Development of low-density sine wave targets for high power laser experiments

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Introduction

The assembly of microtargets for high power laser experiments is a complex and challenging discipline. It typically requires precision (depending on the target design) of a few microns and in some cases to less than a micron. Some target components can be fragile and delicate for which extra care is needed when handling them.

This report looks at such a target. It is a low-density foam target with a sine wave textured, brominated plastic disk. The target is multicomponent with some parts that are very fragile. The main user of the target is based in France at CELIA. Throughout the reporting year the target has gone through many improvements in fabrication which will be described in this report.

Background

The main purpose of the target is to study Rayleigh-Taylor instabilities which can be observed on an interface between two fluids of different densities. When the low dense fluid pushes the higher density one the phenomenon is observed [1]. In everyday life water suspended above oil is an example. But the phenomenon can also be observed in space, for example when a supernova is accelerated towards the thicker outer shell [2]. The target is assembled to recreate this exact effect.

The Target

Figure 1 shows an image of a produced target.

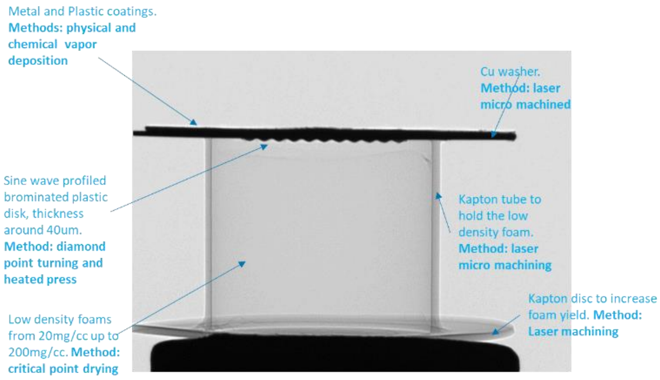

Figure 1: Computer tomography image of an example target

A typical target consists of the following components,

- <u>Kapton</u> <u>tube</u> ranging from 1.5mm to 1mm in diameter. The tube contains the low density foam. Tubes are laser machined to size.
- <u>Kapton</u> <u>cap</u> used to close one end of the tube so that the yield of the foams can be increased. Fabricated using laser micromachining.
- <u>Low</u> <u>density</u> <u>foam</u> ranging from 20mg/cc to 500mg/cc. Acts as the fluid the RT instabilities extend into. Critical point drying is used to manufacture the foams.
- <u>Copper</u> <u>washer</u> used to hold the 'pusher' in place.
- <u>CH</u> <u>coating</u> (also called the pusher) usually around 10 - 15um thick; creates a low dense plasma when the laser interaction takes place.
- <u>Metal</u> <u>coatings</u>. Thin metal coatings of approximately a few microns thickness down to a few 100s of nanometers coated on the top side of the targets depending on the requests of the experimentalists. Au, Cu and Al have been coated during the last few iterations. Physical vapor deposition methods are used for production.
- <u>Sine</u> <u>wave</u> <u>disk</u>. A brominated plastic disk with a sine wave profile. Single sine wave types were made as well as a combination of two waves. Fabricated by diamond point turning a copper block with the wave profile, then pressing the CH powder onto the Cu form using a heated press. The wavy plastic is laser micro machined to size.

Challenges in target development

This target is difficult to fabricate due to its delicate nature. There were a lot of challenges to overcome to improve the quality of the targets; the main ones are addressed below.

One of the first problems that required a solution was the connection between the Kapton tube and the cap. Initially, the method was to use superglue to hold the two parts in place. The problem arose because the glue would spread across the surface of the cap. This created an uneven surface of the base of the tube thus affecting the quality of the foam that was formed inside. The solution was to laser micro machine a small trench on the cap so that when the two parts were glued any excess glue would fill the trench and left a flat base upon which the foams could be fabricated.

Another issue arose when assembling the Cu washer/pusher section. After the first experiment in which the targets were shot it became clear that the CH pusher was not fully adhered towards the edges of the Cu washer which affected the experimental results. Consequently, when tasked with developing the targets, a major goals was to solve the issue.

The initial method was to separately machine the Cu washer and the CH pusher and attach them together. The CH was coated onto a Si wafer and peeled off. However there was poor adhesion towards the edges of the washer which was the most significant issue. There were also issues with excess adhesive on the laser interaction surface, and damage to the 20um Cu because it had to be held with tweezers when the glue was being applied.

To improve quality only part of the Cu washer was laser machined and them the CH pusher was adhered to it. Afterwards the assembly was laser micro machined to give an improved result. Figure 2 demonstrates the process.

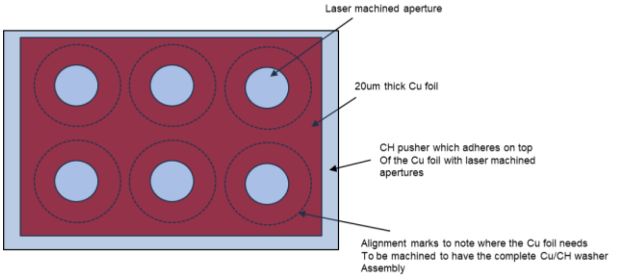

Figure 2: The first iterations of improvements to the Cu/CH washer assembly

The method reduced a lot of the previous. However it gave rise to a new problem; when the CH foil was pulled away from the Si wafer the foil curled which made it difficult to accurately place and attach the two parts. We tried adhering the Cu foil with the aperture holes directly onto the CH and then peeling off but the process added curvature to the Cu/CH aperture assembly which was undesirable.

