Delivery of Targets to the 2015 Orion Academic Access Campaign

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Introduction

This paper describes the range of targets that have been produced by the Target Fabrication group in the CLF for the academic access experiments on the Orion laser facility [1] at AWE during 2015. The experiments were carried out by academic groups from the University of York and Imperial College London with different target designs required for each campaign. During the reporting period a large number of high specification targets and backlighters have been delivered and a number of new technologies have been developed to support the program. This paper reviews the assembly processes, thin film requirements and micro-machining processes needed to produce the targets. Also discussed is the implementation of a gas fill system to produce targets that have an internal fill of gas from 0.3 Bar to 1 Bar. The paper discusses the challenges that are posed by such a target.

Campaign 1 – University of York

The campaign was studying the influence of kinetic effects and magnetic fields on energy transport in high energy density plasmas. The effects are simulated by the irradiation of a target foil with the long pulse beams of Orion and then the probing of the interaction with a proton probe that is produced by the interaction of the short pulse laser beams with a thin gold foil. The target design for the experiment had a number of key factors that needed to be satisfied for the experiment to work. The target foil needed to be positioned so that it could be probed simultaneously face on and transversely by two proton probes. The proton probes needed to be at a fixed and well defined distance from the interaction target and in between each proton foil and each interaction target there needed to be a grid. The grid imprints onto the proton distribution coming from the source allowing measurements to be taken of the source size and feature sizes of the interaction. It is also useful for observing any disturbances due to electric or magnetic fields surrounding the target.

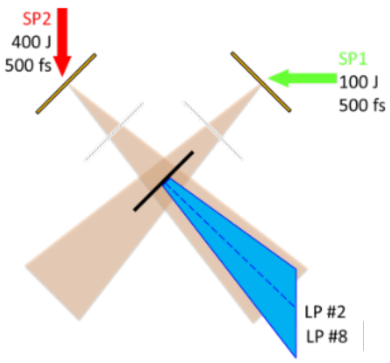


Figure 1. Schematic of the target layout showing the two short pulse beams (SP1, SP2) and the long pulse beams onto the interaction target.

The experimental set-up is shown in figure 1 and the target design in figure 2. All the targets have been mounted from a precision machined block to ensure that the separations are consistent. The proton foils are supported over a washer with a secondary foil on the rear of the washer to shield the proton target from radiation from the main interaction target as this could affect proton generation at a later time to the main target.

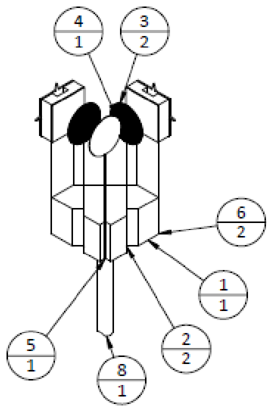


Figure 2. CAD design for the target showing the precision base and the target components for the probing and the interaction target.

The target consisted of the following subcomponents (whose identification numbers are shown in the upper half of the circles in figure 2):

1) The precision machined block; CNC produced with a number of alignment grooves positioned in appropriate places to ensure that the targets mounted above them were aligned along the axis of the probes. Also included in the block (but not shown) was a hole on the underside to insert the carbon fibre stalk (8)

2) Carbon fibre support for proton grid targets (3) which were assembled onto 280um diameter carbon fibre supports and placed so that they were aligned vertically with the proton targets and not tilted or rotated more than would show as a variation in the feature spacing on the diagnostics. The grids were 600LPI, 20um thick gold TEM grids.

4) The interaction target supported by a carbon fibre (5). The interaction target was made from a range of materials including thin (5um) copper, thin (25um) plastic or a combination of a copper (5um) with a plastic (2um or 5um) coating on one side.

6) The proton target frame was etched from aluminum (included a number of alignment features) and it acted as a support for a number of proton target components that are shown in figure 3. Components included the proton target (7), which was 25um or 50um thick gold, and a spacer washer (9) that supported a protection filter (10).

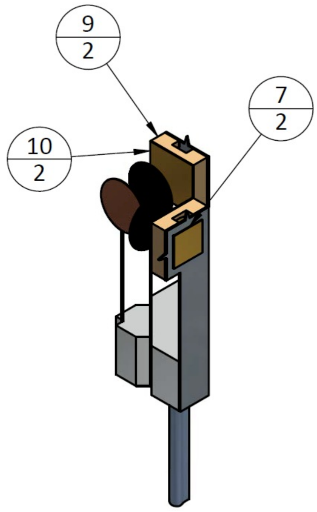
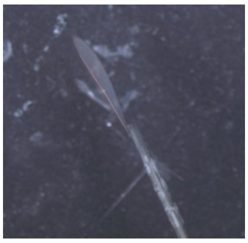


Figure 3. CAD design for the target showing the details for the proton probe target assembly.

