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A Window-less Target for Magnetized Liner Inertial Fusion Characterized using High-Speed Solid-State Framing Cameras

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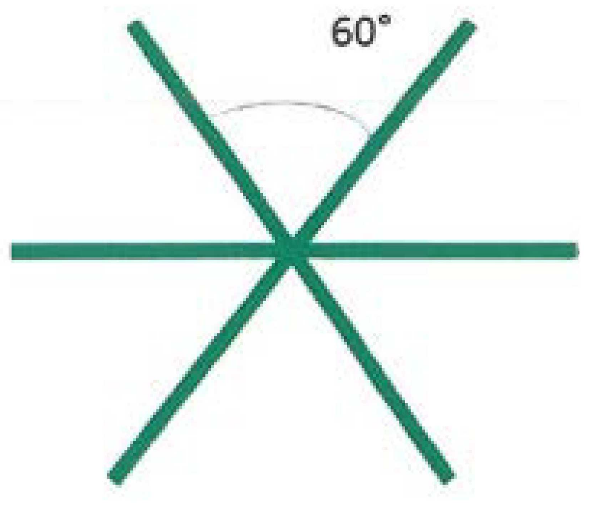
Solving a Problem for MagLIF

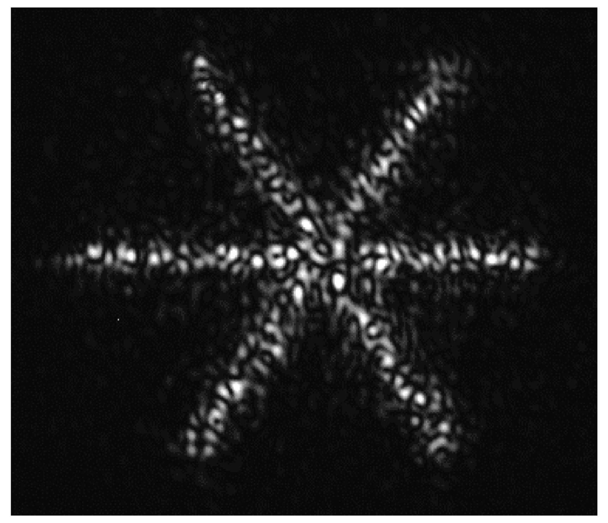
Magnetized Liner Inertial Fusion (MagLIF) compresses a laser-preheated, magnetized, deuterium-filled Be cylinder using magnetic direct drive from a high-current pulsed power device, such as Sandia's Z-machine. A major complication of existing MagLIF targets is the presence of a solid-density window that a preheat laser must pass through before being absorbed in the low-density gas that comprises the fusion fuel. This complication can potentially be eliminated by applying techniques used in shock tubes, where a diaphragm containing high-pressure gas is punctured. Gas expanding from the main target volume will then mechanically push the diaphragm away from the target axis. We use a low-energy laser pulse as the opening mechanism for its nanosecond speed and minimal added experimental footprint and fuel impurities.

Approach and Optical Design

We use a diffractive optical element, fabricated by SILIOS Technologies (www.silios.com), to create a star-shaped focal spot. The petals that result from laser-induced damage open mechanically.



Desired optical pattern.

