Artemis operational statistics

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The Artemis team delivered a total of seven user experiments from April 2014 to March 2015, as well as two weeks of development projects in partnership with facility users. In total, we delivered 24 weeks of user access and seven weeks of dedicated experiment set-up. Table 1 shows the schedule for the year.

Week beginning	Experiment
31/03/14	
07/04/14	Set-up for Schwenke
14/04/14	
21/04/14	Development
28/04/14	Schwenke 13220007
05/05/14	Laser down
12/05/14	
19/05/14	Laser service and maintenance
26/05/14	
02/06/14	Set-up for Cacho
09/06/14	Cacho 13220002
16/06/14	
23/06/14	
30/06/14	
07/07/14	Engineering
14/07/14	
21/07/14	Hollow fibre re-commissioning
28/07/14	
04/08/14	Set-up for Gierz, Monney, Giannetti and Ulstrup
11/08/14	
18/08/14	
25/08/14	
01/09/14	Gierz 13220018
08/09/14	
15/09/14	
22/09/14	Laser service and maintenance
29/09/14	
06/10/14	Laser service and maintenance
13/10/14	Monney 13220016
20/10/14	
27/10/14	Development
03/11/14	Giannetti 13220003
10/11/14	
17/11/14	Set-up for Schwenke
24/11/14	Schwenke 13220007
01/12/14	
08/12/14	
15/12/14	
22/12/14	Christmas shutdown
29/12/14	
05/01/15	
12/01/15	Ulstrup 13220013
19/01/15	
26/01/15	
02/02/15	
09/02/15	Laser down
16/02/15	Set-up for Thornton
23/02/15	Laser service and maintenance
02/03/15	Thornton 13220017
09/03/15	
16/03/15	
23/03/15	Development

Table 1. Artemis schedule for 2014-15.

Experiments and set-up

Six of the seven experiments in this reporting year were studies of time-resolved photoemission from condensed matter. Five of these used the angle-resolved photoemission chamber, and one used the ultrafast demagnetization chamber with time-of-flight detector. The remaining experiment was on XUV coherent imaging.

The Artemis team dedicates approximately one week of set-up to each experiment, before users arrive. Similar experiments are grouped together, to minimize set-up time.

Facility performance and reliability

Figure 1 shows the availability and reliability calculations for the 2014-15 year. We run the laser continuously from Mondays through to Fridays during experiments, and regularly carry on data-taking over weekends. In this calculation, the availability for unsupported data-taking overnight and at weekends is weighted equally with supported hours.

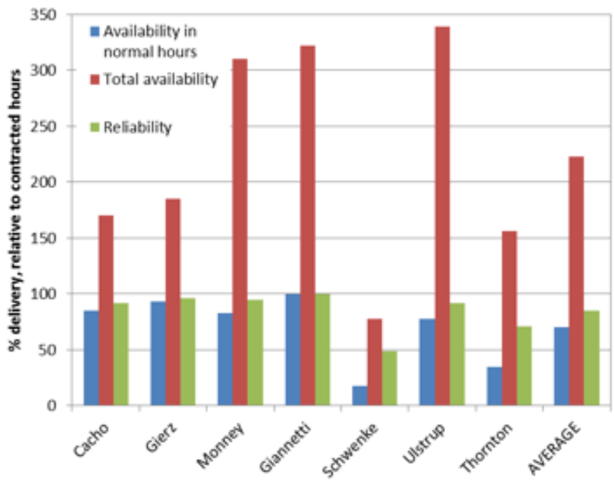

Figure 1. Availability and reliability for user experiments in 2014-15.

The average availability is 223%, very similar to last year. We were able to deliver one two-week experiment without losing any time at all to laser alignment, achieving 100% reliability and availability. However, the overall reliability has dropped from 85% to 70%, because we struggled to deliver two experiments – one due to laser problems (failure of the chiller for the oscillator) and one with faulty XUV filters.

Over the past year, we had two extended periods when the laser was down – both due to problems with the cryogenic cooling and chillers. As a result, we had to change the Ti:Sa crystals in both cryo-heads and lost a total of four weeks' delivery time.

Refurbishment and re-commissioning

The XUV monochromator was refurbished early in the year, with new toroidal mirrors and gratings, which restored the throughput and energy resolution.

