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Investigating at-scale MagLIF preheat on the NIF

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LLNL-PRES-XXXXXX

This work was performed under the auspices of the U.S. Do... under contract DE-AC52-07NA27344. Lawrence Livermore ...

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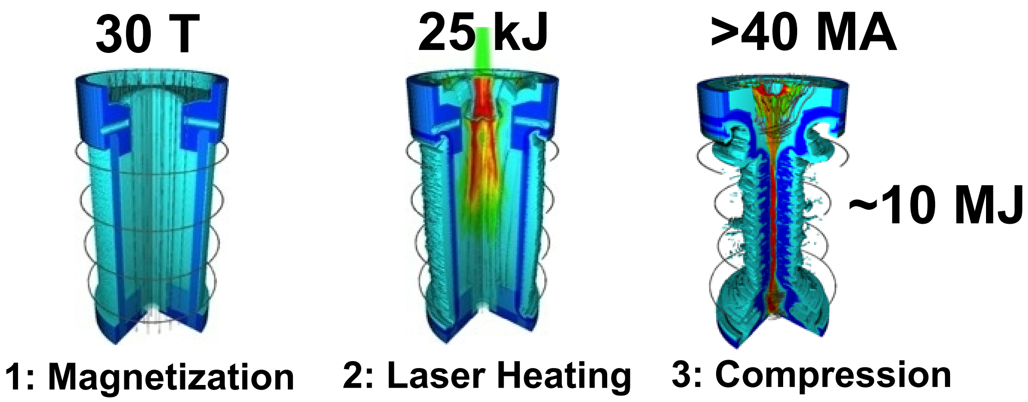
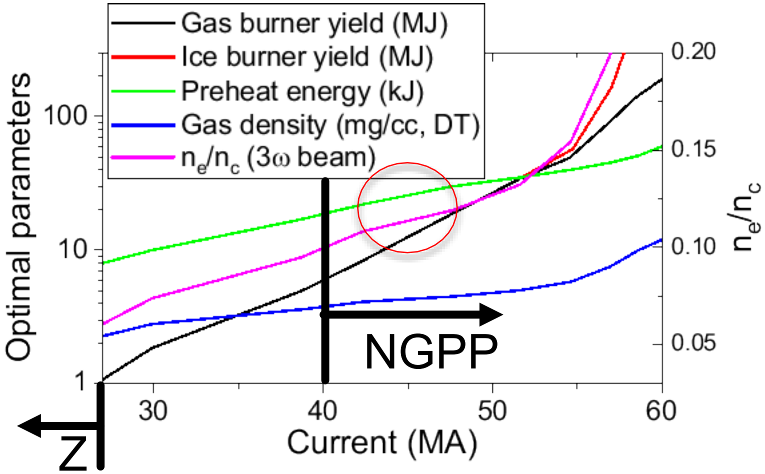
NIF is uniquely capable of addressing preheat scaling to next-gen pulsed power facilities for MagLIF





S. A. Slutz et al., Phys. Plasmas, 23, 022702, 2016

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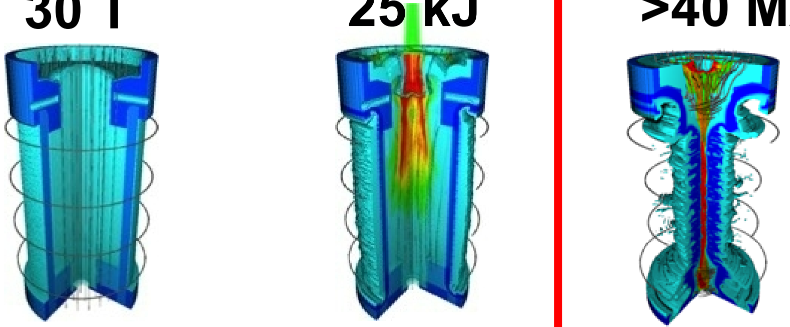
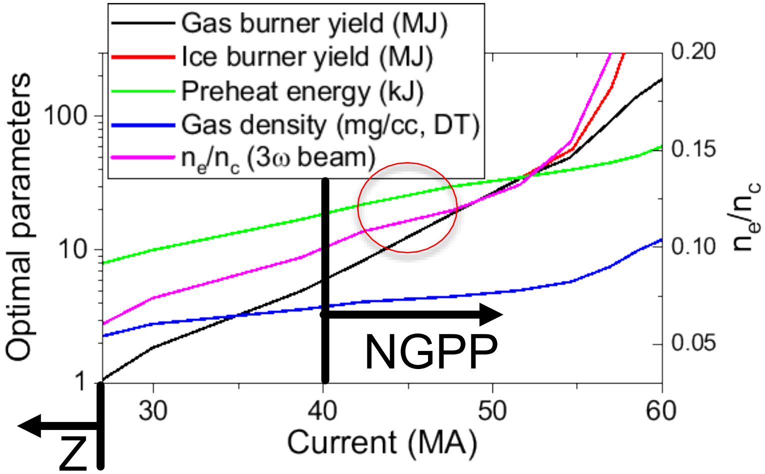
30 T | 25 kJ | >40 MA