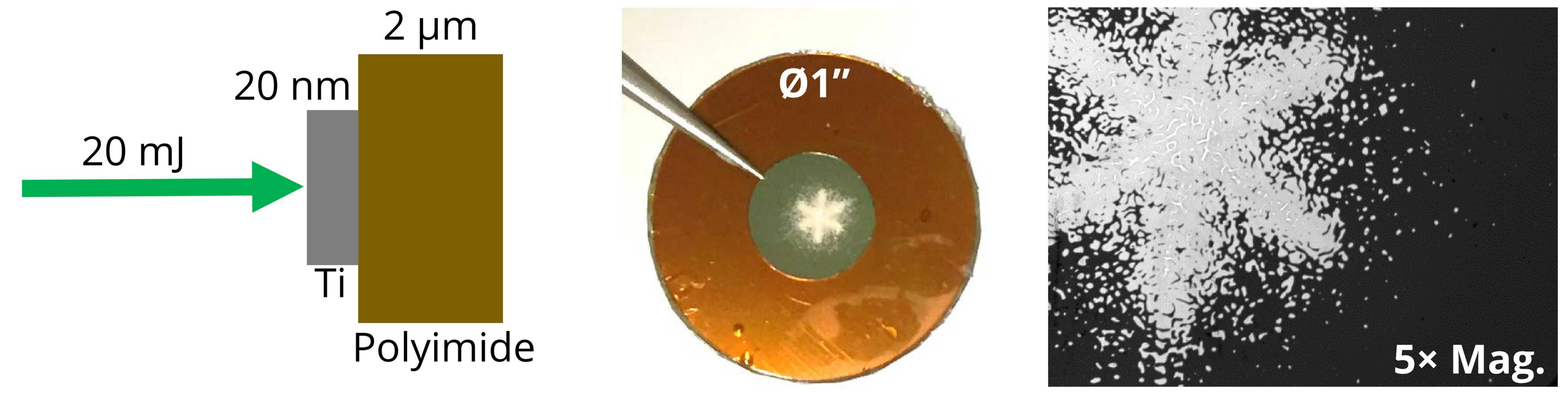


Actual optical pattern. Stripe size: 1.7 mm × 120 μm.

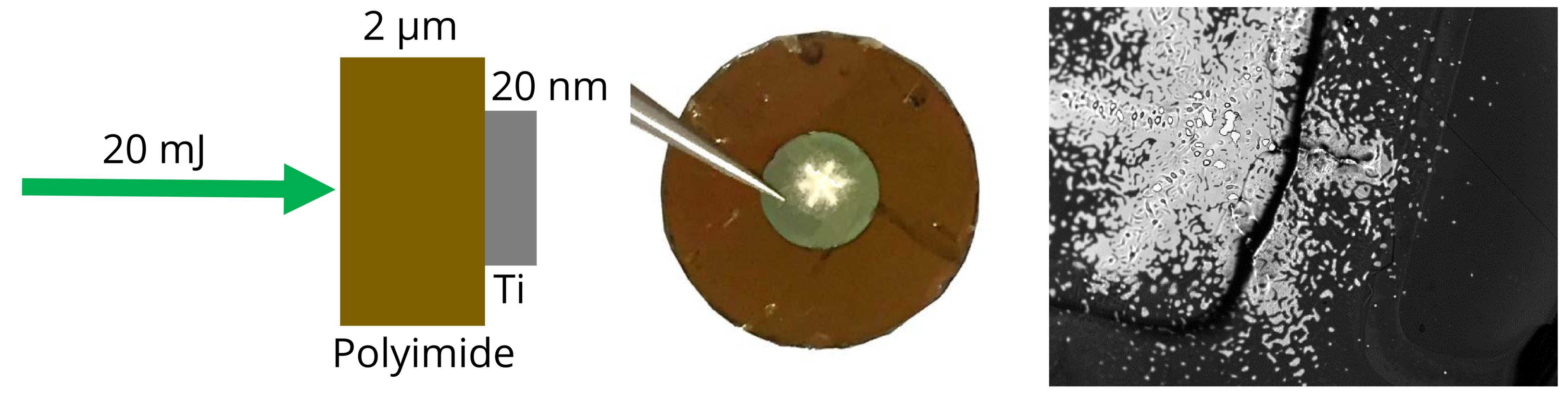
Burn pattern on anodized aluminum. 2 shots on target.

Damage on a 2-μm thick polyimide pellicle. The foil ruptures along the star-shaped focal pattern.