The hollow fibre pulse compressor was re-commissioned and used to obtain sub-10 fs temporal resolution and sub-eV energy resolution in a NIR-pump XUV-probe photoelectron spectroscopy experiment on graphene [1]. This was our first test of the XUV monochromator's performance with <25 fs pulses. We were able to change between good temporal resolution and good energy resolution straightforwardly, which was vital to the interpretation of these ultrafast measurements.

Development

This year, development work on Artemis has continued to focus on widening the range of experiments that we can offer.

We started a development project in collaboration with Imperial College on generation of few-cycle pulses at 1.7 micron. It has been shown that the idler from a commercial OPA can be coupled into a hollow fibre to produce few-cycle IR pulses, which can be used to generate harmonics in the water window [2]. Similar technology is now being transferred from Imperial College to Artemis. In the first two weeks of effort here, we completely upgraded the fibre system (Figure 2), showed that we could achieve sufficient spectral broadening to get pulses below 10 fs (Figure 3), and built diagnostics.

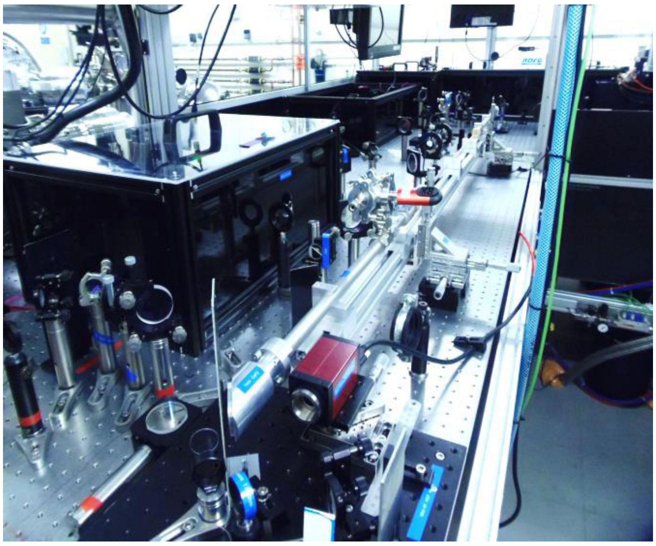

Figure 2. Hollow fibre system for generating few-cycle pulses from the idler of the optical parametric amplifier.

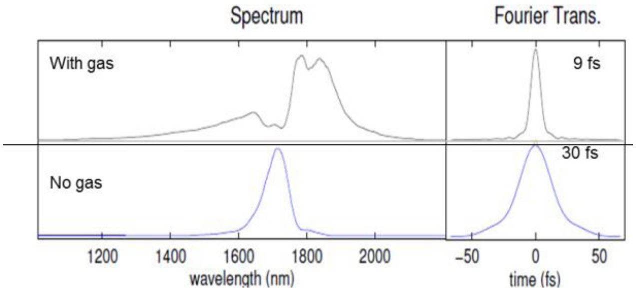

Figure 3. Left: Spectra at the exit of the hollow fibre showing broadening when filled with gas (top), compared to unbroadened spectrum with no gas (bottom).
Right: The corresponding panel shows the corresponding Fourier transform pulsewidths.

We have also continued to develop gas-phase photoelectron spectroscopy experiments with XUV probe, which had previously suffered from low count rate. Last year we installed a molecular beam source to increase the gas density at target. This year, we increased the XUV flux at target by a factor of 30, by using the second harmonic at 400 nm as the HHG drive pulse. Tests incorporating both these improvements showed that the image acquisition time is now sufficiently short to make these experiments feasible, and a proposal was scheduled by the Facility Access Panel.

References

1. I. Gierz, F. Calegari, S. Aeschlimann, M. Chávez Cervantes, C. Cacho, R. T. Chapman, E. Springate, S. Link, U. Starke, C. R. Ast, and A. Cavalleri, "Tracking Primary Thermalization Events in Graphene with Photoemission at Extreme Time Scales", Phys. Rev. Lett. 115, 086803 (2015).

2. S. L. Cousin, F. Silva, S. Teichmann, M. Hemmer, B. Buades, and J. Biegert, "High-flux table-top soft x-ray source driven by sub-2-cycle, CEP stable, 1.85-μm 1-kHz pulses for carbon K-edge spectroscopy", Optics Letters 39, 5383 (2014).

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Gemini operational statistics 14/15

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During the reporting year, April 2014 to March 2015, a total of six complete experiments were delivered to the Astra-Gemini Target Area. In total, 31 high power laser experimental weeks were delivered to the Gemini Target Area, with the delivered schedule presented in Figure 2.