~10 MJ

1: Magnetization | 2: Laser Heating | 3: Compression



Experimental demonstration of ignition-scale MagLIF preheat in gas pipe targets at the National Ignition Facility

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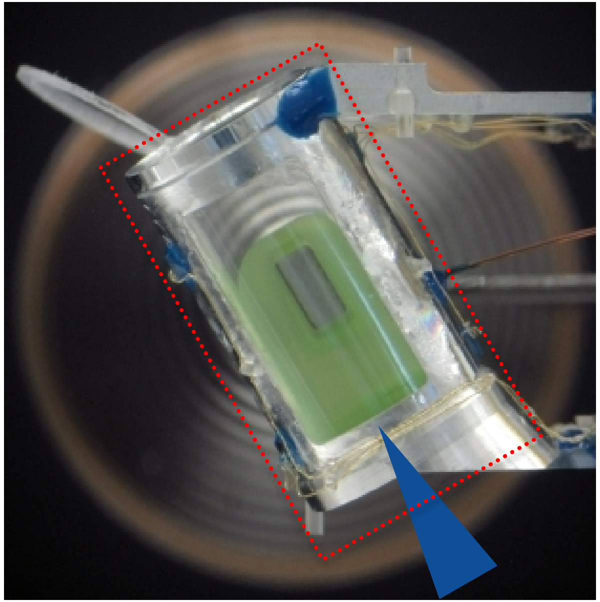
S. A. Slutz et al., Phys. Plasmas, 23, 022702, 2016

PoP submitted, awaiting referee feedback

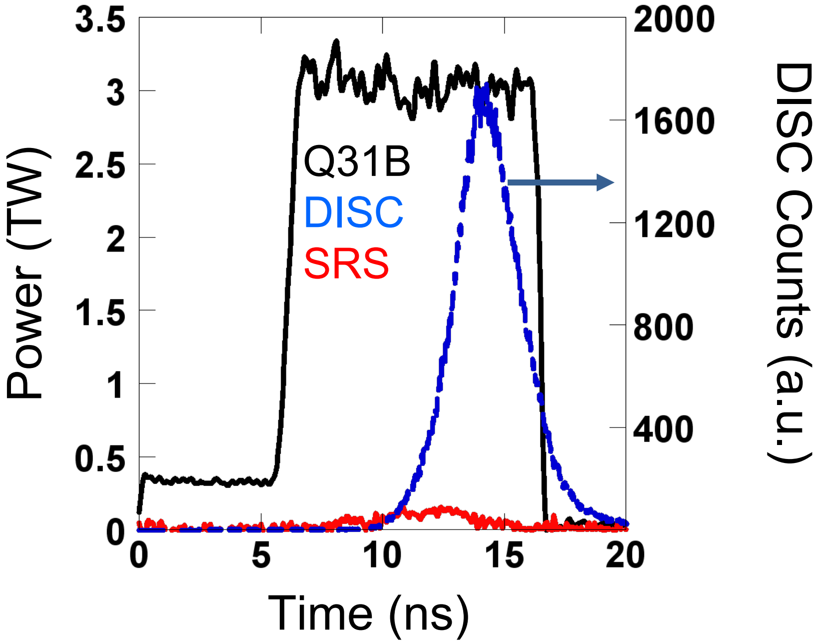
Recently, a cryogenic gas pipe platform has been developed for <~5 mg/cc D2 fill density experiments at NIF

