# Development of a liquid crystal target system for experiments investigating laser-driven proton acceleration

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## INTRODUCTION

Laser-driven proton acceleration holds promise of realizing intense proton beams for tumor therapy [1]. For experiments exploring that application, a target is required, which can be renewed after each shot. In a collaborative project with the Helmholtz Centre Dresden Rossendorf (HZDR), a target system is developed that is based on a liquid crystal. The target system should provide thin films on demand with thicknesses ranging from nanometers to micrometers [3].

## FILM FORMATION PROCESS

Liquid Crystal films can be formed by drawing a precise volume of liquid crystal across an aperture in a rigid frame.
The resulting thin film shape has a thin inner region that widens near the frame edge into a thick meniscus.

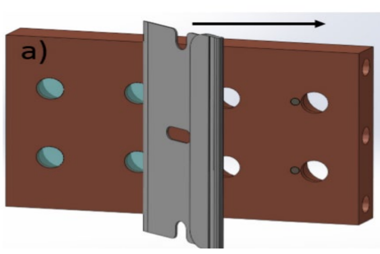


Fig. 1. Liquid crystal film formation apparatus consisting of a copper frame with 4 mm diameter apertures

## FILM CHARACTERISTICS

The inner region of the film consists of tens of layers, while the meniscus may have hundreds of layers.

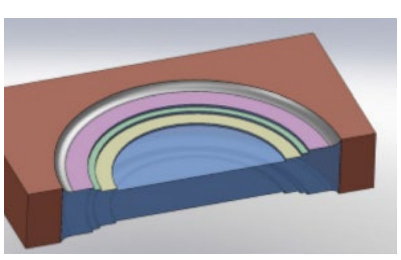

Fig.2. Film morphology cartoon depicting an inner thin region surrounded by a thicker meniscus that attaches the film to the frame.

Fig.3. Photograph of a liquid crystal film showing the inner transparent region surrounded by colored fringes, which indicate larger thicknesses.

## FACTORS AFFECTING FILM THICKNESS

The specific thickness value is determined by factors such as

- the crystal temperature
- the frame geometry
- initial volume of the liquid crystal droplet

Remarkably, these films maintain their initial thickness even after pumping to a high vacuum due to a low vapor pressure of 8CB.

## CRYSTAL TEMPERATURE

Applying heat to the copper frame facilitates the transfer of thermal energy to the 8CB thermotropic liquid crystal film. Notably, thermotropic liquid crystals such as 8CB undergo phase transitions into liquid crystal phases in response to temperature changes.

## TEMPERATURE CONTROL

Achieving films around 500nm and thicker requires temperature control of the film frame or liquid crystal volume. A copper frame heating with the water-cooling system (maintaining the ideal Temperature between 27.5 degrees Celsius and 28.5 degrees Celsius just below the smectic or nematic phase transition)

## THICKNESS CONTROL

Careful Temperature control within the specified range and minimal crystal volume allow film Thickness between 50nm and 500nm.

## FRAME GEOMETRY

The wiper angle and draw speed significantly impact film thickness.

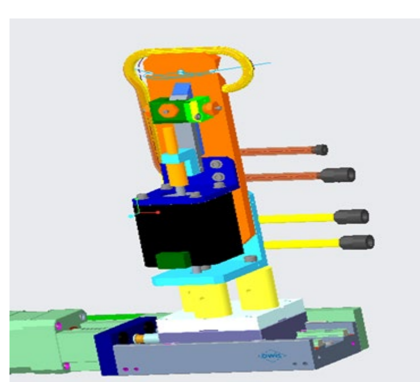

Fig.4. Frame Design of Liquid Crystal Target System

## INITIAL VOLUME

We apply a drop of liquid crystal onto the surface just beneath the wiper's aperture. As the wiper moves, it draws the liquid crystal upward, creating a thin, uniform film.

## CHALLENGES IN FILM THICKNESS CONTROL

Temperature control is critical for thin film generation. The current temperature control provided by water cooling is not sufficient for reproducible results.

1. New thermal diagnostics is developed.
2. The current temperature control (Lauda WK500) will be improved using a commercial thermostat system.
3. The wiper angle and draw speed significantly impact film thickness. Following numerous tests, it has become apparent that the old wiper, constructed from Peek material, exhibits deterioration in its edge quality.
4. Only slow wiping speeds are possible, barely over 1mm/s. Experiments are performed investigating the wiper speed on the film thickness.

## SOLUTIONS

A temperature monitoring system utilizing thermistors and Arduino microcontrollers to achieve precise temperature measurements. Our current focus is on developing temperature control mechanisms to regulate temperatures to desired levels effectively and reliably.

A Lauda E 115 Thermostat is tested to regulate temperature, while a pump will circulate temperature-controlled water throughout the copper block. The wiper is currently made of PEEK. Teflon is tested as it has a low coefficient of friction.

If the wiper speed surpasses 0.5 mm/s, it causes the film formed around the aperture to tear off. Therefore, maintaining lower speeds are tested to provide stable film formation.

## PARAMETRIC STUDIES

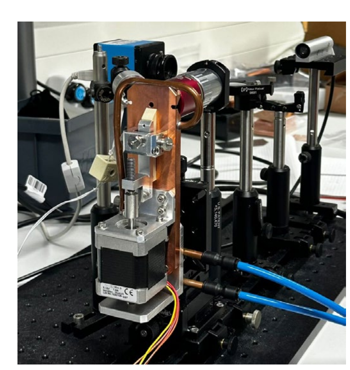

Fig.5. Parametric studies are performed investigating the reproducibility of thin film formation

## REFERENCES

[1] Kroll et al., "Tumour irradiation in mice with a laser-accelerated proton beam“, Nature Physics 18(3), 316-322 (2022)
[2] Poole et al., "Liquid crystal films as on-demand, variable thickness (50-5000 nm) targets for intense lasers", Physics of Plasmas 21, 063109 (2014)
[3] Poole et al., "Laser-driven ion acceleration via target normal sheath acceleration in the relativistic transparency regime“, New Journal of Physics 20(1), 013019 (2018)