The availability of the Gemini laser system (delivery to the Gemini Target Area) was 84% during normal working hours, rising to 158% with time made up from running outside normal working hours. The reliability of the Gemini laser was 91%. An individual breakdown of the availability and reliability for the six experiments conducted is presented in Figure 1.

The high levels of total availability were made possible by the continued unique operational model employed on Gemini, which involves running the laser late into the evening. In addition, frequent weekend operational days were made available.

Two system access slots were made available during the 14-15 operational period. During the first, the entire Femtolasers front end was replaced, including the Synergy oscillator and multi-pass amplifier. The oscillator was replaced with a turnkey Integral Element pro system, which is intended to reduce the system start-up time and is, in principle, a hands-free oscillator. During the second access period, a transmission grating stretcher was installed. This new stretcher was used successfully for the Sarri, Ma and McKenna experiments, and is now the permanent pulse stretcher of the Gemini system (see article in this report by Chris Hooker et al).

Other system developments during the year included the replacement of the Amplifier 1 continuum pump laser for a Quanta Ray system, and the replacement of the Amplifier 2 pump laser for a new, higher energy, Quanta Ray system. All of the 10 Hz multi-pass amplifiers are now pumped by Quanta Ray systems.

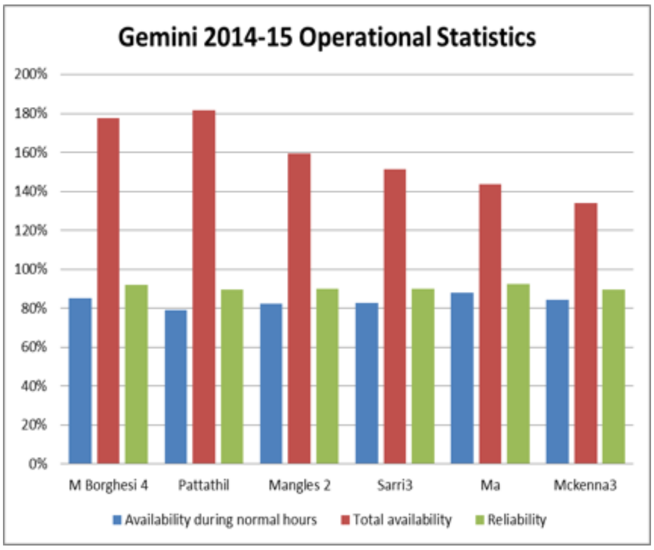

Figure 1. 2014/2015 operational statistics

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31/03/2014	06/04/2014	
07/04/2014	13/04/2014	System Access
14/04/2014	20/04/2014	
21/04/2014	27/04/2014	
28/04/2014	04/05/2014	
05/05/2014	11/05/2014	Set up
12/05/2014	18/05/2014	
19/05/2014	25/05/2014	
26/05/2014	01/06/2014	Borghesi
02/06/2014	08/06/2014	13210014
09/06/2014	15/06/2014	
16/06/2014	22/06/2014	
23/06/2014	29/06/2014	Set up
30/06/2014	06/07/2014	
07/07/2014	13/07/2014	Pattathil
14/07/2014	20/07/2014	13210031
21/07/2014	27/07/2014	
28/07/2014	03/08/2014	
04/08/2014	10/08/2014	Compressor works
11/08/2014	17/08/2014	13210031 (ext.)
18/08/2014	24/08/2014	Quantel Service
25/08/2014	31/08/2014	
01/09/2014	07/09/2014	Mangles
08/09/2014	14/09/2014	13210021
15/09/2014	21/09/2014	
22/09/2014	28/09/2014	
29/09/2014	05/10/2014	
06/10/2014	12/10/2014	
13/10/2014	19/10/2014	System Access
20/10/2014	26/10/2014	
27/10/2014	02/11/2014	
03/11/2014	09/11/2014	Maintenance
10/11/2014	16/11/2014	
17/11/2014	23/11/2014	
24/11/2014	30/11/2014	Sarri
01/12/2014	07/12/2014	13210063
08/12/2014	14/12/2014	
15/12/2014	21/12/2014	
22/12/2014	28/12/2014	Christmas
29/12/2014	04/01/2015	
05/01/2015	11/01/2015	Set up
12/01/2015	18/01/2015	
19/01/2015	25/01/2015	
26/01/2015	01/02/2015	Ma
02/02/2015	08/02/2015	13210052
09/02/2015	15/02/2015	
16/02/2015	22/02/2015	Maintenance
23/02/2015	01/03/2015	
02/03/2015	08/03/2015	McKenna
09/03/2015	15/03/2015	13210040
16/03/2015	22/03/2015	
23/03/2015	29/03/2015	

Figure 2. 2014/2015 Gemini operational schedule

Lasers for Science Facility

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RAL-based experiments

In the reporting period (April 2014 to March 2015), 32 different user groups performed a total of 39 experiments in the Octopus and Ultra facilities laboratories at RAL. A total of 5,623 hours laser time was delivered to the UK user community and European users throughout the year, with 216 hours downtime. Biology and bio-materials formed the majority of the applications (see Figure 1).