Cryogenic targets with D2 fills: 1 cm-long, 6 mm diameter, 2.375 um kapton windows



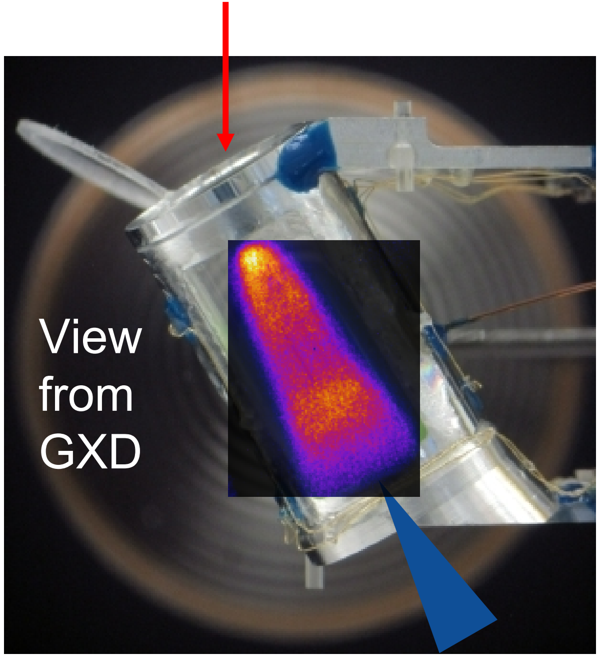
Q31B

N220517: 4 mg/cc D2 fill, 1.9×10^{14} W/cm^2, ~35 kJ



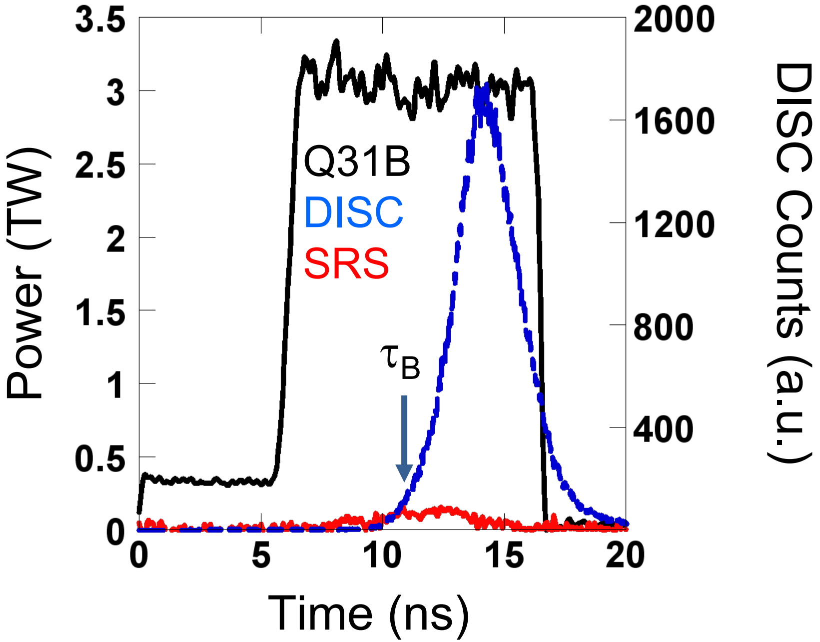
The primary diagnostics are an x-ray streak camera (DISC), x-ray framing camera (GXD), and backscatter (SRS and SBS)

X-ray Streak Camera (DISC)



