# Complex Micro-Target Fabrication to Study Shock Compression

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## Introduction

Recent years have seen target complexity increase due to the increased availability of a range of diagnostic techniques, and also because of the general increase in complexity of experiments that are conducted. Target Fabrication for such experiments typically requires a range of techniques to be integrated to make one target cluster. To meet the demand there has been a rapid development in advanced target fabrication techniques such as robotic assembly, micro 3D printing, single-point diamond turning, laser micromachining and (MEMS-based) lithography.

It is likely that with the increase in the number of laser facilities around the world and the increasing availability of shots on such systems the trend to more complex targetry will continue. Specifically the planned upgrade to Vulcan 20-20 will increase experimental complexity in the CLF and consequently the number of complex targets that will be needed. Inevitably further development of advanced techniques, and most probably new ones, will be required to fully exploit the experimental parameters that will be available.

This annual report details one complex target fabrication programme that was carried out for an experiment in Target Area West on Vulcan.

## Target Design

In the experiment the main objective was to characterise the density profile of an ablator driven by a shock over a picosecond timescale with high spatial resolution (aiming for 1µm) which would be unprecedented for a laser-driven X-ray source. The experiment would also assist in understanding the atomic kinetics of high strain-rate compression which is directly related to many physical phenomena, for example high-speed collisions and ICF implosions [1].

The experiment consisted of shocking a lithium fluoride target and imaging the shock with X-rays that passed through a thin slit to increase the resolution. Figure 1 shows a schematic of the experiment.

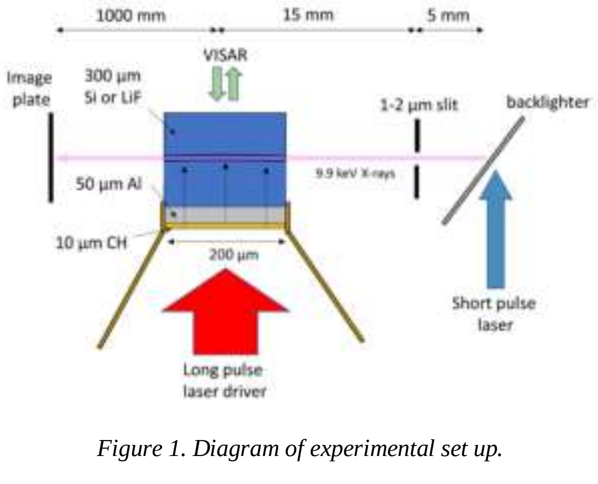

*Figure 1. Diagram of experimental set up.*

For the experiment every shot required three individual targets with a range of components required to make each target:

1. One foil target was required to be the X-ray backlighter to produce X-rays.
2. A slit was required for the X-rays to travel through and to create a small source size
3. A complex assembly that was driven with a long pulse to create the shock. It is this shock that would be measured in high resolution.

Figure 2 shows the three separate targets that were used for each data shot.

*Figure 2. Images of each target component: the backlighter foil (left), slit target (centre), and lithium fluoride assembly (right).*

The first of the three components was the zinc backlighter target. It was a 100um x 100um square foil, 10µm thick which was laser machined (to size from foil) using a femtosecond laser and attached to a 25µm diameter wire. It was essential to have the wire adhered perpendicularly to the edge of the foil to minimise any chance of the laser interacting with the wire and causing unwanted X-rays.

The second component was the slit target. It was critical to the experiment because it set the resolution of the system. The slit was specified to be 50µm long and 2µm wide and was fabricated with a Zeiss Crossbeam 550 XL focused ion beam (FIB) equipped with a gallium ion source (see Figure 3). The substrate was 50um-thick tantalum disk with a diameter of 3mm. The FIB-machined disc was then adhered to another 100µm thick tantalum disk to increase the background X-ray absorption. When shot in the experimental target chamber each slit long axis had to be aligned to within a few degrees of vertical. Alignment of the slit to its mounting stalk was the most challenging part of assembling the slit target and was performed by hand using a microscope.

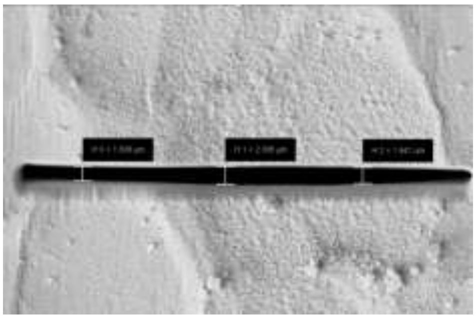

*Figure 3. SEM image of FIB-machined slit.*

The third target component was the scientific package: the lithium fluoride (LiF) crystal assembly which was shocked with the long pulse. The package required the manufacture of a 300µm thick LiF single crystal sample in <100> orientation having a height of 1000µm and a width of 200µm. It was not possible to purchase such a sample due to the small sizes specified and, therefore, it was sourced as a 1mm square and subsequently laser machined to the correct dimensions (see Figure 4).