A full breakdown of number of weeks applied for versus number of weeks scheduled is shown in Figure 2, indicating an oversubscription ratio of 1.96:1. The RAL-based schedule is shown in Table 1. The average user satisfaction marks obtained from the scheduled users are shown in Figure 3, with an average satisfaction of 92.5% across all categories.

There were a total of 52 formal reviewed publications produced from the year's efforts.

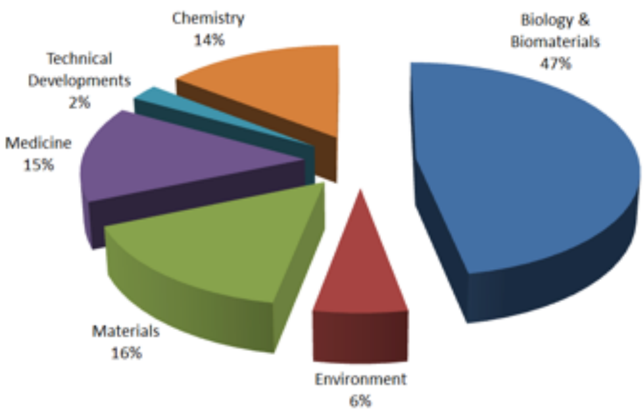

Figure 1. RAL-based bids by subject group

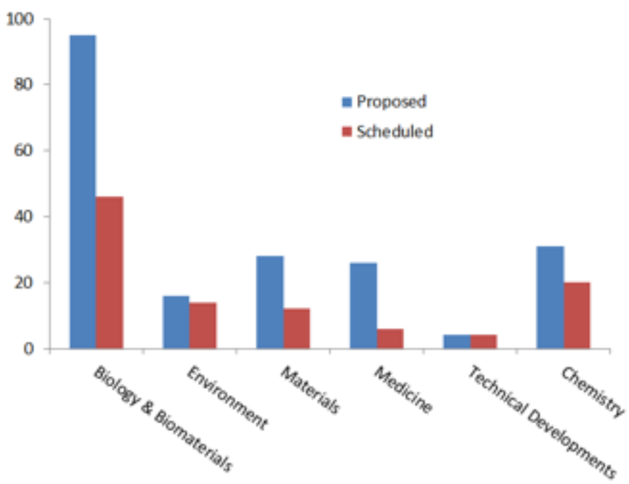

Figure 2. RAL-based experiments by subject

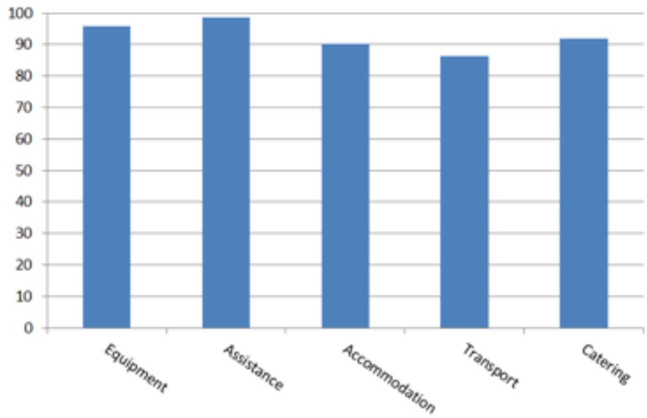

Figure 3. RAL-based average user satisfaction scores

Loan Pool

Throughout 2014/15, the Laser Loan Pool continued to provide laser loans to the UK research community. The facility delivered 328 weeks of laser time in the reporting period, supporting 16 research groups through 17 laser loans, and its work lead to the publication of 10 articles in peer reviewed journals within 2014/15. The ratio of weeks applied for versus weeks scheduled was 2.5:1 and the downtime was approximately 10 %.