Fabrication Challenges

One challenge in making the target was that the process of deposition of the plastic (parylene-N) coating on the copper long pulse targets coated both sides. The requirement that only side should be coated necessitated the removal of plastic by plasma etching from the other side of the target. The process imparted a curvature in the target due to the stress in the remaining plastic. The bending proved impossible to remove without a support for the foil which was not practical in the geometry that was needed for probing. The curvature can be seen in figures 4 and 5 where it is evident that there is approximately a 20um curvature over a 0.5mm distance.



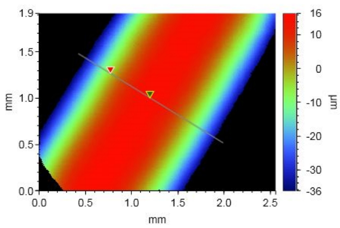


Figure 4 (left). Optical image of target curvature.

Figure 5 (right). Interferometric scan of target surface.

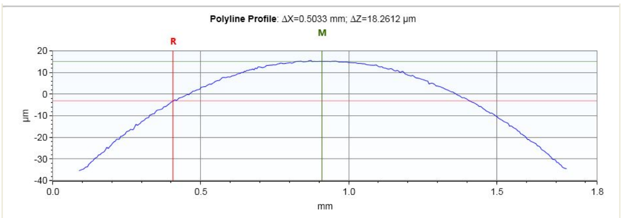


Figure 6 Line out of variation of target surface across its diameter.

This curvature could contribute to a variation in the position of the target with respect to the two long pulse beams and needed to be improved for future targets.

The final assembled target is shown in figure 7 with a proton image shown in figure 8 demonstrating that proton probing was successful with the target design. The assembly design demonstrated that the required accuracy could be achieved for targets on a single mount if the targets were held with appropriate supports. However there are challenges if the target design does not allow for the supports or if the target is complex with a number of coatings imparting stress onto foils that inherently need to be flat to work in the proposed geometry.

A total of 23 target assemblies were delivered for the experiment in Feb 2015 with a further 50 targets delivered in October 2015.

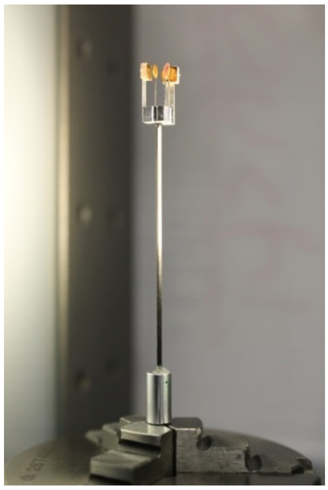


Figure 7. The final target assembly on the Orion target support.

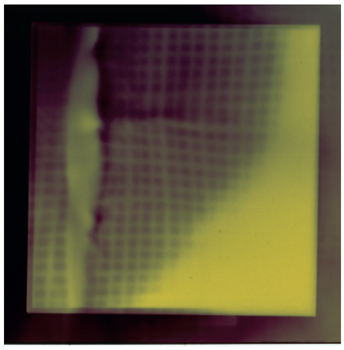


Figure 8. A proton image showing the grid.

Campaign 2 - Imperial College London

The campaign studied radiative shocks in gas filled targets and aimed to image the collision between two counter streaming radiative shocks. The experiment required the production of a gas cell that had a number of windows in it to allow probing of the interaction with optical and x-ray diagnostics. The cell required target material (the pusher) to be held at each end which was irradiated with the long pulse beams of Orion. The interaction of the long pulse beams with the pusher material needed to be shielded from the diagnostics.

A schematic of the target is shown in figures 9 with the detailed CAD design for the target shown in figure 10.

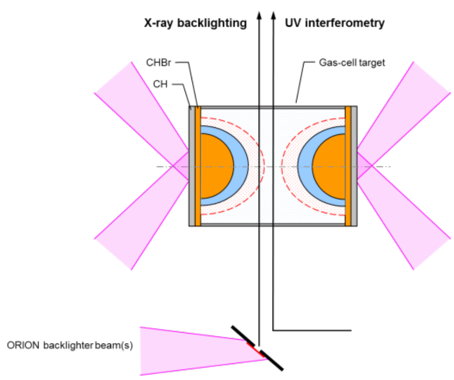


Figure 9. Design for the gas target showing the long pulse beam interacting with the pusher and the backlighter and optical diagnostics.

