Deploying the SLAC liquid target at RAL

Contact *nicolas.bourgeois@stfc.ac.uk*

N. Bourgeois, P. Parsons, D. Symes

Central Laser Facility, STFC
Rutherford Appleton Laboratory,
Didcot, OX11 0QX, UK

G. D. Glenn, C. B. Curry, F. Treffert, M. Gauthier, and S. H. Glenzer

SLAC National Accelerator Laboratory,
High Energy Density Science (HEDS) Division
Menlo Park, CA 94025, USA

C. A. Palmer, M. Streeter,

Centre for Plasma Physics,
Queen's University Belfast
Belfast, BT7 1NN, UK

Introduction

In recent years there has been significant interest in multi-Hz laser solid- and liquid-target experiments. Solid targets frequently require the use of tapes of different materials, which can present engineering difficulties. An alternative approach is a liquid-jet device developed at SLAC [1], which provides mm-scale liquid targets with variable thickness from 100 nm to 100 µm. The approaching availability of high repetition-rate, high-intensity laser technology combined with machine learning techniques enable a deeper understanding of laser-matter interaction. The Astra-Gemini laser provides unique access to a multi-Hz laser with developed active feedback routines [2] enabling complete control of the laser spatial and temporal profile. In this report we describe the implementation of the liquid target in Astra-Gemini Target Area 2.

Generation of the ultra-thin liquid sheets

The system used for generating the ultra-thin liquid sheets consists of a High-performance liquid Chromatography (HPLC) water pump, feeding high purity water to a jet nozzle through 1/16" PEEK (polyether ether ketone) tubing. The high purity water is delivered to a nozzle that produces the water sheet. The length and thickness of the water sheet can be adjusted by varying the water flow in the delivery system. The water is collected by a skimmer, then directed to a catcher before it is pumped out of the target chamber. Figure 1 shows a picture of the nozzle and catcher assembly in the vacuum chamber.

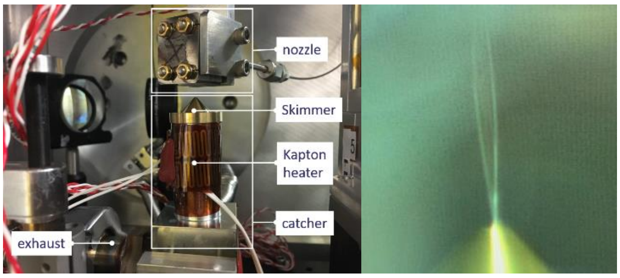

Figure 1: Ultra-thin liquid sheet generation. Picture of the nozzle and catcher in the vacuum chamber (left). A Kapton film heater is used to prevent freezing under vacuum. Image of the liquid sheet (right). The nozzle output is on the top, the liquid is flowing downwards.

It is crucial to evacuate the water from the target chamber as a liquid. Four 4 watt (W) Kapton film heaters attached to the body of the catcher ensure that the water does not freeze in the skimmer-catcher assembly. This setup was able to heat the catcher up to 60 degrees Celsius, however this was not enough to maintain the water as a liquid under vacuum. A new catcher body was designed and the Kapton heaters were replaced with 200 W cartridge heaters, which were able to heat the catcher sufficiently to maintain the temperature at 100 degrees Celsius under vacuum.

Vacuum pressure mitigation

It was of the utmost importance to prevent water vapour from migrating towards the compressor. A thin (<1 mm) transition window was installed in front of the gate valve on the target chamber side. This guaranteed that the vacuum and optics in the compressor would not be compromised water vapour.

An additional vacuum pump (Edward iGx600) was installed on the target chamber to supplement the roughing pumps. The turbo pump located underneath the target chamber was not used, as it could be exposed to water vapour or droplets.

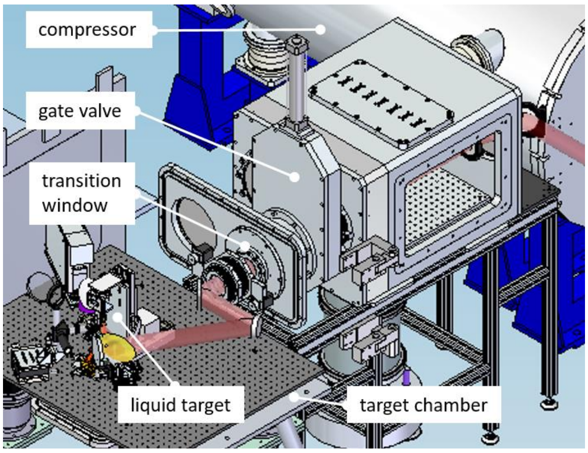

Figure 2: CAD drawing of Target Area 2 vacuum chambers. The gate valve is open during shots. A thin fused silica transition window located between the compressor and target chamber ensure water vapour does not migrate towards the compressor.

The captured liquid water is exported via a pumping line attached to the exhaust from the catcher. Heating elements placed along the exhaust line ensure that the water stays liquid. Liquid water is captured from the exhaust line in a liquid trap then collected in a waste reservoir (Figure 3).

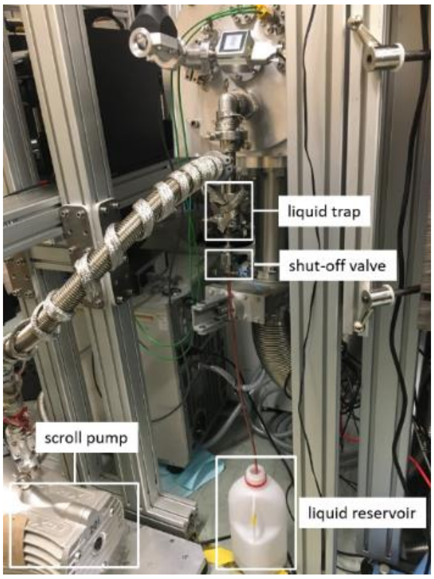

Figure 3: Exhaust line for the waste water.

Conclusions

The SLAC water target was used successfully during a high repetition rate experiment in Astra Gemini Target Area 2. On some experimental days, up to 10,000 laser shots were fired at the target. In future tests a vapour trap will be necessary to better protect the vacuum pump on the exhaust line.

References

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2. Shalloo, R.J., Dann, S.J.D., Gruse, JN. et al. Automation and control of laser wakefield accelerators using Bayesian optimization. Nature Commun. 11, 6355 (2020). https://doi.org/10.1038/s41467-020-20245-6