At the end of 2014, EPSRC announced that it would no longer fund the Loan Pool, so this was the last full year of operation. To ensure that the community benefits from the assets of the loan pool, an open call was issued for bids from groups wishing to permanently house the loan pool lasers. The assessment process was underway at the time of writing.

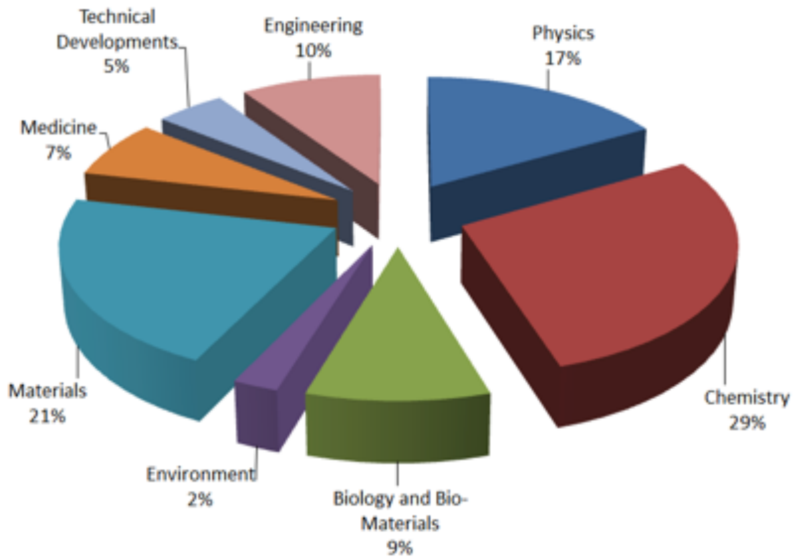

Figure 4. Loan Pool bids by subject group

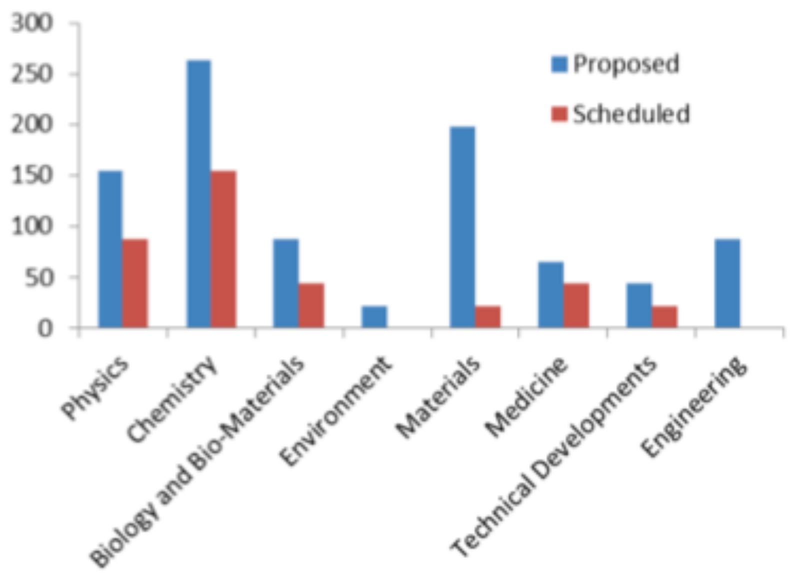

Figure 5. Loan Pool experiments by subject

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Target Fabrication

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RAL Experiments

A total of six Gemini and seven Vulcan experiments were supported by the Target Fabrication Group in the reporting period April 2014 to April 2015. The total number of experiments supported increased by three in this reporting period compared with the last. The Target Fabrication Group supported a total of 30 experimental weeks for Astra Gemini and 34 weeks for Vulcan. The total number of weeks support for solid target experiments was 64 weeks, up from 50 in the last reporting period. The Target Fabrication Group also provided targets for two academic access experiments at AWE, which are reported separately within this publication. This report does not include support for other areas of the CLF including Artemis and the LSF.

Target Numbers

For the reporting year, the total number of targets produced is shown in Table 1. The table is broken down into separate experiments, and gives data on total target numbers produced and the subset consisting of high specification targets that have been produced. High specification targets are defined as targets that have taken significant, highly-skilled micro-assembly or micro-machining to be produced, above and beyond typical target manufacture.

The total number of targets for use at RAL produced by the Group in 2014-2015 was 1,937 compared to 2,507 in 2013–2014 and 1,801 in 2012-2013. During 2014-2015, the number of high specification targets decreased from 334 to 87, accounting for 4% compared to 13% in the last reporting year. The drop can be accounted for by the fact that there were no experiments in this reporting year fielding mass-limited targets, the most popular high specification target last year.