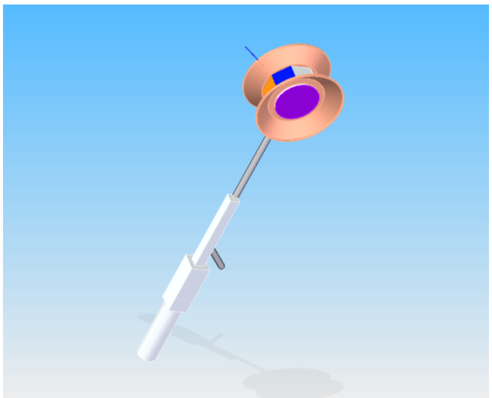


Figure 10. Detailed CAD design for an octagonal cell with a fill tube.

In figure 10 an alignment wire is shown with the optical windows in blue and the x ray windows in yellow.

The gas fill in the target was a static fill in which the target was prepared outside the chamber, sealed and then inserted into the Orion chamber on a TIM. The target pressure could be monitored up to the shot time but the target needed to be gas tight as there was no way of filling it when inserted into position in the chamber.

Target Manufacture Processes

One of the main constituents of the target was the pusher: a 50um thick brominated plastic disk attached to a 25um thick plastic ablator. One was mounted at each end of the gas cell. Previous work [2] in the production of brominated plastic produced films that were granular in nature. The granularity might affect the shock dynamics and uniformity by seeding small scale perturbations and so a more homogenous foil was needed. A new raw material was used that produced a much better quality film. The process for manufacture (by pressing) was very similar, however, the film produced was very brittle and the removal of it from the backing foil required an etching process after cutting to size.

The cell body was CNC machined and produced with as little burring as possible around the edges because such regions would be possible leak sites in the target. A number of cell designs were tested with large area openings for the pusher and also one design with smaller openings to try to reduce the deflection of the foil due to the pressure differential between the cell and its environment. The deflection of the foil was a key parameter because the laser focal spot size varies if the foil is not in the correct plane.

The x-ray windows were laser machined out of polyimide and the glass windows were produced with an AR coating designed for the optical probe. A fill tube was commercially sourced with a bend that allowed it to act as both the target stalk and the fill tube.

The targets were assembled using an Araldite ® adhesive with a long curing time to allow the glue to form a good seal around the components. The targets were then attached to a gas filling system to allow them to be tested for integrity.

Target Filling System

A system for filling targets with gas (figure 11) was designed by Imperial College based on an AWE design used on the HELEN laser system. The target was placed in a vacuum chamber (figure 12) and the fill tube of the target connected to a separate line allowing it to be pumped and re-filled independently to the main chamber. Monitoring of pressure transducers allowed a leak test to be performed on the target and imaging of the target windows allowed for a deflection test to be conducted.

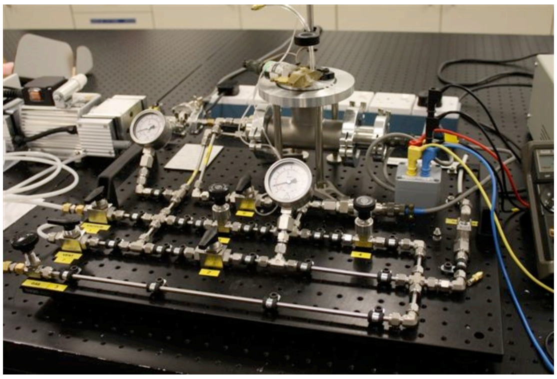


Figure 11. Gas system used at AWE for filling targets to specified pressures.

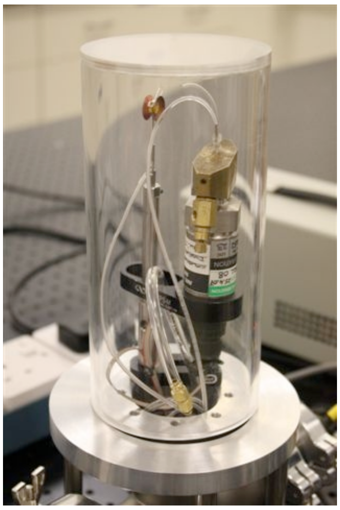


Figure 12. Target in the vacuum chamber with the attached transducer.

Gas Fill Test Results

The results from the first deflection test in which a target was pressurised in an evacuated chamber (see figure 13) showed that there was a bowing outwards of the pusher target on the end windows of the order of 150 microns. The deflection was reasonably consistent across the range of targets and was used to determine the offset of the laser focal spots to ensure the correct plane.

