VMI) spectrometer specifically designed for the study of highly energetic fragments has been designed and built at the Artemis facility. The chamber contains a molecular beam source and VMI spectrometer that can be configured to collect both ions and electrons with kinetic energies up to 200 eV.



The AMO endstation at the Artemis facility

Astra

An assessment of the reproducibility of the Gemini retro focusing system

64

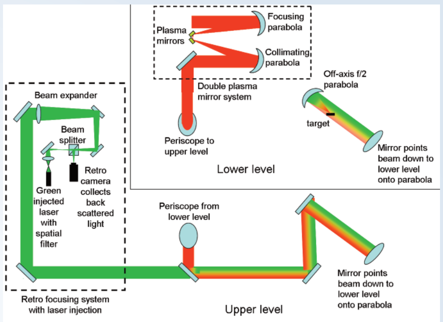
D. C. Carroll, M. Coury, G. Scott[1], P. McKenna
(University of Strathclyde, UK)
M. J. V. Streeter, H. Nakamura, Z. Najmudin
(Imperial College London, UK)
F. Fiorini, S. Green
(University of Birmingham, UK)
J. S. Green, P. Foster, R. Heathcote, K. Poder, D. Symes, R. J. Clarke, R. Pattathil, D. Neely
([1]STFC, Rutherford Appleton Laboratory, UK)

D. Carroll
david.carroll@strath.ac.uk

The retro-focus system in the Astra-Gemini laser area is used in experiments to position solid targets relative to the tight focus of the laser focused by the off-axis parabolic mirror.

The consistency of positioning a target relative to tight focus was tested. Multiple attempts of positioning the target using the retro-focus system were measured for multiple operators.

It was found that any individual attempt at placing a target at tight focus was not sufficiently consistent to ensure that the target position was within the Rayleigh range. It was found that taking the average of multiple attempts at positioning the target was considerably more consistent such that for all operators their average was either close or within the Rayleigh range.



Astra Gemini Beam path with Retro system layout. It also shows how the beam path is split between an upper and a lower level in the chamber.

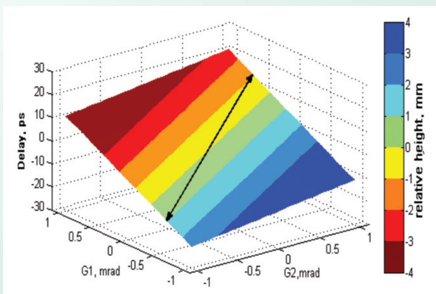
Modelling of relative delay for scattered rays in a grating stretcher

65

O. Chekhlov, C. J. Hooker
(STFC, Rutherford Appleton Laboratory, UK)

O. Chekhlov
Oleg.Chekhlov@stfc.ac.uk

We analyse a mechanism by which scattered light could contribute to the contrast pedestal seen in the compressed pulse in Astra Gemini and other CPA laser systems. The suggestion is that light scattered in a range of directions can return to its starting point in the stretcher and scatter into the direction of the output pulse within the acceptance angle of the system. We used a Zemax model of a grating pulse stretcher similar to the one in Astra, using virtual mirrors in the positions of the two stretcher gratings to simulate scattering events. We found that light at a particular wavelength scattered at both the first and the second diffraction gratings can follow either shorter or longer paths through the pulse stretcher. Our estimates of the delay such scattered beams could experience agree fairly closely with the observed temporal extent of the pedestal.



Dependence of relative delay of ray propagation through grating stretcher on angle rotation of virtual mirrors, which simulate fans of scattered rays, at the positions of G1 and G2 gratings. The colour map corresponds to the relative height of the rays returning to the G1position.

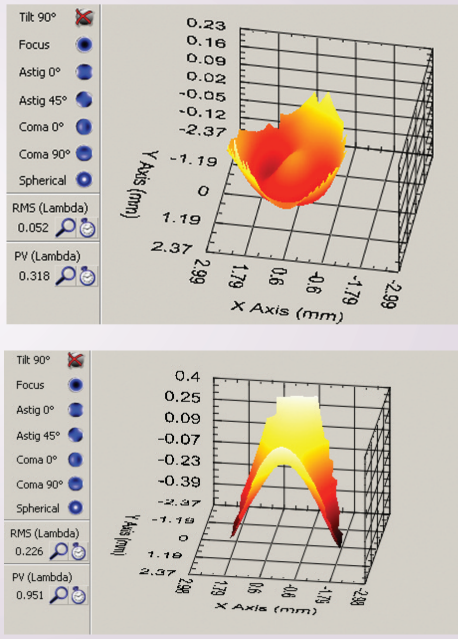
Characterisation and correction of the Gemini wavefront

66

S. Hawkes, C. J. Hooker, B. Parry
(STFC, Rutherford Appleton Laboratory, UK)

S. Hawkes
steve.hawkes@stfc.ac.uk

The wavefront quality of any ultra short pulse laser system is of fundamental importance as it determines the on target intensity. The wavefront quality of the Gemini CW and repetitively pulsed beams have been characterized. Measurements were made at the output of the Gemini amplifier and after the pulse compressor using a HASO 32 Shack-Hartman wavefront sensor. The wavefront has been corrected to 0.3 waves PV using a Static Astigmatism Corrector. Further improvement is still required for the more demanding Gemini experiments and this will require an adaptive optic, which is under development.



CW Wavefront distortion (Top Right) and Astra 10 Hz Wavefront distortion (Bottom Right)

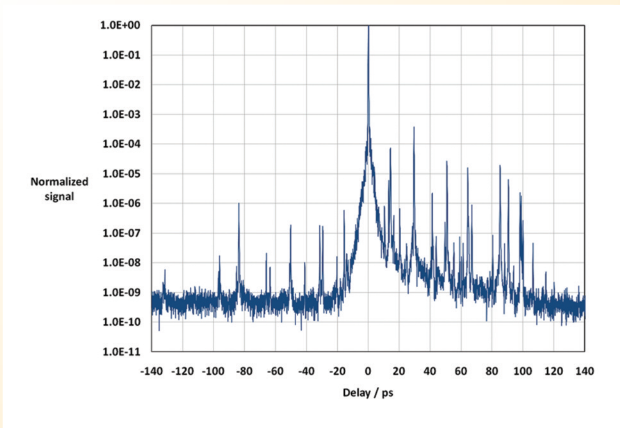
Improving the contrast of Astra Gemini

67

C. J. Hooker, Y. Tang, O. Chekhlov, J. L. Collier, E. J. Divall, K. Ertel, S. J. Hawkes, R. P. Pattathil and D. R. Symes
(STFC, Rutherford Appleton Laboratory, UK)

C. J. Hooker
chris.hooker@stfc.ac.uk

We have investigated the origin of one of the most serious contrast problems affecting Astra Gemini. The "coherent pedestal" is the triangular feature that occupies the 15 or so picoseconds around the main pulse in the Sequoia trace shown in figure. It has potentially severe consequences for the kinds of experiments that are possible using Gemini. We made measurements in which various stretcher optics were bypassed by realigning the beam, and the results showed that the gratings in the stretcher were the main source of the feature. Modelling has shown that light scattered from the gratings can travel along both longer and shorter paths through the stretcher, and this can explain the origin of the pedestal. Replacing the old gratings with new ones has reduced the level of the coherent pedestal by a factor of 20, which is consistent with the reduced levels of scatter from the new gratings.



Example contrast trace of Astra Gemini showing the triangular shape of the coherent pedestal around the main pulse.

Spatial overlap measurement of two F/2 parabolas on Astra-Gemini

68

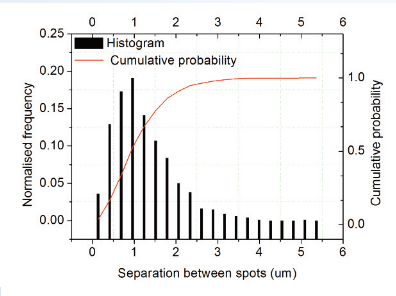
K. Poder, N. Booth, P. Brummitt, O. Chekhlov, K. Ertel, P. S. Foster, S. Hancock, S. J. Hawkes, P. Holligan, C. J. Hooker, D. Neely, D. Neville, B. Parry, D. Rathbone, D. Rose, D. Symes, Y. Tang, A. Zayyani, P. P. Rajeev

(STFC, Rutherford Appleton Laboratory, UK)

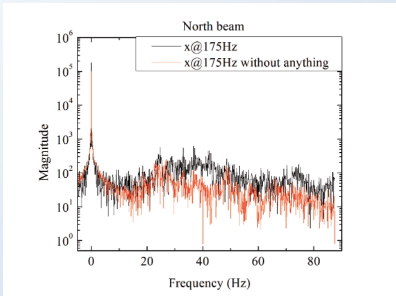
K. Poder
kristjan.poder@stfc.ac.uk

The spatial overlap of two focal spots produced by F/2 parabolas was measured. The ~2.5 μm focal spots were found to vibrate about their mean position with submicron RMS amplitudes, for the north beam this was 0.59±0.01 μm and for the south beam the displacement was 0.43±0.01 μm. A 75% energy overlap, which requires the separation between spot centroids to be less than 0.53 μm, was achieved on 20% of shots.