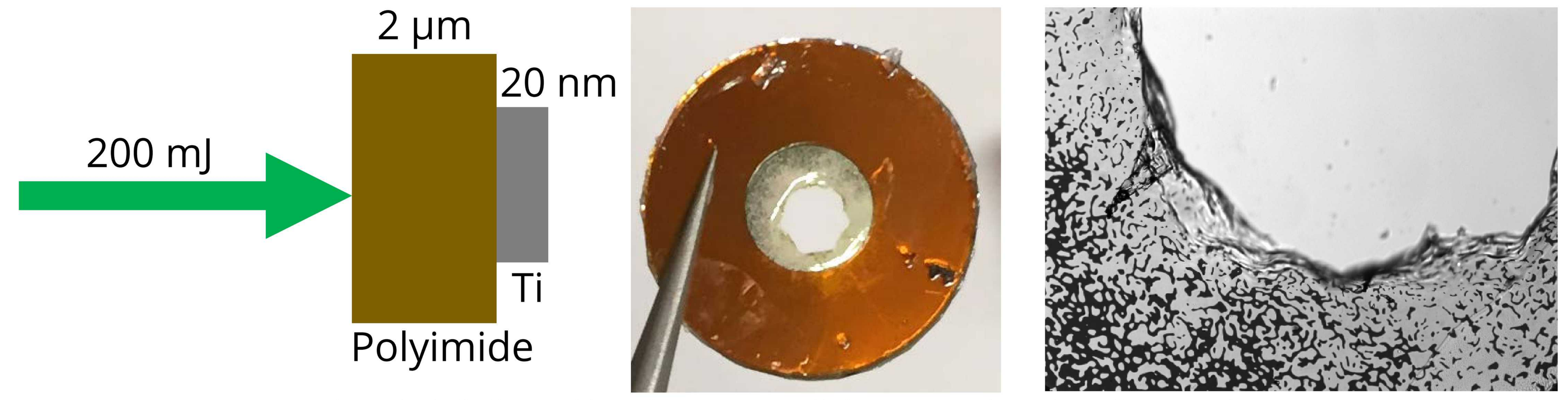
Damage Fluence vs. Foil Composition



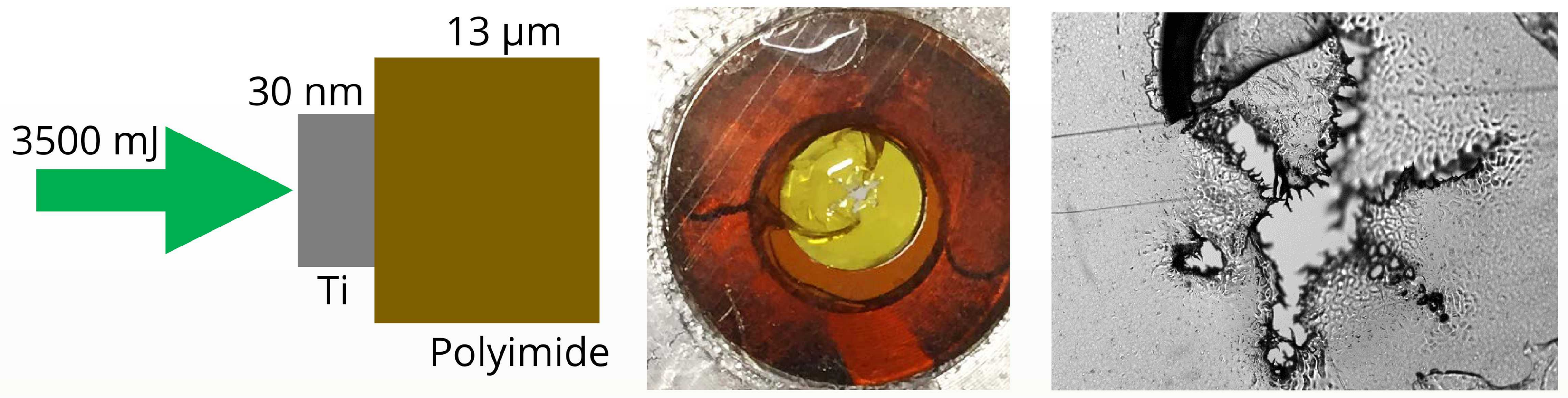
The Ti has been ablated within the focal spot pattern, but the film has not ruptured.



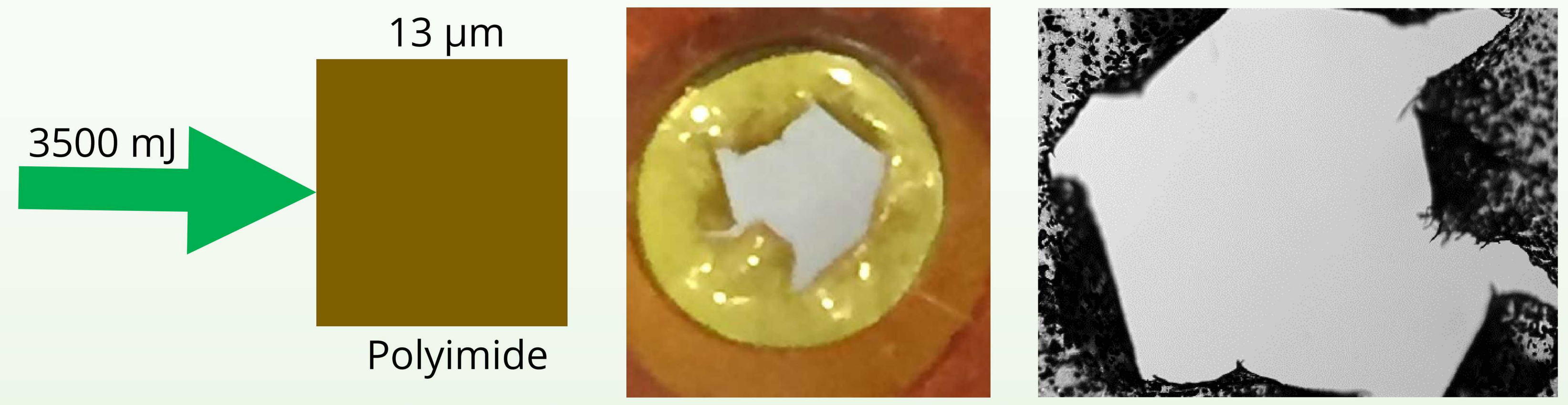
The Ti has been ablated within the focal spot pattern, and the film is heavily punctured.