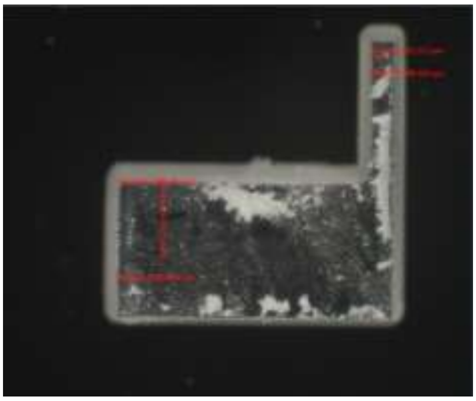

*Figure 4. Machined LiF target component. Some debris from machining is visible which was carefully removed during target assembly.*

The laser-cut LiF piece was required to be attached to a multi-layer foil assembly consisting of 300nm Al, 10µm polypropylene, and 1.5µm Au. This assembly was then attached to a 25um thick, shaped Au foil to shield the diagnostic lines of sight from the laser interaction. The target assembly process included laser machining the shield with a precisely located slot and then placing the area of interest of the LiF package in the slot to allow the drive laser to interact with the region of experimental interest. Figure 5 shows the complete LiF assembly. It was the component of the experiment that went through the most changes.

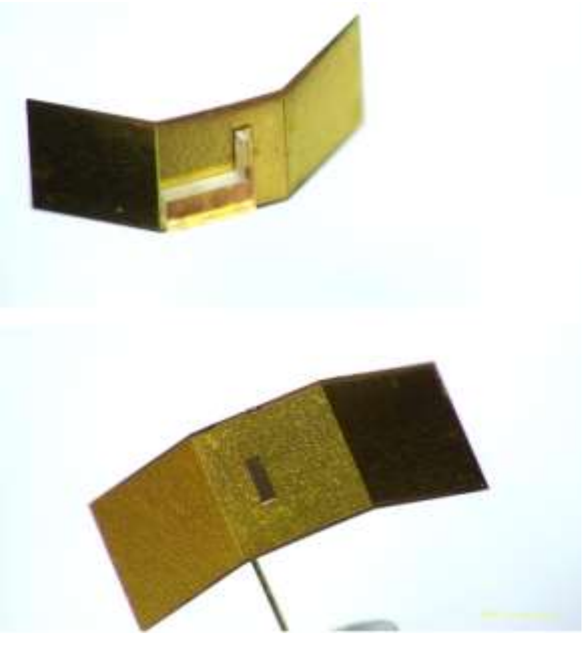

*Figure 5. LiF assembly and shield seen from the drive laser side (top) and the diagnostic side (bottom).*

A cluster of all three of the targets was required for each experimental shot and as the experiment progressed each component went through design changes to improve the performance of the target cluster.

### Backlighter Target Modifications

The component was initially 10um thick zinc with dimensions of 100x100um. However, from shot images, it became apparent that due to the square shape of the foil it was difficult to distinguish between the edge of the foil and the propagating shock. Consequently the users modified the design to a circular geometry with a diameter of 270um. The circular edge made it easier to disambiguate the edge of the foil and the shock in the experimental data.

### Slit Modifications

Initially the target was designed as a 50um-thick tantalum foil with a copper ring around it. The copper ring was required to aid the focused ion beam machining of the slit. During the experiment it was observed that excessive numbers of X-rays were being produced and consequently the Ta foil needed to be thicker. Because of overall time constraints it would not have been possible to use the FIB to directly machine a thicker foil (because of the slow machining rate). It was, therefore, decided that the original 50um-thick slit would be additionally shielded by bonding to it a 15mm diameter Ta disk of 50um thickness to reduce the flux of X-rays reaching the detectors. After this modification most of the unwanted X-rays were blocked but there was still a significant background signal. To reduce the X-ray flux to an acceptable level a 100um diameter Ta pinhole was mounted on top of the 50um x 2um slit to reduce the background X-rays even further. Precisely aligning the pin hole using optical microscopes was very challenging and it took a long time to ensure specifications were met. To improve the final slit alignment fiducial marks were laser micro-machined onto the outer shield to allow it to be mounted parallel to the axis of the experiment.

### Lithium Fluoride Assembly Modifications

The initial component had a Au shield and a foil stack (300nm Al, 10um Parylene-N, 1.5um Au) which were adhered to the LiF crystal. However, alignment of the physics target with the shield attached proved difficult during the experimental set-up. The first change was the removal of the Au shield because it was blocking one of the detectors. Because of this change the foil stack dimensions needed to be modified from square to a form that closely matched the shape and size of the laser-machined LiF.

It was also critical that there were no gaps between the layers of the targets as they would affect the shock breakout. To ensure perfect contact the LiF samples were modified to be directly coated with the foil pack rather than being part of an assembly. However, because the LiF pieces were supplied machined to size, it was possible to coat them with Au but not the CH in the timescales of the experiment and, consequently, not all inter-layer gaps were removed. Nonetheless great care was taken when gluing the ablator to the target.

## Future developments

Whilst there were some considerable challenges in the fabrication and deployment of the target, and significant changes in the design, several targets were shot in the final weeks of the experiment giving excellent results as shown in Figure 6.

In the future there is the possibility to reintroduce the Au shield with some adjustments to the size. Also there could be a modification to the initial FIB slit machining step to aid the final assembly. Thirdly there is the potential to 3D-print a jig for holding a larger piece of Ta to simplify slit machining which would make alignment easier with the extra layers of attenuation metals.

In the next iteration the fabrication method of coating the thin film stack directly onto the LiF could be improved to remove any interfacial gaps in the targets.

## References

1. Grant Application to Vulcan User Program: application number 222111 – “Direct imaging of the inelastic response of silicon to shock compression”, M. Oliver et al.