Fast Fourier Transforms were performed on the displacement data of the focal spots to investigate distinct vibration frequencies; however the analysis revealed little of their nature. In order to improve the spatial overlap and minimize the vibration of individual spots a closed loop correction system is proposed. This system is currently being commissioned and results are expected to be reported soon.



The separation between two focal spots: red line shows the cumulative probability to obtain a separation or less, black line is a histogram.



Frequency spectrum of vibrations of the focal spot with and without compressor, roughing pumps, turbo pumps and diggers.

Measuring and optimizing the pulse front tilt for Astra-Gemini laser

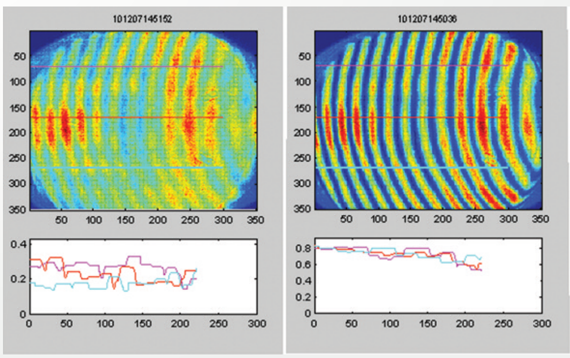
69

Y. Tang, O. V. Chekhlov, C. Hooker, S. Hawkes, K. Poder, P. Foster and R. Pattathil

(STFC, Rutherford Appleton Laboratory, UK)

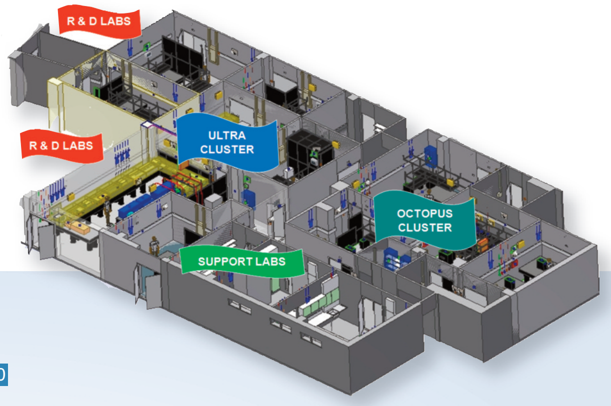
Y. Tang
Yunxin.Tang@stfc.ac.uk

The alignment of the stretcher and compressor in the CPA laser system is absolutely crucial as the residual angular dispersion due to minor misalignment could result in a significant pulse front tilt (PFT) and hence severely affect the laser performance in the focal plane, i.e. the temporal and spatial broadening of laser pulses. To overcome the limitations of conventional alignment techniques, a field-inverted interferometric autocorrelator (FIAC) has been implemented and used to characterize the PFT presented in the Astra-Gemini laser beam. By analyzing the visibility of spatial interference fringes of FIAC as a function of time delay between the two replicas, the temporal dependences of visibility across the beam could be retrieved from the interferogram patterns, and thus the PFT and corresponding residual angular dispersion could be quantitatively derived with a resolution <0.1μrad/nm. Optimization of the stretcher and compressor by minimizing the PFT resulted in further enhancement of laser performance.



Examples of interferogram at different time delays (top) and visibility profile lines (bottom) spatially sampled from corresponding lines of interferograms.

Lasers for Science Facility



The LSF within RCaH.

The Lasers for Science Facility in the Research Complex at Harwell

70

D. T. Clarke, M. Martin-Fernandez, M. Towrie
(STFC, Rutherford Appleton Laboratory, UK)

D. T. Clarke
dave.clarke@stfc.ac.uk

The Research Complex at Harwell (RCaH) provides facilities to undertake new and cutting edge scientific research in both the life and physical sciences, and at the interface between them. RCaH operates as a partnership between STFC, MRC, BBSRC, EPSRC, NERC, and Diamond Light Source. STFC's major contribution to RCaH was the move of the LSF to the complex, begun at the end of 2009. The LSF completed its move to RCaH at the beginning of 2011, and is now operating a full user programme, including a growing number of new multidisciplinary and cross-facility projects working in collaboration with other RCaH residents. Recent examples of multidisciplinary research enabled by the LSF include single molecule studies of cell signaling networks, investigations of dynamic structural science, and imaging across multiple time and length scales. Many of the collaborative programmes involve work with other campus partners such as Diamond and ISIS.

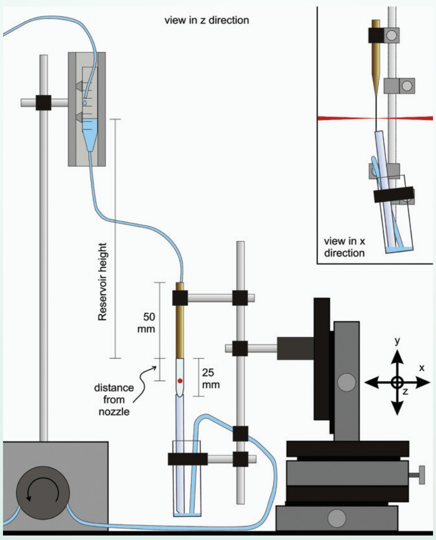
Developments in sample management in the ULTRA Laboratory

71

B. Coles, M. Towrie, A. W Parker, I. P. Clark and P. Burgos, G. M. Greetham
(STFC, Rutherford Appleton Laboratory, UK)
A. Lauer, P. Kukura
(Oxford University, UK)

B. Coles
benjamin.coles@stfc.ac.uk

There have been two main sample management developments in the ULTRA laboratory this year relating to time resolved pump-probe spectroscopy. The use of a peristaltic pump is a common method of circulating samples through a target flow cell. However, this imposes several limitations; namely restricting the minimum sample volume and operating temperature ranges.



The experimental configuration.

The high flux and power of the lasers can lead to unwanted background signals from non-linear optical processes induced in the window and/or photo-degradation of sample at the window fluid interface.

Here we present developments to overcome these issues; a closed nitrogen flow cell system when using low temperature and volume samples, and an open flow wire guided liquid jet to minimise unwanted background signals.

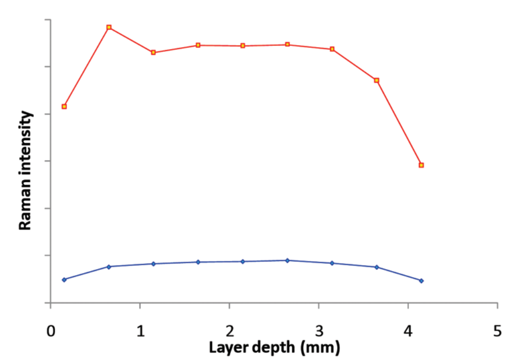
Signal dependence on depth in transmission Raman spectroscopy

72

P. Matousek
(STFC, Rutherford Appleton Laboratory, UK)
N. Everall
(Intertek-MSG)
D. Littlejohn and A. Nordon
(University of Strathclyde, UK)
M. Bloomfield
(Cobalt Light Systems Ltd, UK)

P. Matousek
pavel.matousek@stfc.ac.uk

Recently, transmission Raman spectroscopy has been shown to be a valuable tool in the volumetric quantification of pharmaceutical formulations. In this work a Monte Carlo simulation and experimental study are performed to elucidate the Raman signal depth dependence. The transmission Raman signal is shown to exhibit a moderate bias towards the centre of tablets and that this bias can be considerably reduced using a recently developed Raman signal enhancer, 'photon diode'. The enhancing element not only reduces the bias but also increases the overall Raman signal intensity and consequently improves the signal to noise ratio of the measured spectrum. Overall, its implementation with appropriately chosen reflectivity results in a more uniform volumetric sampling across the tablet and enhanced overall sensitivity. These findings are substantiated experimentally on a segmented tablet by inserting a PET film doped with TiO_2 at different depths and monitoring its contribution to the overall transmission Raman signal.