Experiment	Targets Produced	High Specification Targets
0514 GTA	86	5
0614 GTA	73	
0814 GTA	76	20
0814 TAP	165	
0914 TAP	174	8
0914 TAW	240	
1114 GTA	54	
1114 TAW	166	54
1114 TAP	229	
0115 GTA	8	
0115 TAW	330	
0315 GTA	146	
0315 TAW	190	
TOTAL	**1942**	**87**

Table 1: Target production summary for 2014-2015. High specification targets include 3D micro-structures, low density targets and mass-limited targets.

Target Categories

Targets can be separated into seven main categories, as shown in Figure 1 and Table 2.

Ultra-thin foil targets are specified as having a thickness <500 nm and require a skilled micro-fabricator to assemble them; thick foils make up the rest of the single component foils. Multilayer foils are stacks or layers of foils that require thin film coating capability to deposit multiple layers onto an existing foil; they often involve different composition layers with different thicknesses. Alignment targets are specified as wires or pinholes that are used for set-up purposes. 3D micro-structures are complex 3D geometries that require skilled assembly or micro-machining to produce them. Foam targets are low density polymer structure manufactured through chemistry-based techniques.

Target Category	Targets Produced 2014-2015
Ultra-thin Foil	530
Thick Foils	708
Multi-layered Foils	500
Alignment	85
3D Micro-structures	82
Foams	5
Mass-limited	0

Table 2: Target category summary. 3D micro-structures are targets that require micro-machining or skilled micro-assembly. Mass-limited targets are targets designed to have minimal support structures.

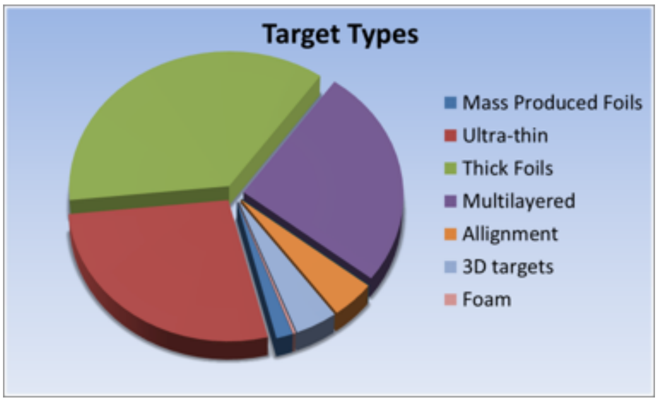

Figure 1: Target delivery summary by type

It should be noted that Figure 1 is not a reflection of staff effort. Assembly time for a single thick foil target is relatively short; however, for a batch of five foam targets, trials, manufacture and characterisation activities can amount to weeks of effort.

Each experiment usually requires similar targets with varying thickness, composition or geometry. For example, a thin foil experiment typically requests a thickness scan of a particular material. For foil experiments each thickness or composition change requires a separate coating run, and for 3D experiments each geometry change requires a new assembly set up.

Within the total of 1,942 targets, there were 330 unique target variations, which averages six targets per variation. The flexibility provided by the group is a key capability of the CLF, and enables the user community to fully utilize the limited time that is available during each experiment on both the Vulcan and Astra Gemini laser systems.

Experimental Response

It is seen as a significant strength of the Target Fabrication Group to be rapidly responsive to experimental results and conditions, by working collaboratively with user groups. The Target Fabrication Group responds to experimental changes during a campaign, and often implements a number of modifications or redesigns to the original requests. The number of modifications and variations on each experiment can differ, and is dependent on the type of experiment and also on experimental conditions, such as diagnostic and laser performance. For this reporting period, a total of 489 targets were modified or redesigned from the target list agreed upon in the planning stage, which makes up 25% of the total targets delivered. In the last reporting year the percentage was 22%, and in the year prior to that the modified percentage was 33%. Three of the thirteen experiments in this reporting period used 347 modified targets; in 0914TAP, 71% of the total targets were modified, 48% for 0914TAW and 75% for 0315GTA. These three experiments were particularly demanding for the Target Fabrication Group, which often produced modified targets in less than a day. Target modifications required significant effort, whether for complete geometry change or alterations to coating specifications.