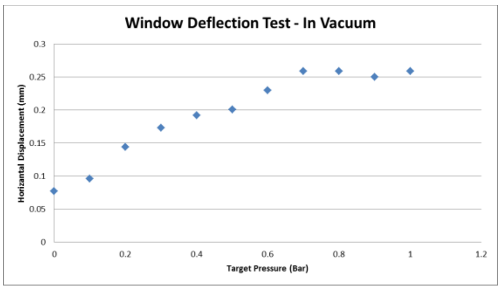


Figure 13. Deflection of a target in vacuum at a range of fill pressures.

A second set of tests was carried out using a target that was filled in the range of 0.1-1 bar in an external environment of atmospheric pressure. The target bowed inwards and the results are shown in figure 14. There was a slightly larger deflection than seen in a vacuum environment of approximately 250 microns. The effect was caused by the pusher having been slightly modified for the second set of tests; a smaller brominated plastic disk on a larger support reduced the rigidity of the target compared to the previous target in which a brominated plastic pusher was attached to a polypropylene ablator of the same size.

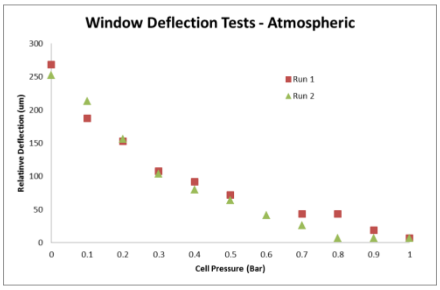


Figure 14. Deflection of target pusher window in an atmospheric pressure environment at a range of fill pressures.

Pressure testing of the targets showed that there was a leak rate on the RAL system of ~ 2mbar/min. It was improved from the ~5-10mbar/min during first tests by using 1) fixed attachments to the targets, 2) removable gas tight fittings to transfer the targets from fill station to chamber and 3) a thorough and robust pressure test regime.

First Target Shots

Target shots were taken in March 2015 and further shots in July 2015 with final shots planned in October 2015. The targets were irradiated by the Orion laser and optical and x-ray diagnostics were used. The backlighter targets were a standard design as used in previous campaigns [3]

The leak rates for the targets when in the chamber were improved from the first to the second weeks of shots by the steps described earlier and the target shots leak rates can be seen in figure 15

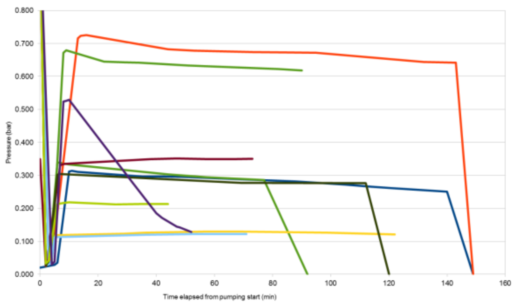


Figure 15. Target leak rates in the Orion chamber.

An example of the data taken from the x-ray diagnostic is shown in figure 16 and it can be seen that the two shocks have propagated into the target and collided in the middle.

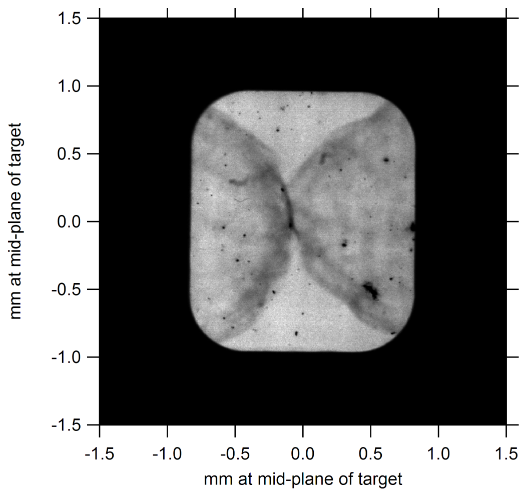


Figure 16. Example data from the Orion – Imperial College experiment

A total of 141 targets consisting of backlighters and interaction targets have been delivered over 3 weeks for the campaign.

Conclusions

In total, during the reporting period, 215 targets have been delivered for a total of 6 weeks academic 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 for use on other facilities.

References

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2. Spindloe C, Wyatt D, East I, Haddock D, Cross J, Gregori, G, Foster J. '*Delivery of POLAR Targets to the First Academic Experiment on the Orion Laser Facility'*, CLF Annual Report 2013-2014
3. Spindloe et al, "*Target Fabrication for the POLAR experiment on the Orion laser facility",* High Power Laser Science and Engineering **3, e8** (2015)