Experimental dependences of transmission Raman signal on the depth of its origin within a bare tablet and a tablet with an enhancing element applied to the laser incident side.

Improvement of laser tweezer experiments using kHz-rate feedback control

73

M. Pollard, I. Brawn, S. W. Botchway, A. Clark, E. Freeman, R. N. J. Halsall, A. W. Parker, M. Towrie, R. Turchetta and A. D. Ward
(STFC, Rutherford Appleton Laboratory, UK)

M. Pollard
mark.pollard@stfc.ac.uk

We report the improvement in control of microscopic particles using laser tweezers and a feedback control system, developed in collaboration with STFC colleagues. The system was developed to improve force measurement techniques by reducing the effect of thermally-generated collisions with other particles in a liquid environment. This was achieved by imaging the microscopic particles using an active pixel sensor, measuring unwanted movement in particle position and responding through the adjustment of the laser tweezers position. These tasks were performed within 140 microseconds using field-programmable gate array electronics. This resulted in a reduction of the particle's position variance by 60 %.

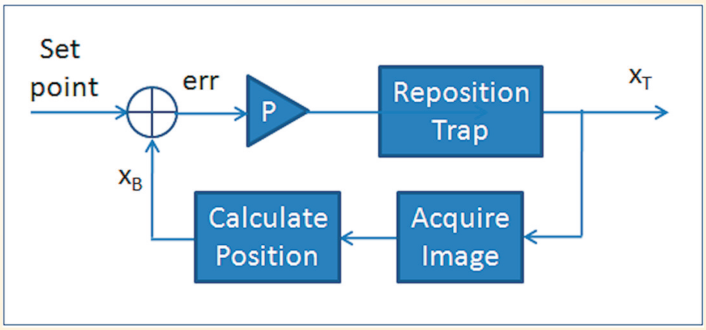


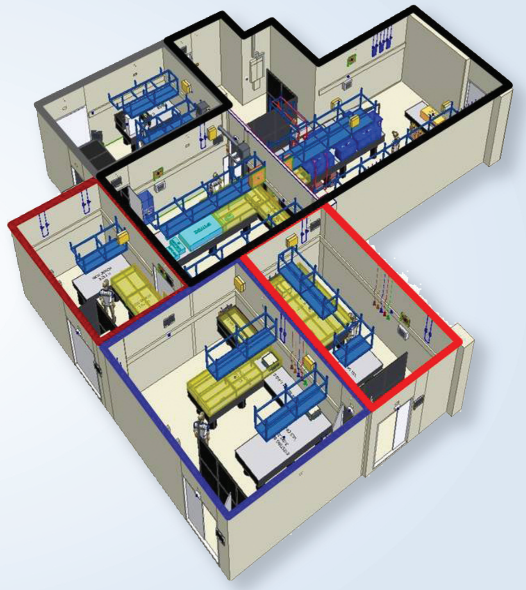
Diagram of the feedback loop within the control system.

Molecular structure & dynamics in the Research Complex at Harwell

M. Towrie, G. M. Greetham, M. Pollard, A. W. Parker, I. P. Clark, P. Burgos, V. Sachdeva
(STFC, Rutherford Appleton Laboratory, UK)

M. Towrie
mike.towrie@stfc.ac.uk

November 2010 saw the move of the Molecular Structure and Dynamics (MSD) Group to the Research Complex at Harwell (RCaH). This was completed successfully, enabling the MSD operations to continue, with minimal interruption. The move has enabled redesign of the ULTRA facility with increased capability and advances in the Facility Development project, TRMPS. As well as allowing major technical developments, the positioning within the RCaH permits access to shared facilities improving support for staff and visiting scientists and encourages formation of new cross-departmental and interdisciplinary collaborations. Current capabilities and future developments are presented here.



Cross-facility research activities in the Lasers for Science Facility

A. Ward
(STFC, Rutherford Appleton Laboratory, UK)

A. Ward
andy.ward@stfc.ac.uk

The relocation of the Lasers for Science Facility (LSF) to the Research Complex at Harwell (RC@H) has seen an increase in the number of collaborations and projects that are running across STFC facilities and Diamond Light Source. The science is largely of a multi-disciplinary nature and typically focuses on cross-cutting themes rather than specific facility techniques. As such, the topics are aligned with the scientific challenges addressed by the STFC Futures programme. The scope of activities falls into two general areas. The first consists of campus based scientists who have teamed up with the intention of extending the technical capability of their facilities and therefore allow new science to be performed. The second category involves academics who wish to utilize expertise and techniques of the LSF in combination with other facilities in a complementary approach to addressing their specific research needs.

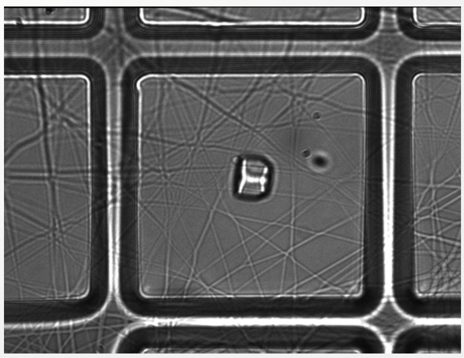
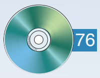


Image of an optically loaded protein crystals (size approx. 10 microns) positioned onto fiber coated micromeshes of 50 micron aperture. The image is only possible through cross-Facility collaborations. The crystal was captured and carefully positioned, using a laser optical tweezers (LSF), onto an MNTC- prepared custom micromesh backed with electro-spun fibres and then frozen prior to X-ray diffraction on Diamond beamline I24.
Armin Wagner (DLS), Andy Ward (CLF), Bob Stevens (MNTC)

Vulcan

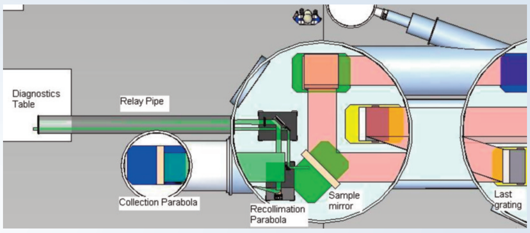
10PW short pulse laser diagnostics



A. Boyle and M. Galimerti
(STFC, Rutherford Appleton Laboratory, UK)

A. Boyle
alexis.boyle@stfc.ac.uk

In this article we present a possible layout for the 10PW short pulse diagnostics. Vulcan 10PW will require a more sophisticated version of the Vulcan diagnostics as the pulse length is much shorter, 30fs, with 300J of energy. The full size diagnostics will be taken from a leak through the back of the sample mirror, see figure. This channel will be used for the spatial diagnostics. To reduce the B-integral, the short pulse diagnostics will be taken from a hole drilled in the sample mirror. This channel will be used for the temporal diagnostics.



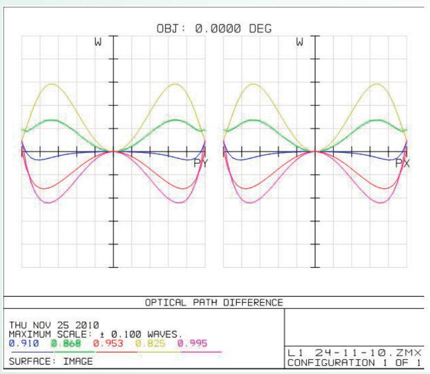
Sketch showing part of the compression chamber after the last grating, which houses the short pulse diagnostics channel.