A clean hole is formed but does not go all the way to the edge of the washer.

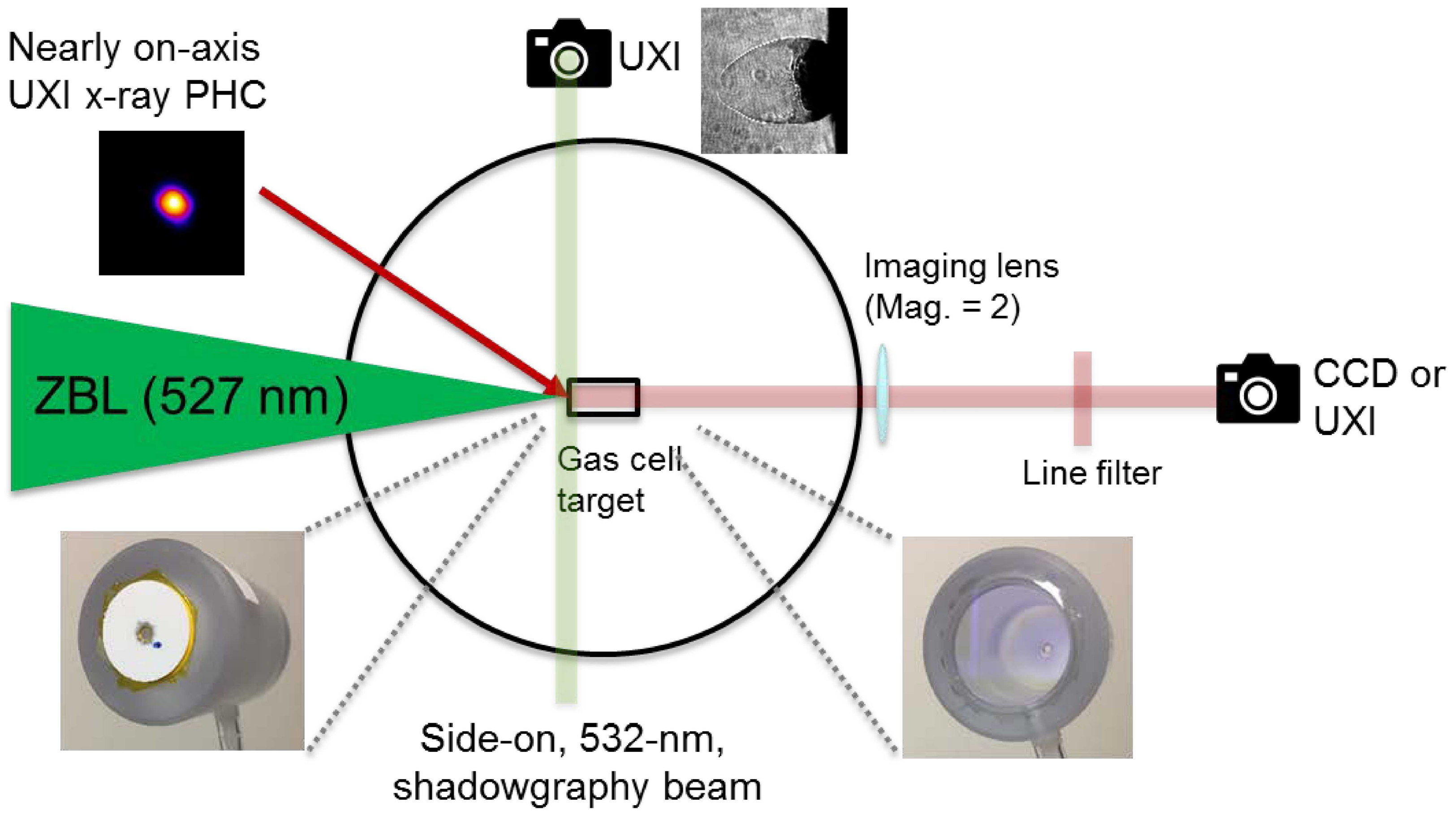


The polyimide tears along the star-shaped focal pattern.