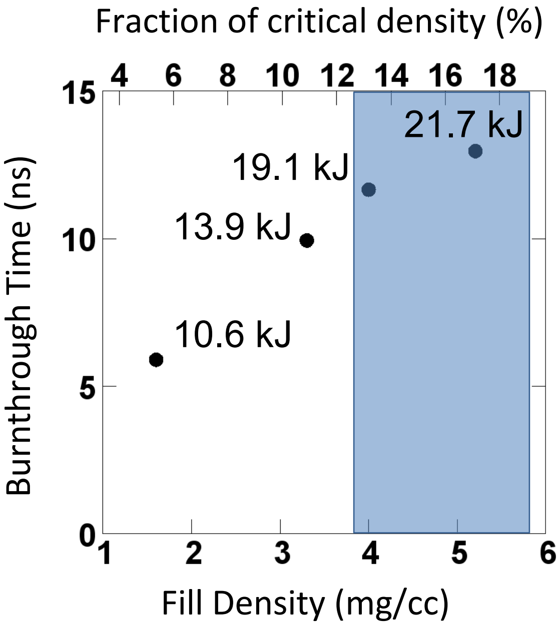
Q31B

SRS is ~600 J, with no SBS

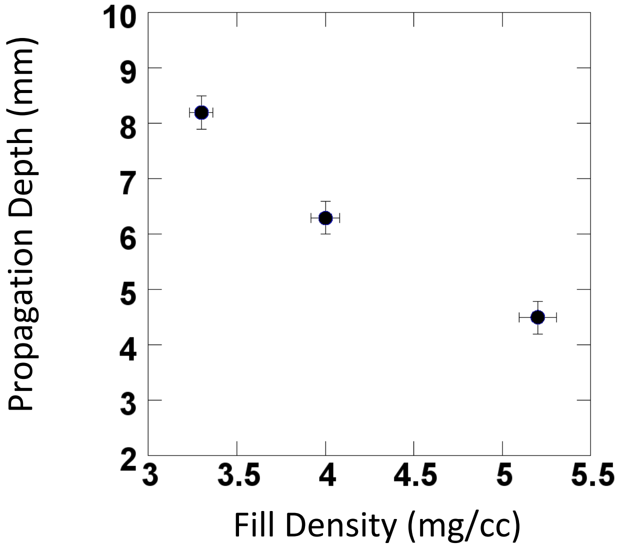


The fill density has been scanned from 1.6 to 5.1 mg/cc, with >20 kJ of laser energy coupling at the highest density

MagLIF relevant: 3.8-5.8 mg/cc

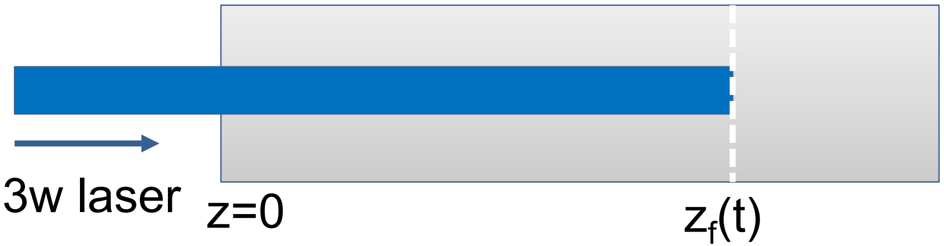


Propagation depth at 9 ns



The warm propagation data compares well with the 1D analytical inverse Bremsstrahlung absorption model of Denavit and Phillion

Laser absorption



Laser propagation front

$$z_f = \frac{2}{3}\left(\frac{5}{3}\right)^{0.6}\left(\frac{I_0 t}{n_e}\right)^{0.6}\left(\frac{1}{(k_B T_e)^{1.5}\kappa}\right)^{0.4}$$

$$E_c \sim A_{spot}\lambda^{4/3}L^{5/3}n_e^{7/3}$$

- This model excludes hydrodynamic expansion, thermal conduction, ion heating, and all transverse effects