Fighting chromatic aberration in 10PW

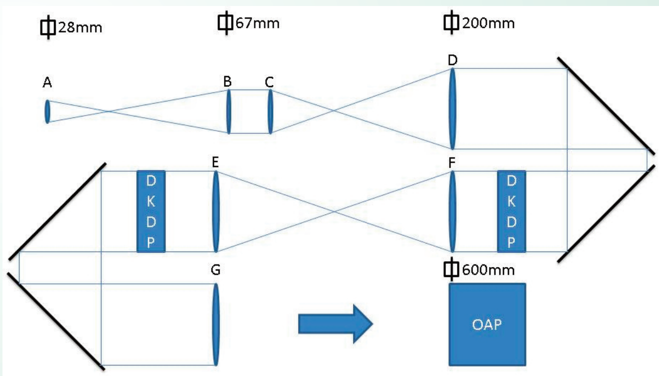
A. Boyle and M. Galimerti
(STFC, Rutherford Appleton Laboratory, UK)

A. Boyle
alexis.boyle@stfc.ac.uk

We present two possible optical layouts for the propagation of high power laser pulses at large bandwidth, 150nm centered at 910nm. The proposed Vulcan 10PW laser delivers a 300J, 30fs pulse on target. Zemax lens design software was used to optimize the beam propagation system through the OPCPA amplifier crystals to the compressor. The compressor requires a wavefront quality of λ/10. The large aperture doublet solution uses fused silica, CaF_2 and F2 lenses and has wavefront aberrations <λ/10 at the output and collimation <0.05mrad in the amplifier crystals. The mixed lens and off-axis parabola solution is diffraction limited over the required bandwidth. Both solutions have no ghosting issues.



Zemax OPD across the pupil at the output of the optical system for the doublet solution over 170nm.



Simplified layout of the beam propagation system through the OPCPA amplification stages. Letters A to G denote lens positions.

10PW compressor requirement analysis

78

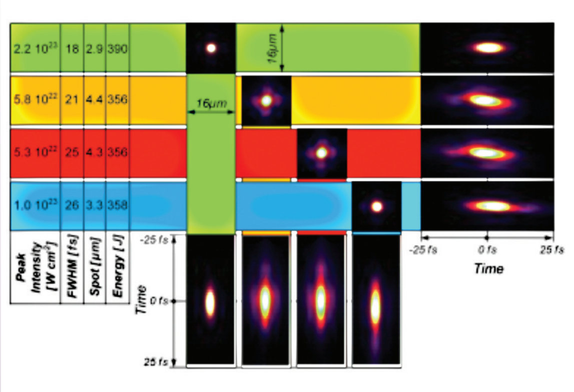
M. Galimberti, S. Blake, S. Hancock, C. Hernandez-Gomez, I. Musgrave, I. Ross, T. Winstone

(STFC, Rutherford Appleton Laboratory, UK)

M. Galimberti
marco.galimberti@stfc.ac.uk

To be able to achieve the specification on the 10PW project it is important to study the influence of different parameters of the compressor and input beam. A detailed analysis of each degree of freedom for the compressor optics and for the beam characteristics was required to specify the optics and the requirements on the incoming beam to guarantee the final specification.

Two different methods have been used. With the first a tolerance for each of the different parameters has been fixed to guarantee the specification of the project while the second tested those tolerances, using a corner montecarlo analysis, and provided the expected laser pulse shape in the focal spot for the target area TAP10. The expected pulses are in agreement with the specification of the project, showing good focusability and pulses shorten than 26fs.



Expected pulses in the focal spot.

Influence of the deuteration level on DKDP OPCPA amplifier

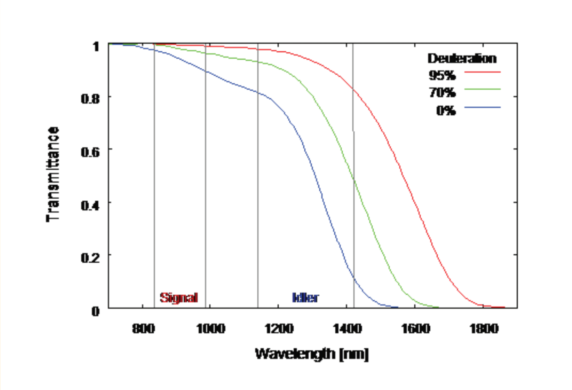
79

M. Galimberti, C. Hernandez-Gomez, I. Musgrave, I. Ross, T. Winstone

(STFC, Rutherford Appleton Laboratory, UK)

M. Galimberti
marco.galimberti@stfc.ac.uk

In this article we present the study performed about the influence of the deuteration level of the DKDP crystal on the performance of the OPCPA amplification stages of 10PW project, where the seed pulse it is expected to have 150nm bandwidth around 910nm. Different level of deuteration has a significant impact on the optical characteristics of the crystal, mainly the refractive index and the absorption in the infrared. The results of the study provide a minimum level of deuteration of 80% to guarantee the specification of the 10PW project while higher level of deuteration will provide better performance in terms of bandwidth and efficiency.



Spectral small signal gain for different deuteration levels. Each curve has been shifted for clarity. The two green vertical lines indicate the spectral region of the signal, 150 nm around 910 nm.

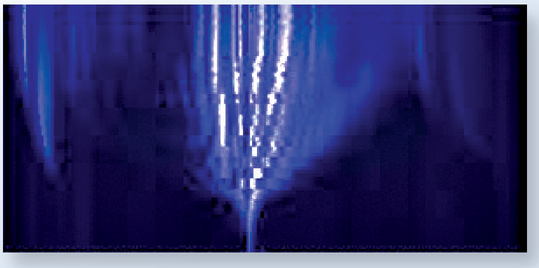
Study of self frequency shifting solitons in photonic crystal fibre to generate a synchronised 1053nm for the 10PW upgrade project

80

I. Musgrave
(STFC, Rutherford Appleton Laboratory, UK)

I. Musgrave
ian.musgrave@stfc.ac.uk

The 10PW upgrade project for the Vulcan Laser will include the provision for joint PW and 10PW operations in Target Area Petawatt for pump-probe experiments. For these type of experiments to be successful the pulses for the two beams to be synchronised with a relative jitter better than 200fs (FWHM). One way of achieving this is to use a common seed for both beam lines. This report outlines the effect of soliton self frequency shifting in fibres to investigate if it can be used to generate a seed pulse for the PW system from the 10PW front-end.



830nm output spectrum with waveplate angle. Background removed, and intensity logarithmic scale for clarity.

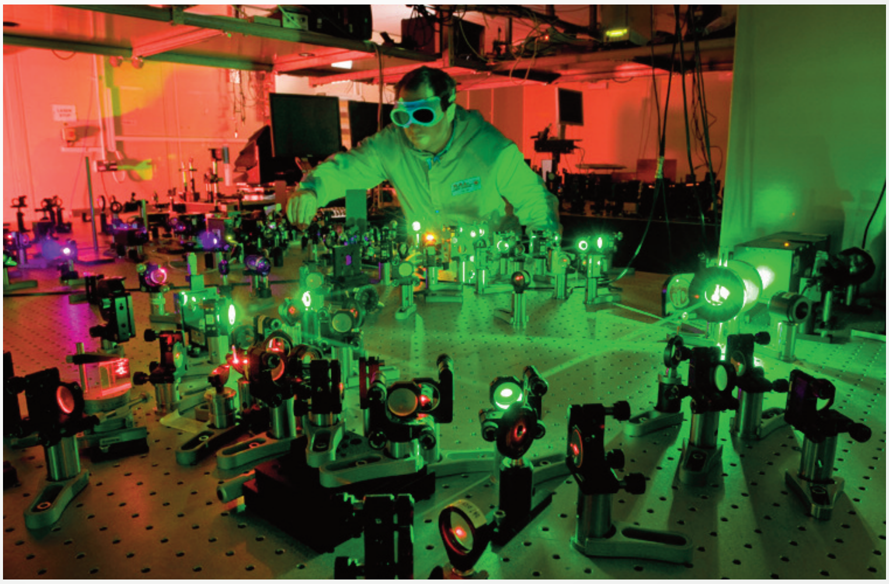
Study of the 10PW front-end contrast

81

A. Lyachev, I. Musgrave, M. Galimberti, C. Hernandez-Gomez, I. Ross and Y. Tang
(STFC, Rutherford Appleton Laboratory, UK)

A. lyachev
andrey.lyachev@stfc.ac.uk

In this contribution we report on the study we have conducted into the contrast performance of the 10PW front-end. We have measured the contrast at two points in the front-end system and found that the contrast of the whole system is not limited by the OPCPA technique. The contrast has been measured to be better than 10^{10} on the nanosecond timescale and 10^{7} at 5ps.