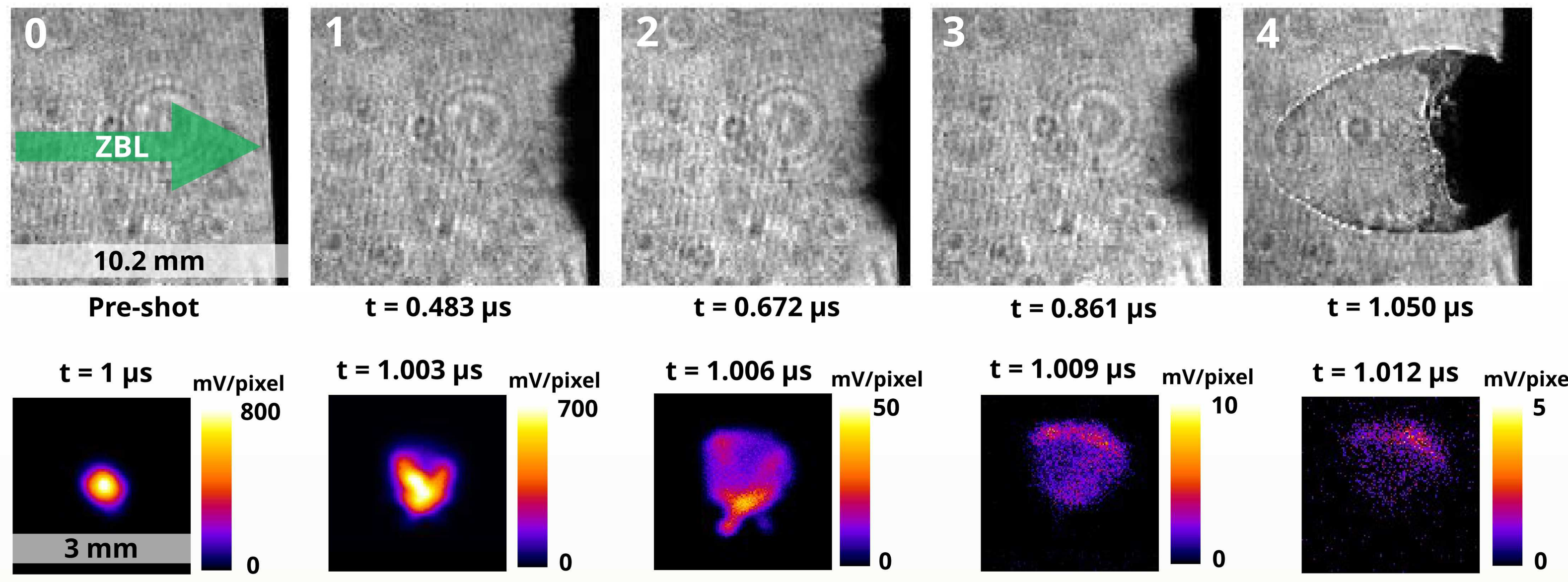


The polyimide tears open along the star-shaped focal pattern.

Measuring Foil Dynamics



A 3.5-J pre-pulse with the star-shaped focal pattern hits the entry window of the gas cell (72 psi He) at t = 0 s. The side-on shadowgraphy, acquired with an ultrafast x-ray imager (UXI) records the plasma evolution. At t = 1 μs, a 100-J Z Beamlet laser (ZBL) pulse probes the plasma condition, which is recorded by the last frame at t = 1.050 μs. A 200-μm x-ray pinhole camera (PHC) records the plasma state and evolution at the laser entry window.



Side-on shadowgraphy reveals modest plasma blow-off from the target foil, which evolves slowly (frames 0 – 3) until the ZBL probe beam interacts with the remaining low-density gas (frame 4). At this point, we suppose that the gas is rapidly heated and ionized, which accentuates the existing density gradients that are caused by a shock front. This shock front is due to some combination of the ablated window material and the He gas expanding into vacuum. The bright spot recorded with the x-ray PHC spot is consistent with this interpretation.

In summary, we commissioned the experimental configuration and diagnostic capabilities that will allow us to determine if this novel laser-target coupling scheme is viable for MagLIF targets.

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