Adapting to Demand

The Target Fabrication Group endeavours to be adaptable to the changing demands of the user community as experiments develop. Each experiment that is carried out often has widely varying target demands and, as a result, the Group is constantly developing its capabilities.

Foils have dominated the target types during this reporting year and the last, comprising just over 90% of targets delivered.

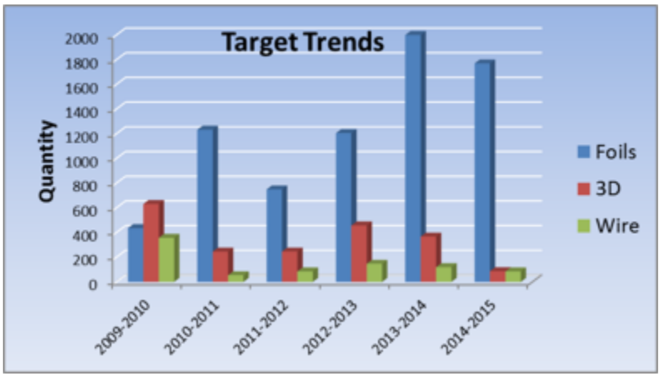

Figure 2: Target numbers produced by type. Foil targets encompass ultra-thin foils, thick foils and multilayered foils. 3D targets include microstructures and foams. Wire targets include alignment and mass-limited targets.

Ultra-thin and multilayer targets are reliant on coating plant capability and have made up over half of the delivered targets. Multilayered targets have been particularly popular, with four experiments requesting over 50% of their targets with coated layers. This is in contrast to last year where there was only one experiment that requested the vast majority of the multilayered targets (1113TAW).

Waste Reduction

Unexpected delays or changes during an experiment often result in a number of targets that have been fabricated but that are not shot by the end of experimental campaign. Targets are collected at the end of the experiment period and logged. Returned un-shot targets totalled 313, accounting for 16% of total targets made. In 2012-2013 a 19% return of un-shot targets was recorded, in 2011-2012 it was 10%, while for 2010-2011 and 2009-2010 the proportion was 23% and 43% respectively.

Any un-issued or returned targets are carefully sorted, and high specification targets are stored under closely controlled conditions for potential use on future experiments. Where possible, all spare target components and mounts are also stored for future use. The variety of mounts and components held in stock by the Target Fabrication Group contributes to their ability to adapt target designs quickly in response to experimental changes.

There has been a noticeable reduction in waste since the complete implementation of the ISO9001 Quality Management System (QMS), which has allowed the Target Fabrication Group to plan experimental delivery of targets in a more structured way. The improved planning processes enable long-term delivery projects to be managed effectively. It should be noted that this has not led to less flexibility, as the percentage of modified and re-designed targets is in line with the figures for the years before the implementation (2009-2010, 2010-2011).

Less than one percent of targets were returned as non-conforming under the QMS in this reporting period. This number is likely to be inaccurate, as user requests often fail to properly record non-conformities, and instead request additional targets. The Target Fabrication Group is working to improve the recording of these by working with user groups to keep records of which targets they do no use due to non-conformities.

Orion Academic Access

The Target Fabrication Group has supplied targets to the AWE Orion academic access campaign for groups from the University of York and Imperial College London. In total, 215 targets have been delivered for a total of six weeks access to Orion. The targets have been complex and have called for the implementation of a range of existing and new technologies, including micromachining and gas filling of targets. Further work will be carried out to develop the technologies, to enable new target types to be offered to CLF users.

External Contracts

Scitech Precision Ltd (a spinout company from the CLF Target Fabrication Group) has supplied micro-targets, specialist coatings and consultancy to a number of external contracts. In the year 2014-2015, a total of 53 contracts were completed for coatings, characterization, and also full target design and assembly, an increase from 44 in the previous year. The contracts were delivered to external facilities in countries including France, Germany, Italy, India and the USA. In this reporting year, Scitech Precision has supplied phase plates to LULI, LCLS, GSI and other large facilities.

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Vulcan Operational Statistics

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Introduction

Vulcan has completed an active experimental year, with 46 full experimental weeks allocated to target areas TAW (Target Area West) and TAP (Target Area Petawatt) between April 2014 and March 2015.

Numbers in parentheses indicate the total number of full energy laser shots delivered to target, followed by the number of these that failed and the percentage of successful shots. The second set of numbers is the availability of the laser to target areas during normal operating hours and outside hours operations.