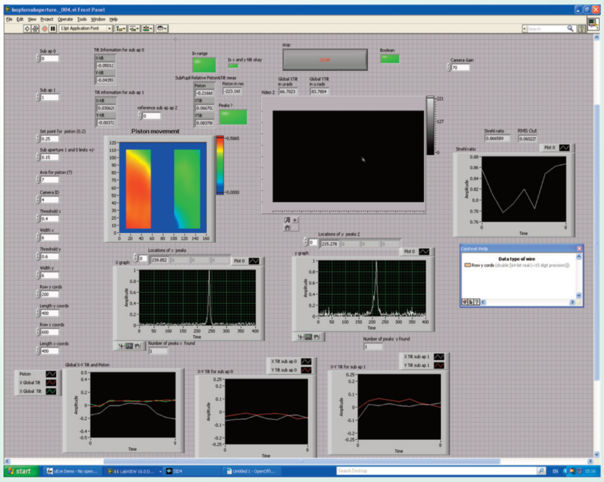
Vulcan 10PW front-end

Two beam spatial phasing with CW laser

P. J. Phillips, C. Hernandez-Gomez, I. Musgrave, J. Collier
(STFC, Rutherford Appleton Laboratory, UK)

P. J. Phillips
jonathan.phillips@stfc.ac.uk

High average powered lasers are attractive owing to their potential for a diverse range of experiments. One way of achieving this is by combination of several beams into a monolithic beam, which immediately reduces the requirements for the amplifier to a more modest level. This report describes a system developed to investigate the combination of two separate beams by the use of a dedicated wave front sensor (WFS). This has been achieved by software control of actuators for tip / tilt and piston errors. These errors are derived from the wave front sensor, including the piston which is taken from the interference from the two beams in the central part of the WFS. We have achieved a calculated Strehl ratio of greater than 0.8.



Shows the software for monitoring the coherent overlap of the two pulses.

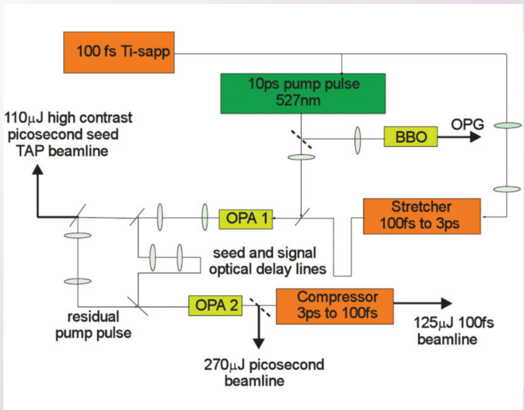
Improvements in the Vulcan picosecond OPCPA

W. Shaikh, I. Musgrave
(STFC, Rutherford Appleton Laboratory, UK)

W. Shaikh
waseem.shaikh@stfc.ac.uk

We have previously reported [1] on the generation of a broad bandwidth picosecond OPCPA system which is now routinely used as the seed for the nanosecond Vulcan OPCPA - by providing ~110μJ picosecond pulses as the seed for the second and third stages of the Vulcan OPCPA preamplifier, the nanosecond contrast in Target Area Petawatt has been improved by at least two orders of magnitude [2].

[1] W.Shaikh et. al. CLF Annual report 2008-2009 pp 292-293
[2] I. Mugrave et. al. Appled Optics Vol 49 Issue 33 pp 6558-6562



Schematic of two stage OPCPA system. The ‘dashed’ lines represent removable mirrors.

Vulcan 10PW project : Design of the long pulse pump laser

84

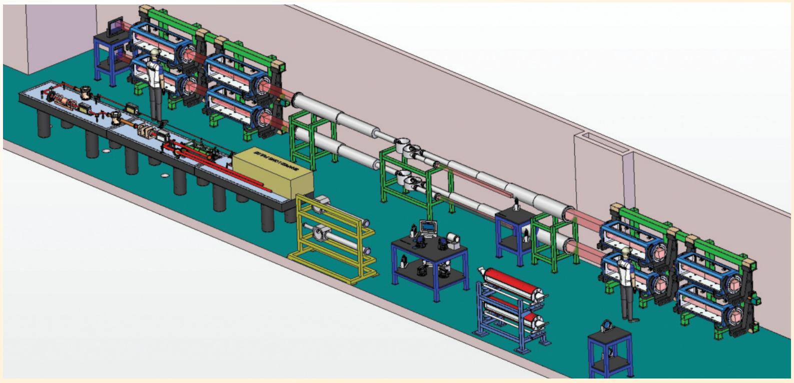
T. B. Winstone, S. Blake, A. Frackiewicz, M. Galimberti, S. Hancock, R. Heathcote, C. Hernandez-Gomez, P. Holligan, A. Kidd, I. O. Musgrave, D. Pepler, W. Shaikh

(STFC Rutherford Appleton Laboratory, UK)

T. Winstone
trevor.winstone@stfc.ac.uk

The Vulcan 10PW OPCPA project requires two long pulse beams to pump the two large aperture crystals. The 10PW team have brought together Frantz-Nodvik calculations, MIRO modelling, and experience of the existing Vulcan system to design a pump laser suitable for delivering two 3ns adjustable pulse shape infra-red beams at 1.2kJ each and a lower energy beam of 30J to pump a booster stage.

Using building blocks of a shaped long pulse oscillator, a rod amplifier chain and a disc amplifier output section we have settled on a final design through modelling to deliver the required specification. This requires the use of new technology for Vulcan such as rectangular disc amplifiers and double passed amplification using angularly multiplexed beams.



Long pulse pump laser potential layout.

Rectangular slab amplifier development

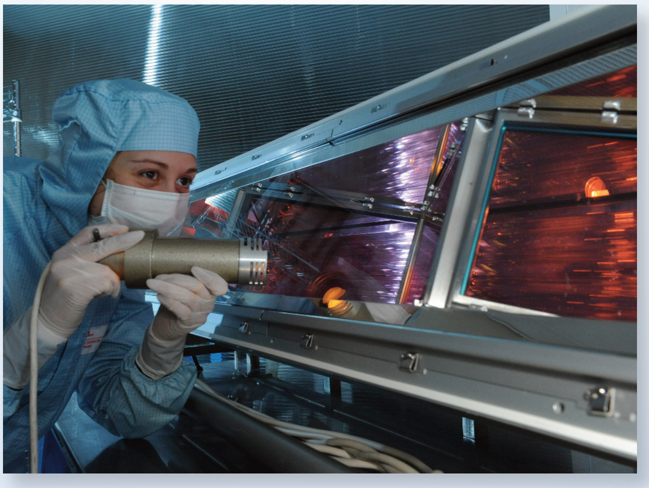
85

T. B. Winstone, A. J. Frackiewicz, S. E. J. Chapman, D. A. Pepler, S. Hancock, S. Blake, C. Hernandez-Gomez

(STFC, Rutherford Appleton Laboratory, UK)

T. B. Winstone
trevor.winstone@stfc.ac.uk

Manufacture of Nd:doped laser glass has undergone a revolution in recent years moving from a pour clad manufacturing process to a glue clad system. This leads to a higher yield and a better transmission quality. Disc amplifiers of the Vulcan Glass Laser System currently use the elliptical pour clad design. In future we will require glue clad rectangular slab technology both for the continued operation of the Vulcan System and also for the Vulcan 10PW Upgrade. A 150 size and a 200 size amplifier have been developed, with the 200 size having concluded gain testing.



Inspection of 150 Rectangular slab amplifier.

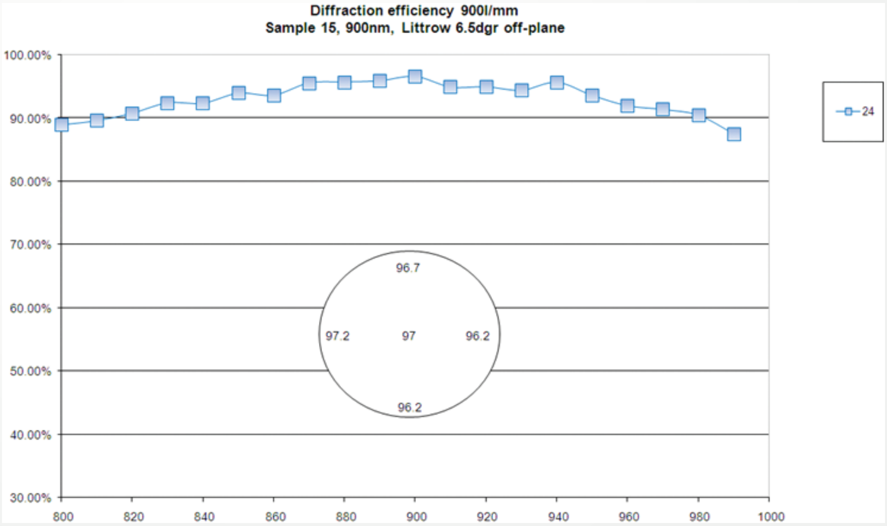
Vulcan 10PW upgrade: Development of metallic 900 lines/mm pulse compression gratings

86

T. B. Winstone, I. N. Ross, M. Galimberti, A. Lyachev, C. Hernandez-Gomez
(STFC Rutherford Appleton Laboratory, UK)
D. Smith, M. McCullough
(Plymouth Grating Laboratory, USA)

T. B. Winstone
trevor.winstone@stfc.ac.uk

The Vulcan 10PW upgrade requires large scale high efficiency gratings to compress the beam to 30fs. We report on progress on the development process we have undertaken to develop 900 line/mm gold gratings and how we worked with the manufacturer to produce metallic coated diffraction gratings with diffraction efficiencies regularly in excess of 90% across a bandwidth of greater than 160 nm and suitably high short pulse laser damage thresholds to ensure the specification of the facility is achievable.