To improve target quality further we adhered the part-machined Cu foil to the Si wafer with the CH coatings and laser machined the washer in situ on the Si wafer. The modified process dramatically reduced the curvature.

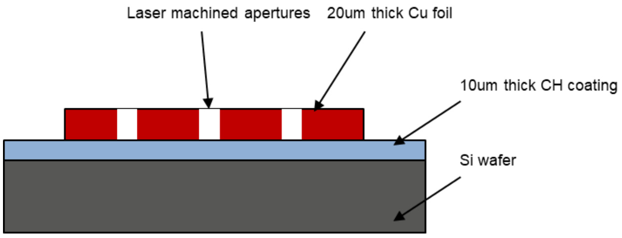

Figure 3: The second iteration of improvements to the Cu/CH washer assembly; adhering the Cu foil directly onto the CH coating prior to laser micro machining the washers.

Results

Figure 4 compares two targets. The target on the left is unsatisfactory whereas that on the right is acceptable. Fabrication solutions that were iteratively developed enabled suitable progress.

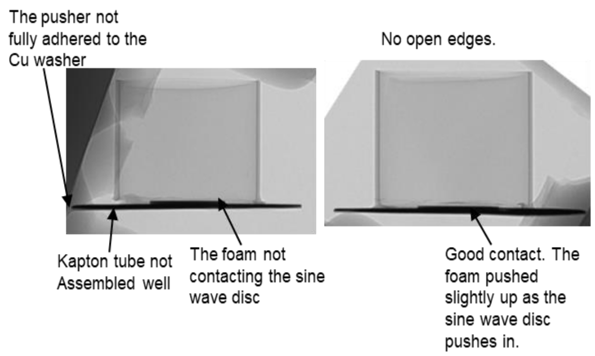

Figure 4: A comparison of a poor target (on the left) and a good target (on the right). Any gaps in the contact between the parts can affect the experiment greatly. The CT scans carried out prior to handover demonstrates the best targets for the experiment.

The experiments that have been conducted using the targets have been a great success. Figure 5 shows some data collected from an experiment carried out at LLE (Rochester) using the targets showing Rayleigh-Taylor instabilities.

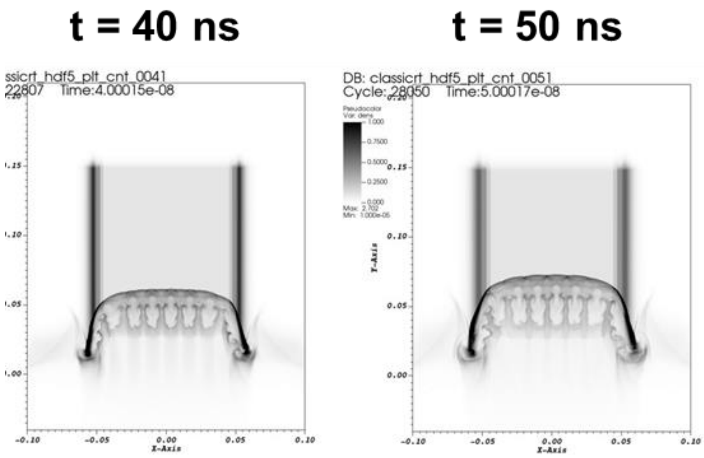

Figure 5: Data from an experiment conducted on the Omega laser in Rochester. [Experiment designed and performed by W. Theobald (LLE), A. Casner (CELIA), V. Bouffetier (CELIA), L. Ceurvorst (CELIA), F. Barbato (CELIA), Thibault Goudal (CELIA), L. Antonelli (York, UK), R. Scott (RAL, UK), N. Woolsey (York, UK), K. Glize (RAL, UK), M. Khan (York, UK), M. Koenig (LULI), G. Rigon (LULI)]

Conclusion

This low-density sine wave target described has gone through several iterations during the last few years. With each set of targets small changes were demonstrated and then introduced to improve the quality of the targets as well as ease the assembly process.

The two biggest changes were 1) the inclusion of a small trench to reduce the excess glue effects and 2) the development of a method to fabricate the pusher/washer assembly without any damage to the foils. Further improvements will be made in the upcoming experiment by reassessing the production of the foam fill to establish how the yield can be improved.

Bibliography

[1] Sharp, D.H. (1984), "An Overview of Rayleigh-Taylor Instability", Physica D: Nonlinear Phenomena, Volume 12, Issues 1–3, July 1984, Pages 3-10, IN1-IN10, 11-18

[2] Wang, C.-Y & Chevalier R.A (2000), “Instabilities and Clumping in Type Ia Supernova Remnants”, The Astrophysical Journal, **549(2)**: 1119-1134