	2014	
07 Apr – 25/18 May	**D Riley** XUV probing of warm dense matter (72, 9, 87.5%) (88.2%, 115.4%)	**S Kar** A novel scheme for simultaneous focusing, energy selection and post-acceleration of TNSA proton beam (113, 17, 85.0%) (73.3%, 108.4%)
28 July – 31 Aug	**M Roth** Probing new laser driven ion acceleration schemes with thin cryogenic targets (47, 9, 80.9%) (90.4%, 101.7%)	
22 Sep – 26 Oct	**G Gregori** Laboratory study of carbon white dwarf crystallization using high power lasers (99, 9, 90.9%) (87.9%, 114.8%)	**N Woolsey** Extreme X-ray radiation fields created during an ultra-intense laser-solid interaction (93, 9, 90.3%) (82.8%, 109.7%)
10/17 Nov – 21 Dec	**D Riley** Structure of warm dense matter (155, 18, 88.4%) (89.2%, 117.7%)	**P McKenna** Towards mono-energetic ion acceleration via shocks driven by tailored laser (125, 28, 75.8%) (78.3%, 109.0%)
	2015	
26 Jan – 15 Feb	**M McMahon** Probing ramp compressed metals using single photon energy dispersive X-ray diffraction (147, 11, 92.5%) (92.3%, 113.6%)	
9 Mar – 22 Mar	**DSTL** (100, 6, 94.0%) (94.9%, 119.4%)	
23 Mar – 5 Apr	**C Brenner** X-ray imaging with laser sources (136, 17, 87.5%) (83.2%, 113.7%)	

Table 1: Experimental schedule for the period April 2014 – March 2015

(Total shots fired, failed shots, reliability)

(Availability normal, additional hours)

The total number of full disc amplifier shots that have been fired to target this year is 1,087. Table 2 shows that this figure compares very favourably with recent years. 133 shots failed to meet user requirements. The overall shot success rate to target for the year is 88%, compared to 89%, 92%, 89% and 88% in the previous four years. Figure 1 shows the reliability of the Vulcan laser to all target areas over the past five years.

	No of shots	Failed shots	Reliability
10 - 11	764	87	89%
11 - 12	641	54	92%
12 - 13	860	93	89%
13 - 14	1015	121	88%
14 - 15	1087	133	88%

Table 2. Shot totals and proportion of failed shots for the past five years

The shot reliability to TAW is up very slightly at 90%, compared with 88% in 2013-14. The shot reliability to TAP is around 85%, down from 91% the previous year.

Analysis of the failure modes reveals that, as in recent years, the two overriding causes of failed shots are alignment and front end related issues. It is difficult to distinguish these two causes and we are in the process of commissioning high repetition rate diagnostics (camera-based energy monitors, spectrometers and autocorrelators) in the front end and throughout the laser area to identify and resolve specific sources of instability.

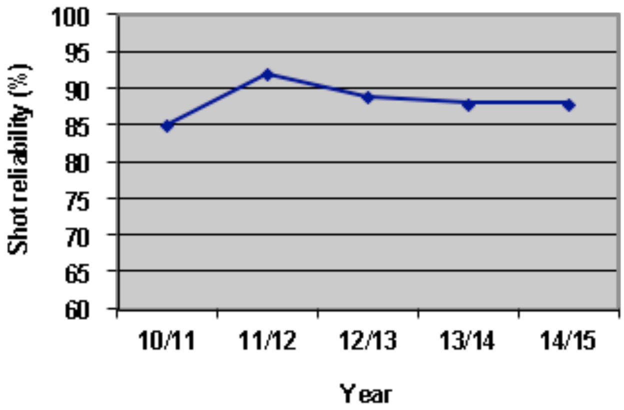

Figure 1. All areas shot reliability for each year 2010-11 to 2014-15

There is a requirement, which was originally instigated for the EPSRC FAA, that the laser system be available during the five week periods of experimental data collection, from 09:00 to 17:00 hours, Monday to Thursday, and from 09:00 to 16:00 hours on Fridays (a total of 195 hours over the experimental period). The laser has not always met the start-up target of 09:00, but it has been common practice to operate the laser well beyond the standard contracted finish time on several days during the week. In addition, the introduction of early start times on some experiments continues to lead to improvements in availability.

On average, Vulcan has been available for each experiment to target areas for 85.3% of the time during contracted hours, compared with 78.8% for the previous year. Although this is encouraging, the overall availability is down from 119.2% in 2013-14 to 111.9% to all target areas. The time that the laser is unavailable to users is primarily the time taken for beam alignment at the start of the day.

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