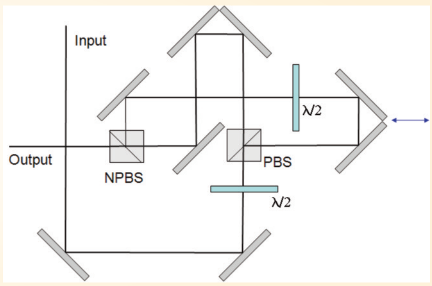
Pre-pulse generator for controllable picoseconds pre-pulses in TAP

87

I. Musgrave
(STFC, Rutherford Appleton Laboratory, UK)

I. Musgrave
ian.musgrave@stfc.ac.uk

In this contribution we discuss the optical arrangement used to generate controllable picosecond pre-pulses in TAP. We present a simple device that enables the generation of controlled pre-pulses on the picosecond time domain. This device was successfully used in the experimental campaign in TAP in September 2010.



Laser R&D

Current status of the DiPOLE project 88

S. Banerjee, K. Ertel, P. Mason, J. Phillips, P. Rice, S. Tomlinson, S. Blake, C. Hernandez-Gomez, J. Collier, T. Davenne, M. Fitton, A. Lintern
(STFC, Rutherford Appleton Laboratory, UK)

K. Ertel
klaus.ertel@stfc.ac.uk

We describe the current status of the DiPOLE project. We have developed a concept for a cryo-cooled diode pumped laser amplifier suitable for generating ns laser pulses at multi-Hz repetition rate and kJ-level pulse energy. Such lasers will form the basis of next generation ultra-high intensity research facilities and they are also required to make real-world applications of laser generated plasmas a reality. Over the last year we have constructed a scaled-down prototype amplifier. At the time of writing, all major components such as cryogenic cooling system, amplifier head containing ceramic Yb:YAG disks, diode laser pump sources, and front-end laser have been installed and commissioned. Over the coming months the optical and laser-physical parameters of the amplifier will be thoroughly characterised, culminating in the completion of a full system demonstration to amplify pulses to the 10 J level at 10 Hz repetition rate.

DiPOLE prototype cryogenic amplifier with cooling system in background.

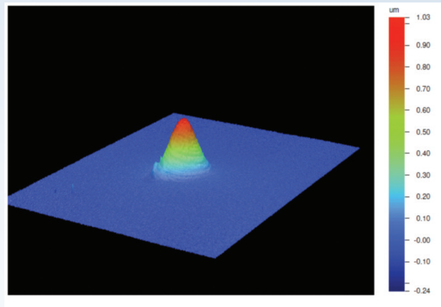
Target Fabrication

Production of novel Gaussian-shaped micro-bump targets 89

I.C. East, H. F. Lowe and C. Spindloe
(STFC, Rutherford Appleton Laboratory, UK)

I. C. East
ian.east@stfc.ac.uk

There has been continuing research into producing Gaussian-shaped targets with a view to producing well collimated, higher energy and spectrally narrow beams of ions from laser target interactions. The laser has a Gaussian focal spot which means it's more intense at the centre of the focal spot and less intense in the wings. A target was fabricated for an experiment for which the aim was to establish whether making the target thicker in the centre of the interaction point would compensate for the Gaussian shape of the laser beam and maximize ion production by RPA. Gaussian shaped metallic micro-bump targets with varying thickness and bump diameters were fabricated. They consisted of aluminium targets on a backing foil between 0.2µm-0.5µm with the height of the micro-bump being 1µm. The Target Fabrication Group used their experience and knowledge of metal coating processes to investigate options for the production of this novel target type using a thermal evaporation process.



A white light interferometric scan of a micro-bump target

Following many discussions and tests the Target Fabrication Group successfully manufactured a novel approximately Gaussian-shaped metallic micro-bump target on a thin foil for an experiment on Vulcan using a variety of novel masking techniques. There is potential to continue research and development into these novel targets using different materials, thicknesses and sizes of micro-bumps.

Overview of the Target Fabrication new chemistry laboratory 90

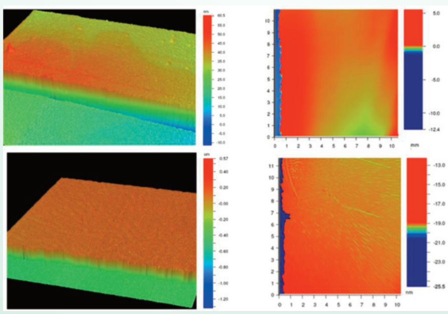
S. Serra, C. Spindloe, H. Lowe and M. Tolley
(STFC, Rutherford Appleton Laboratory, UK)

S. Serra
sam.serra@stfc.ac.uk

The CLF Target Fabrication Group has recently commissioned a new chemistry laboratory to further expand the capabilities for the research, development and production of high power laser targets for internal delivery and also to the external high power laser community.

The electroplating of metals is used for the deposition of thick metal layers (up to 30µm) and allows the coating of complex intricate forms.

There is an increased need from the user community for polymer thin films that are CH pure or contain oxygen in their molecular structure, with polystyrene and formvar being the most commonly used. There is also an interest in deuterated polyethylene thin films. Polymer films with thicknesses between 10nm and 2.7µm have been produced by spin coating and dip coating.



3D and 2D profilometry images of formvar and polystyrene films.

The wet etching of metals, polymers and ceramics is often required for the purposes of micromachining and release of sacrificial layers from mandrels.

Sample cleaning is another important process for removal of contaminants and surface activation. Hand surface lapping and polishing is also used to change the roughness of samples and remove waviness.

Finally the Target Fabrication Group is developing a capability to produce low density materials for laser targets and has been requested to produce polymer foams with pore sizes down to 1µm and densities between 3 mg/cm^{-3} and 800 mg/cm^{-3}. The housing of the laboratory in a dedicated room will ensure a more suitable environment for the chemistry processes that are sensitive to environmental factors.

Novel micro-focusing cone target fabrication

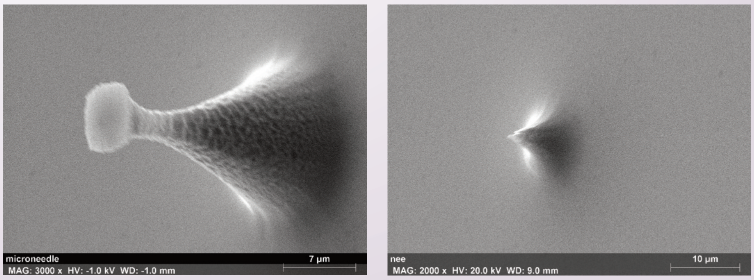
91

C. Spindloe, G. Scott, S. Serra, D. Neely, E. Barber and D. Jenkins
(STFC, Rutherford Appleton Laboratory, UK)

C. Spindloe
christopher.spindloe@stfc.ac.uk

It has been shown that typically 30% of laser energy is absorbed by a target in a high power laser interaction with the rest being specularly reflected and usually lost from the system. Therefore it can be seen that if the laser target interaction could be increased in efficiency this would lead to a highly cost effective way of increasing the energy that is coupled into a target. It has been suggested that micro-cone geometries integrated into a target design have the potential to increase the laser absorption. The Astra Gemini laser has a focal spot size that is limited to approximately 1.26 times the diffraction limit of the laser beam and it is very difficult to focus the laser beam any further using conventional techniques. The limit for the Astra Gemini system is about 2μm full width half maximum.

