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Experimental Aspects of MagLIF Pre-Heat Studies: The Pecos Target Area

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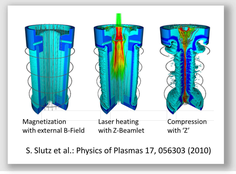
MagLIF

Motivation

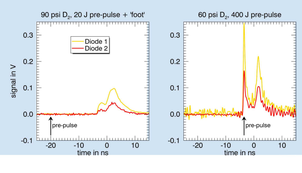
Magnetized Liner Inertial Fusion (MagLIF) is a magneto-inertial fusion program pursued by Sandia National Laboratories in collaboration with multiple institutions around the US (e.g. LLNL, LLE). It is based on using Sandia's "**Z**" pulsed power facility to compress D_2 fuel after it has been heated with the Z-Beamlet laser and magnetized by external field coils. Magnetization suppresses heat conduction and facilitates thermonuclear burn. The laser pre-heat is a critical step in the process and investigated in dedicated experiments.



LEH Diagnostics

Si X-ray Diodes

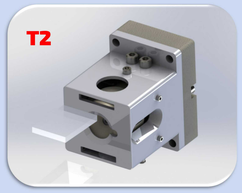
Two differently filtered diodes record the X-ray emission along a line-of-sight to the laser-entrance-hole (LEH). The signal is mostly dominated by emission of the window, which is made of polyimide and radiates more intensely. The filters are set so that 1 keV X-ray emission would cause a difference of a factor of two between the diodes. The overall intensity of the X-ray emission is also an indicator for absorbed laser power and smooth window destruction.

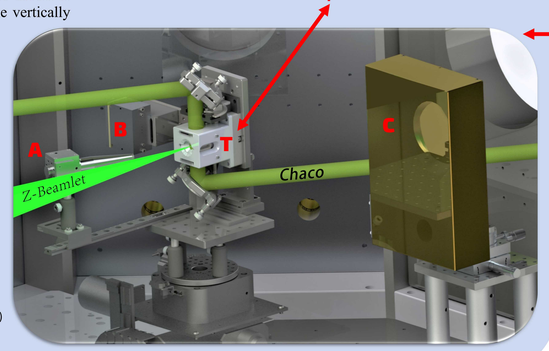


In-Chamber Setup

The Experiment

A gas cell* (**T1**, right) is filled with 0.7-1.4 mg/cc of deuterium or helium, optionally with argon or neon dopant (typically 0.1% Ar). The cell allows gas access via a ¼ inch hose. The *Z-Beamlet* laser enters through a conically recessed window and delivers 1.5-3 kJ of energy in a few nanoseconds at a wavelength of 527 nm. The gas cell is nested inside an aluminum debris box (**T2**, far right), that protects optics and instrumentation in the target chamber from the massive debris that is generated when the heated cell bursts. Diagnostic access is granted via two optical windows for the vertically propagating 4-pulse **Chaco** probe laser, and via two side-mounted slits with 3 µm polyester windows, and the laser-entrance hole itself.

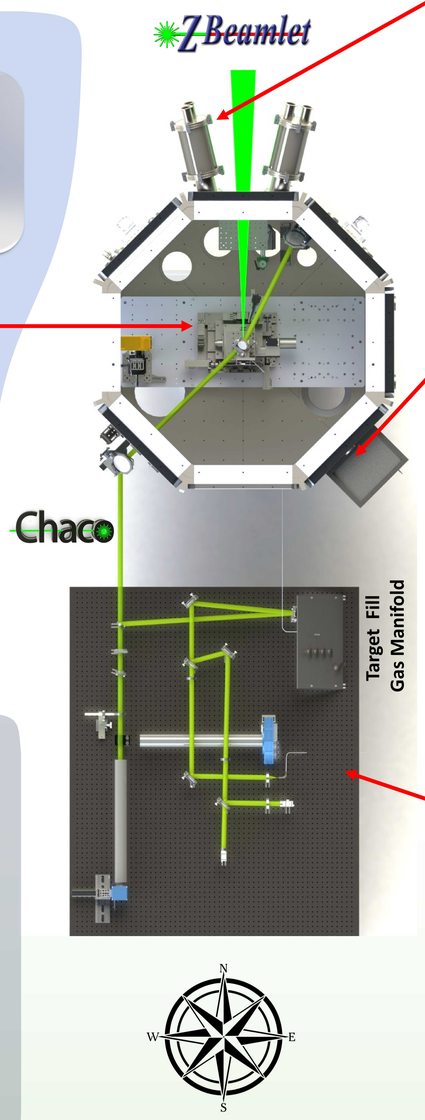




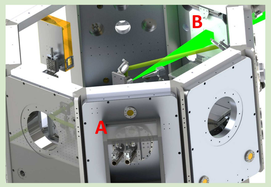
The X-ray diagnostics **A**, **B** (pinhole cameras), and **C** (X-ray imaging spectrometer) are described in more detail below.

