Delivery of POLAR Targets to the First Academic Experiment on the Orion Laser Facility

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Introduction

This paper describes the fabrication of a range of Polar targets made by the Target Fabrication group in the Central Laser Facility for the first academic access experiments on the Orion laser facility at AWE. A large number of complex fabrication technologies and research and development activities were required to field a total of 80 high specification targets for the academic access experiments.

Here we review the Polar geometries for an astrophysics experiment in which high power laser pulses were used to heat and compress an interaction target to a high-energy density state, mimicking that of a magnetic cataclysmic variable star, for the purpose of monitoring accretion shock formation and propagation in the extreme environment.

Target Design

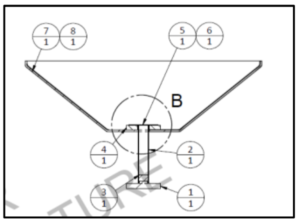
There were two main targets for each shot: a Polar target and a complex backlighter (which is not described in this article). The main interaction target was the Polar target which underwent a number of modifications during the experiment. The target was mounted onto the Orion target positioner. For their manufacture the targets required the full scope of the Target Fabrication group's capabilities including research and development into new cost effective materials.

Polar Interaction Target

Specification

The Polar interaction target was a combination of 1) a quartz obstacle which reflects the material flow at the end of the tube, 2) a polyimide (PI) tube inside which the material could flow, 3) a low density foam insert, 4) a washer for holding the target material, 5) a pusher material that was either a brominated plastic, a gold/plastic layer or a chlorinated plastic, 6) a slit in the tube to allow diagnostic view of the flow and shock in the tube for the DANTE diagnostic, and 7) a copper cone to shield the diagnostics from the laser beams. (These numbers correspond to those in Fig 1.)

A number of alignment features and coatings were added to protect the target and to allow for the positioning of the target in the Orion chamber. The features included carbon fibres along the length of the tube to measure the propagation of the shock and fibres on the target stalk to allow for precise alignment in the target chamber during the experiment. A 3D representation is shown in figure 2 depicting the incident laser beam onto the pusher foils.



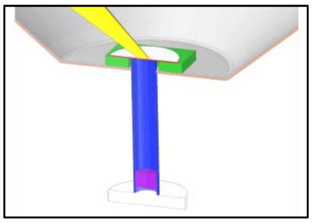


Figure 1 (left). A CAD representation of the target sliced through the centreline. Annotations are described in the text above. Figure 2 (right) shows a 3D CAD cut away of the target and indicates the position of the pusher foil and also shows the foam insert at the bottom of the tube.

Target Components

Brominated Foil

Brominated plastic for the pusher material was not commercially available in the thickness required and purchasing a bespoke foil was not possible within the budget. A research programme was initiated to press plastic films of brominated plastic from a commercially available powder. Using a heated press, that had previously been used to manufacture deuterated plastic films, a number of tests were carried out to heat and mould bromopolystryene (C_8H_7Br) that had a Br content of 43% by weight.

Initial uotcomes of pressing CHBr were mixed showing temperature, pressure and mass to be important variables in producing a good quality film. At low temperatures (<200C) the powder did not show significant melt and was just fused together to form a brittle pressed pellet that was too thick. When the temperature was increased to ~280C the sample showed signs of melt and the use of the correct amount of material produced a film ~25um thick. (To produce better uniformity films a temperature of > 300C would be required.) SEM analysis using EDX confirmed that sufficient bromine was present after processing although there was some structure present in the pressed disk due to the target foil not going through a full melt when forming as shown in figure 3.

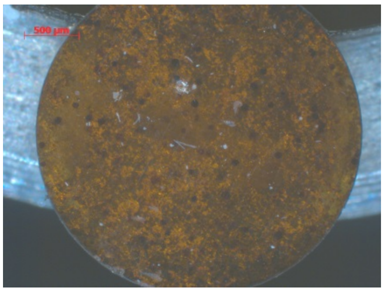


Figure 3. A fully processed brominated plastic disk showing internal structure.