It is suggested that if a micro cone is produced in a thin foil that is of the order of 5μm at its opening diameter it will increase the absorption of the laser energy. We have shown that micro-conical designs can be fabricated using known technologies and that these can be adapted and tailored for use on high power laser facilities. The use of the micro-needles as moulds to pattern a thin foil target can produce micro-cone geometries that can be controlled by the variation of the process parameters. More work is needed to fully characterise the cones and to understand the tip geometries as these are challenging to image with standard techniques. These targets also need to be tested experimentally and will be fielded in upcoming LIBRA experiments at RAL.



A SEM image of a micro-needle and a cone in a thin foil

Production of novel thin-walled cone micro targets for an astrophysical jet experiment

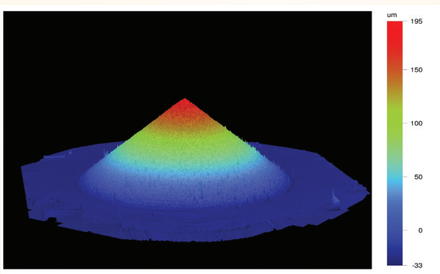
92

D. L. Wyatt and C. Spindloe, P. Hiscock and M. Beardsley
(STFC, Rutherford Appleton Laboratory, UK)

D. L. Wyatt
donna.wyatt@stfc.ac.uk

The Target Fabrication Group was requested to supply a number of thin walled cones with an opening angle of 140 degrees. These targets were required to be fabricated with a gold wall that was a thickness of 3μm or less. 20 Cones were required for the TAW experiment in June 2010.

Targets have been previously fabricated by the Target Fabrication Group that were thin walled aluminium cones that had a similar opening angle, a diameter at the open end of ~1mm and with wall thicknesses of approximately 3μm. Initial tests to produce the new batch of targets focused on techniques that have been used to produce other thin foil structures. This consists of coating onto a mandrel and then etching the material away to leave a hollow target of the required geometry.



White light interferometer scan of thin cone mandrel

The work showed that existing coating processes and high precision micro-machining can be used to produce thin walled micro cones precise dimensions and thicknesses that kept the form of the mandrel without collapsing during the etching process. Further work will be needed to expand this technique to batch production to deliver to the high rep-rate laser systems that are coming online across the world.

Instrumentation and Plasma Diagnostics

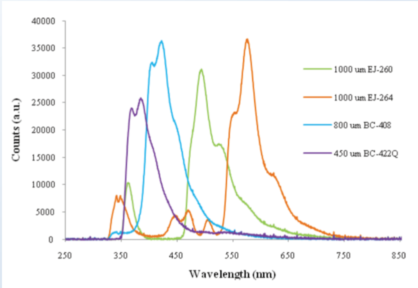
Characterisation of plastic scintillators for detection of laser-accelerated protons

93

J. S. Green, G.S. Scott[1] and D. Neely[1]
(STFC, Rutherford Appleton Laboratory, UK)
D. Kirby and D. Parker
(University of Birmingham, UK)
S. Green
(University Hospital Birmingham, UK)
M. J. Merchant and K. Kirkby
(University of Surrey, UK)
[1] also with University of Strathclyde

J. S. Green
James.green@stfc.ac.uk

Next generation intense, short-pulse laser facilities require new high repetition rate diagnostics for the detection of ionising radiation. We have designed a new scintillator-based ion beam profiler capable of measuring the ion beam transverse profile for a number of discrete energy ranges. The optical response and emission characteristics of four common plastic scintillators has been investigated for a range of proton energies and fluxes.
The scintillator light output (for 1 MeV > E_p < 28 MeV) was found to have a non-linear scaling with proton energy but a linear response to incident flux. Initial measurements with a prototype diagnostic have been successful, although further calibration work is required to characterise the total system response and limitations under the high flux, short pulse duration conditions of a typical high intensity laser-plasma interaction.



Optical emission spectra for BC-422Q, BC-408, EJ-260 and EJ-264 thin organic scintillators. Spectra were obtained by illuminating each scintillator with a 2.5 MeV proton beam.

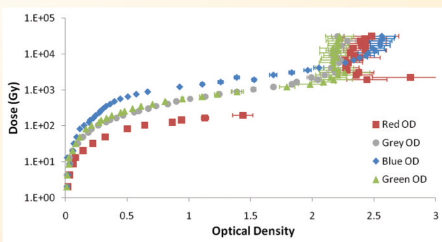
Maximising the dynamic range of radiochromic film through novel scanning techniques

94

G. G. Scott [1,2], J. S. Green and D. Neely [1,2]
([1] STFC, Rutherford Appleton Laboratory, UK)
M. R. Mitchell and P. McKenna
([2] University of Strathclyde, UK)
F. Fiorini, D. Kirby and S. Green
(University of Birmingham, UK)
J. Rickman
(Imperial College London, UK)

G. G. Scott
graeme.scott@strath.ac.uk

Radiochromic film is a common diagnostic in laser-ion acceleration studies used primarily for the characterisation of ion beam spatial profiles for a range of ion energies. The viability of scanning different spectral regions to increase the recoverable dynamic range relative to greyscale scanning is investigated. In particular Gafchromic HD810 is used.
The recoverable dynamic range of RCF can be extended relative to greyscale scanning by analysing the film separately in the three colour channels that a commercially available flatbed transmission scanner typically records. The recoverable dynamic range of the film can be shown to increase by an order of magnitude compared to a conventional greyscale scan.
Taking this concept further by ultra violet backlighting of the film, the maximum measurable dose can be increased to at least 200 kGy, an order of magnitude greater than the three colour method and up to two orders of magnitude greater than using greyscale.



Nikon Super Cool Scan 9000 ED calibration of HD810 optical density with dose.

Engineering

Nitrogen usage and Nitrogen generation

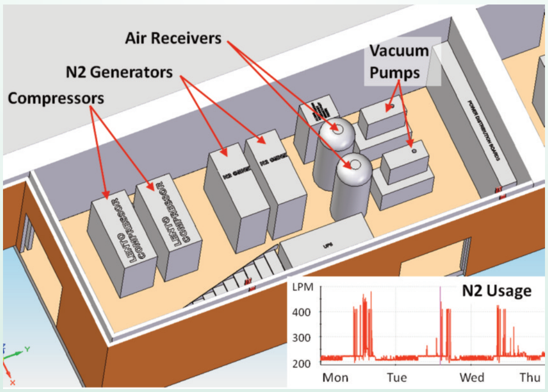
95

S. Blake
(STFC, Rutherford Appleton Laboratory, UK)
R. Taylor
(Activ Air Automation Ltd, UK
www.activ-air.co.uk)

S. Blake
steve.blake@stfc.ac.uk

Nitrogen is used throughout the CLF as a reliable supply of compressed gas to operate laser shutters, purge laser cavities and purge vacuum pumps. We explored the reasons for using Nitrogen and evaluated our usage over a number of years looking at how the CLF has evolved. Once the usage was determined the different technologies were investigated to identify methods to generate sufficient compressed air and convert this to pure Nitrogen. It was necessary to select the required purity as this has a significant impact on the size of the compressors and the size and type of generators.

Service intervals, maintenance downtime, redundancy and Plant Room space were all explored to find the most suitable compromise and propose two solutions.



Environmental and equipment monitoring

96

S. Blake
(STFC, Rutherford Appleton Laboratory, UK)

S. Blake
steve.blake@stfc.ac.uk

Monitoring of the mechanical hardware and mechanical services throughout the Central Laser Facility has been limited. Failure of plant has been apparent when working back from the effect rather than being aware of the cause.

A number of solutions were considered that could monitor temperature, relative humidity, vacuum level, pressures etc and the best solution was deployed in TAP. This has now been rolled out to many of the areas.

The unit has a fixed memory size and displays the latest data with old data being progressively overwritten. A script has been written to capture the data weekly and store it on the network. When alarm set points are triggered emails are sent to key people to investigate.

Motion control system development

97

P. Holligan, D. Rathbone, J. Suarez-Merchan, A. Zayyani
(STFC, Rutherford Appleton Laboratory, UK)

P. Holligan
paul.holligan@stfc.ac.uk

Motion control is an essential component of the laser system and a major contributing factor to the successful operation of the facility. With much of the beam propagation under vacuum, it is essential that beam pointing adjustments can be made remotely, and with pulse characteristics and experimental success sometimes reliant on sub micron accuracy, attention must be given to both the mechanical design of the optical stages and the motors, encoders and other feedback devices used to ensure these control parameters are achievable. A generic motion control system will satisfy the motion control requirements of both the laser and target areas.