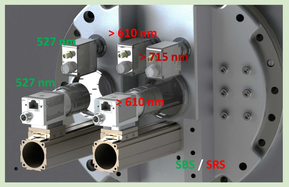
The probe laser is analyzed by a suite of instruments on a dedicated diagnostic table south of the target chamber.

*R.R. Paguio et al.: Fusion Sci. Technol. **73**, 414 (2018)



Backscatter Diagnostics



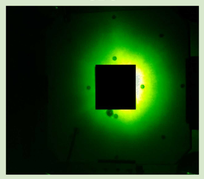


Near Beam Imaging (NBI)

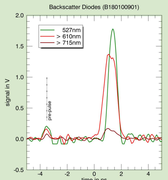
A Near Beam Imaging backscatter station (**A**) contains cameras and photodiodes that record light after being reflected from a PTFE screen (**B**). The screen frames the incoming laser beam. Any light that 'escapes' through the screen's aperture is reconstructed with a fit-superposition of multiple 2D-Gaussian distributions. The brightness of the screen is calibrated, and the fit allows an estimate of the total backscatter.

To date, SBS is by far the dominant source of backscattered energy. SRS is observable, but mostly negligible (<10 J). Please note that cameras and diodes are set to be much more sensitive to SRS than SBS, which can reach several 100 J for extreme target/laser configurations, but has been reduced to <50 J for the most recent experimental designs.

SBS



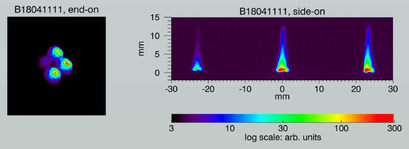
SRS



Imaging X-ray Diagnostics

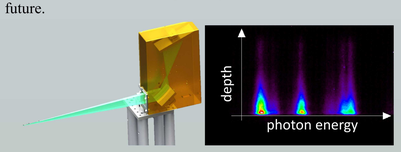
Pinhole Cameras

Two X-ray pinhole cameras observe soft X-ray emission with multiple, differently filtered pinhole-inserts. The two lines of sight are end-on (through the LEH) and side-on. The former is a good indicator of laser energy being clipped at the LEH, while the latter provides additional laser propagation information, complementing the shadowgraphy measurements. The side-on image below is plotted in a logarithmic scale.



Spatially Resolving X-ray Spectrometer

A crystal spectrometer is used to analyze the emission of argon dopant in the gas. It can provide an estimate of the electron temperature in the plasma. The green, semitransparent body in the picture below indicates the path of X-rays, reflecting of the crystal in the lower part of the instrument and being recorded on a strip of image plate (IP) in the upper part. It is planned to replace the IP with a fast gated hybrid-CMOS detector in the future.



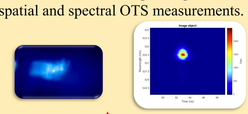
Probe Laser (Chaco) Diagnostics

CW Alignment

Correct installation of the target and beam routing are validated with a traditional CCD camera and an eye-safe CW alignment beam at the start of the experimental setup. The laser is picked off the regular beam path only at this time.

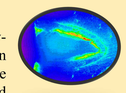
Optical Thompson Scattering

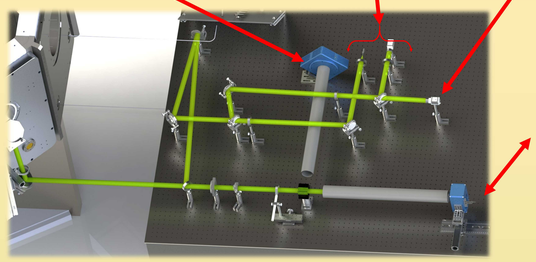
A small fraction of the probe is guided to camera and fiber-coupled spectrometer for spatial and spectral OTS measurements.



Schlieren Imaging

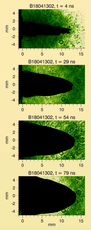
As a complement to the shadowgraphy, a (dark-field) Schlieren imaging is used to enhance density gradients in the gas and discover potential self-emission regions (beam stop not shown in picture).

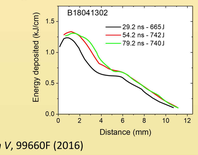




Shadowgraphy

Sandia's ultrafast hybrid-CMOS camera* records a series of images that capture the expansion of the laser-induced blast wave. An analysis of the blast wave provides the deposited energy in the gas, which can exceed 1.5 kJ for D2 fills of 1.4 mg/cc.





*L. Claus *et al.*: Proc. SPIE 9966, *Target Diagnostics Physics and Engineering for Inertial Confinement Fusion V*, 99660F (2016)

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Z-Beamlet

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