Foam Insert

Low density foam of density 300mg/cc was to be placed at the end of the PI tube. The foam was required to be positioned next to the obstacle and to be 400µm in length. The foam was manufactured using a critical point drying (CPD) technique [1] and a number of techniques were trialled to form the foam inside the target tube. Firstly, to make the foam in-situ, the PI tube was filled with the production liquid and UV cured. However filling of the liquid in the tube was not reproducible and therefore the foam did not cure to the correct length. Secondly the foam was manufactured from a PMMA tube which transmitted UV, however, when running the CPD process the tube was incompatible with the chemicals used and consequently lost shape and the foam produced was contaminated and not usable. The resolution was to manufacture foam in a tube that would survive the chemical processing and was UV transmissive. The cast foam sample was then removed from the tube, cut to length and inserted into the final Polar target tube. An example of the foam in the final target assembly can be seen in figure 4.

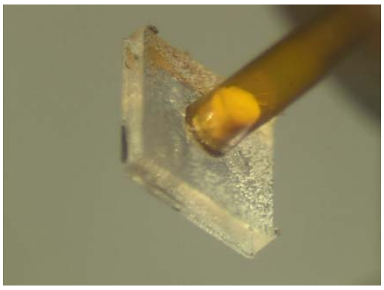
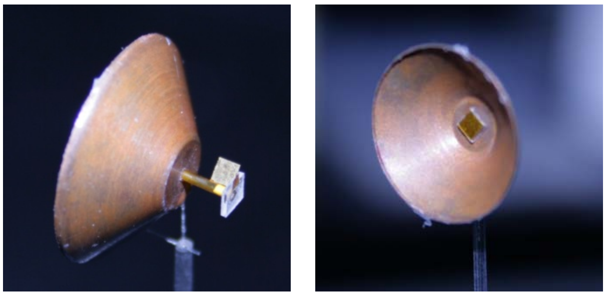


Figure 4. A low density sample placed at the end of the polyimide tube next to the quartz obstacle.

Final Target Assembly

The other target components were produced using precision micromachining (for the washer and the cone shield) and thin film coatings (gold plastic layered pusher). All of the components were integrated into the final target assembly as shown in figures 5 and 6. The target was mounted on an AWE Orion mount with a cross brace to stabilise the cone. Additionally a 400 LPI gold grid, for calibration of the x-ray backlighting, was added as shown in figure 7. The Dante diagnostic slit, although not visible, had been laser machined into the tube.



Figures 5 and 6. Images of the Polar target showing the obstacle side (left) and the Au/CH pusher (right).

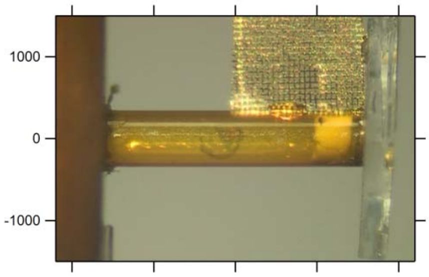


Figure 7. Side view of the foam inside the tube and the grid.

Conclusions

A total of 34 Polar targets were delivered for two weeks of academic access on Orion during November 2013 and further targets were delivered in 2014. The development of a number of new target fabrication techniques at the Rutherford Appleton Laboratory has enhanced the capabilities that are available and has contributed to a successful academic access campaign. Further work is to be carried out to improve the quality of the brominated plastic pushers to remove defect points in the target that may lead to instabilities in the plasma as it propagates along the tube. Developments are also required to produce a more uniform foam target for positioning next to the obstacle.

.References

1. In situ production of very low density micro porous polymeric foams. Journal of Vacuum Science & Technology A: Vacuum, Surfaces, and Films (Volume:13 Issue: 4) 1995. Falconer, J.W. Department Of Chemistry, University of Dundee, Dundee DD1 4HN, Scotland Nazarov, W. ; Horsfield, C.J.