No commercial software solution was available to satisfy the need to use a variety of different motion controllers supplied by a number of manufacturers which was required to be easily reconfigurable with changing technologies and reconfigured for each experiment. An in house solution was needed to utilise existing hardware whilst allowing the evolution of both motion controllers and the equipment under control.

Drive System Editor which aids experimental setup and drive connections.

Pulsed power developments

98

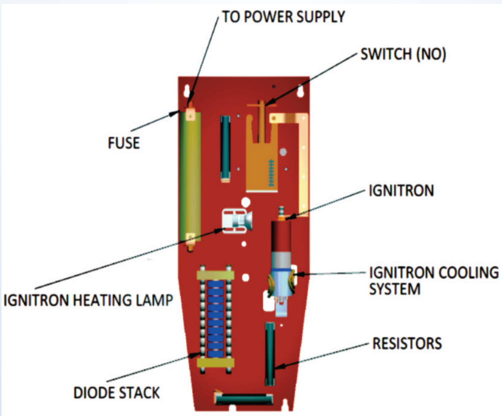
P. Holligan, Luis S. Caballero Bendixsen, M. R. Pitts, C. Sawyer
(STFC, Rutherford Appleton Laboratory, UK)

P. Holligan
paul.holligan@stfc.ac.uk

The Vulcan Laser Facility and proposed 10PW upgrade utilise disc amplifiers which rely on flash lamp pumping technology[1-3]. An electrical discharge is driven through a gas producing an arc, and the radiation produced in the discharge is then used to pump the active amplifier medium (i.e. Nd: glass) achieving the population inversion required for lasing.

A high voltage/current pulse is delivered by a Pulsed Power System (PPS) to create the electric discharge.

The existing Vulcan pulsed power system is too large for the proposed 10PW building, so a more compact pulsed power system needed to be designed to fit in the proposed building footprint. The existing ignitron configuration was bulky and offered scope for a reduction in size by utilising a more modern design.



Ignitron board

[1] J. P. Markiewicz and J. L. Emmett, IEEE Journal of Quantum Electronics, QE-2, 11, 707, (1966)

[2] H. T. Powell, A. C. Erlandson and K. S. Jancaitis, SPIE, 609, 78 (1986)

[3] W. Koechner, "Solid-State Laser Engineering", (Springer Series in Optical Sciences), Springer 6th Edition, May 2006

Flash lamp test facility pulsed power and control upgrade

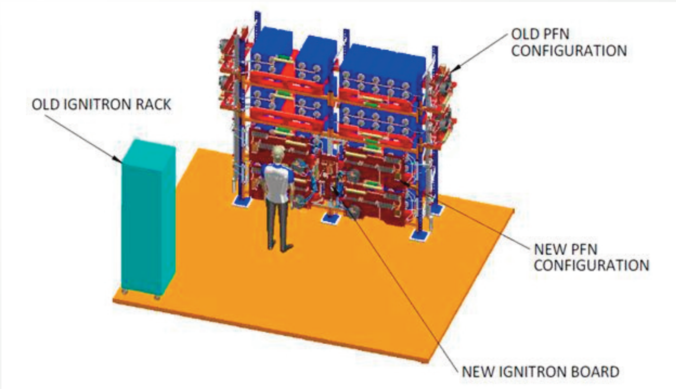
99

P. Holligan, L. S. Caballero Bendixsen, M. R. Pitts, C. Sawyer, A. Zayyani
(STFC, Rutherford Appleton Laboratory, UK)

P. Holligan
Paul.Holligan@stfc.ac.uk

The flash lamp test facility is used to test flash lamp pumped disc amplifiers before they are put in to operation on the Vulcan Laser system. It also serves as a test bed for pulsed power components as the hardware is identical to that used on the main facility.

In order to test the technology chosen for the Vulcan 10PW upgrade, one whole amplifier circuit was changed to incorporate the new ignitron and PFN design, leaving one amplifier circuit in the original configuration for testing and support of Vulcan components. To automate the testing of flash lamps and any pulsed power components, the control software has been upgraded to allow continuous firing and recording of data.



New Test Facility Circuit Configuration

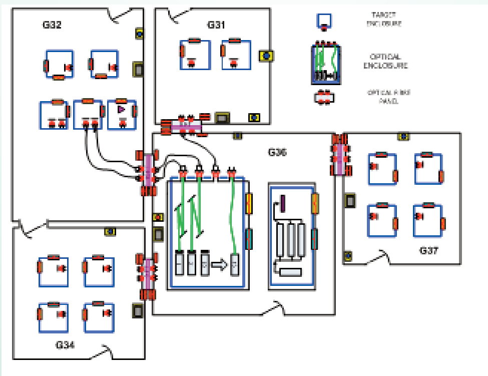
Research Complex laser interlocks system

100

C. John, A. Tylee, P. Holligan, D. Robinson, T. Roper, N. Symcox
(STFC, Rutherford Appleton Laboratory, UK)

C. John
chris.john@stfc.ac.uk

The development of the Research Complex at Harwell (RCaH) in R92, is set to provide a multi-disciplinary research facility, that will attract world-class research and world-class scientists.
In order for Lasers for Science Facility (LSF) to successfully occupy lab space in RCaH, a multi-room laser interlock and control system was required for safe laser operation.
This report highlights the design challenges and solutions employed to implement them.



Operational layout of Octopus area

Laser Interlock Safety

The LSF occupies three areas or clusters within RCaH incorporating 15 laser rooms, they are:

- FBI – Functional Biosystems Imaging known as Octopus
- ULTRA - Molecular Structure and Dynamics MSD
- Analytical Services - R&D labs

Laser interlock systems have been developed and used throughout the Central Laser Facility (CLF) for many years, but a new approach was employed in dealing with the FBI cluster as its requirements posed new design challenges.

Developments of the laser interlocks

101

C. John, A. Tylee, P. Holligan, D. Robinson, T. Roper
(STFC, Rutherford Appleton Laboratory, UK)

C. John
chris.john@stfc.ac.uk

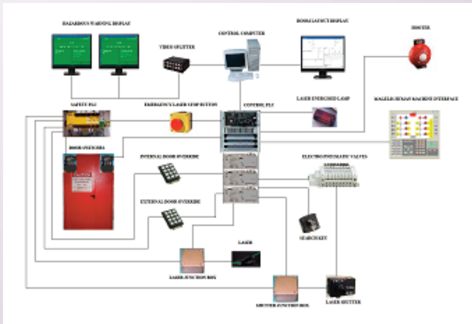
As well as the moral obligation to avoid harming anyone, there are laws set in place that require machines to be safe, thereby avoiding accidents.

The Flixborough incident in June 1974, which resulted in 28 deaths focused the UK public and media attention on the importance of safety of equipment controlling hazardous processes. The cause of the disaster was found to be related to a simple mechanical failure.

In terms of laser systems, if the control system were to fail with power remaining on to all outputs, this would cause the connected lasers to remain permanently switched on. An unknowing user for example could walk into a room with a high possibility of eye damage from exposed laser hazards present in the room. The human eye is the part of the human body that is most sensitive to light and can most easily be damaged by lasers if ever contact is made as a result of direct exposure or from reflected beams. This can result in permanent visual impairment. The power of laser beams, particularly pulsed power lasers, can be so high that not only the main beam but also weak reflections and diffusely scattered radiation can be hazardous.

Hazards can also occur when the skin is exposed to high power laser beams which can cause very painful burns. Photo-chemical burns can also occur from ultraviolet laser beams.

The aim of this report is to draw the readers' attention to laser safety within the CLF and the steps taken by the Electrical Engineering Section to improve interlock safety and design procedures.



Architecture of interlock systems

Vulcan TAW vacuum system under experimental loading conditions

102

D. A. Neely, S. P. Blake, R. Clarke, P. A. Rice and A. Cox
(STFC, Rutherford Appleton Laboratory, UK)

S. Blake
steve.blake@stfc.ac.uk

Laser plasma experiments routinely require a fast pump down of the vacuum chamber to give the maximum number of shots possible during the experimental run. The Target Area West Interaction Chamber was taking longer to pump than expected with all of the experimental hardware fitted. A range of tests were commissioned to identify the items that had the biggest impact on the pumping speed and identify changes that could be made to improve the pumping speed. Standard conditions were adopted to try to replicate normal operational running making the tests as realistic as possible.