Denavit and Phillion, PoP 1, 1994

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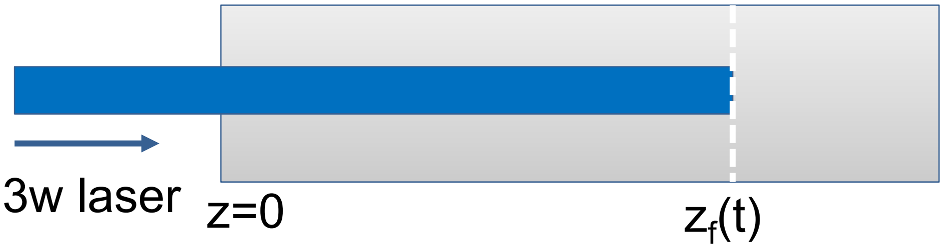
Laser absorption



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$$E_c \sim A_{spot}\lambda^{4/3}L^{5/3}n_e^{7/3}$$

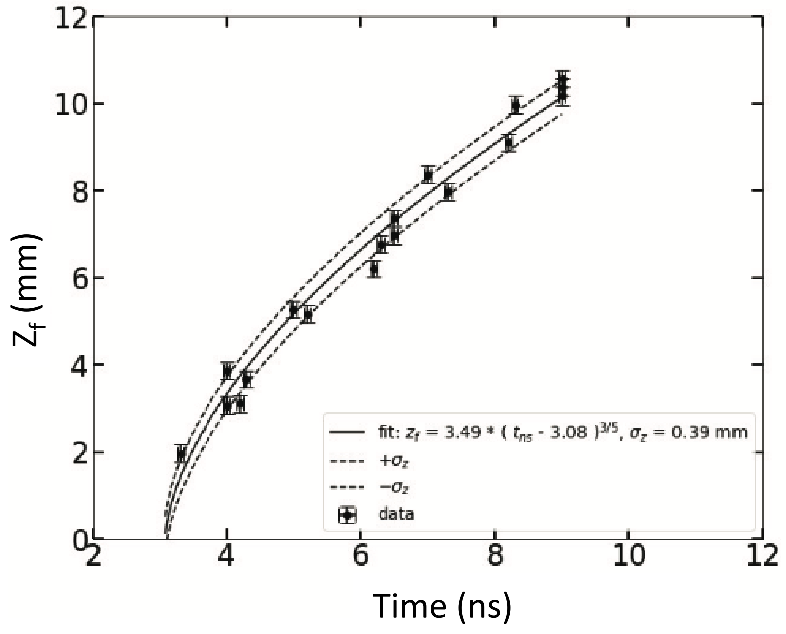
$$z_f = a(t-b)^{3/5}$$

- This model excludes hydrodynamic expansion, thermal conduction, ion heating, and all transverse effects

Denavit and Phillion, PoP 1, 1994

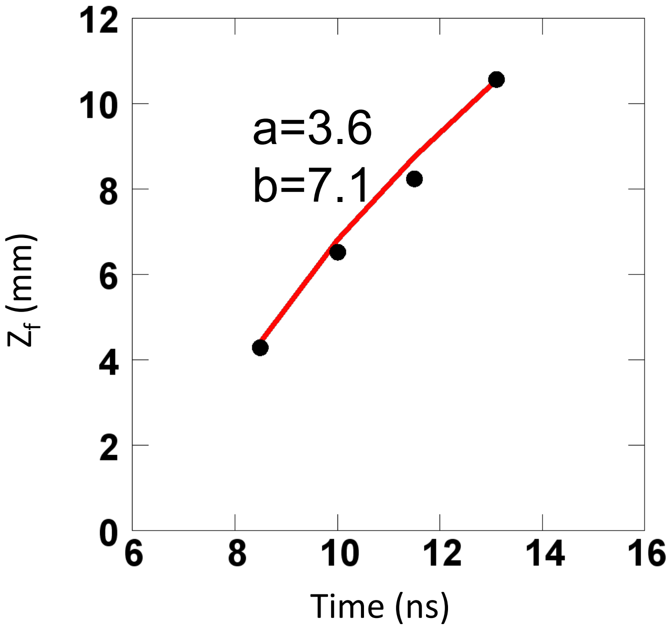
The warm hydrocarbon data and 5.1 mg/cc D2 data can be fit with the functional form $z_f = a(t-b)^{0.6}$

11.5% nc CH: a=3.69



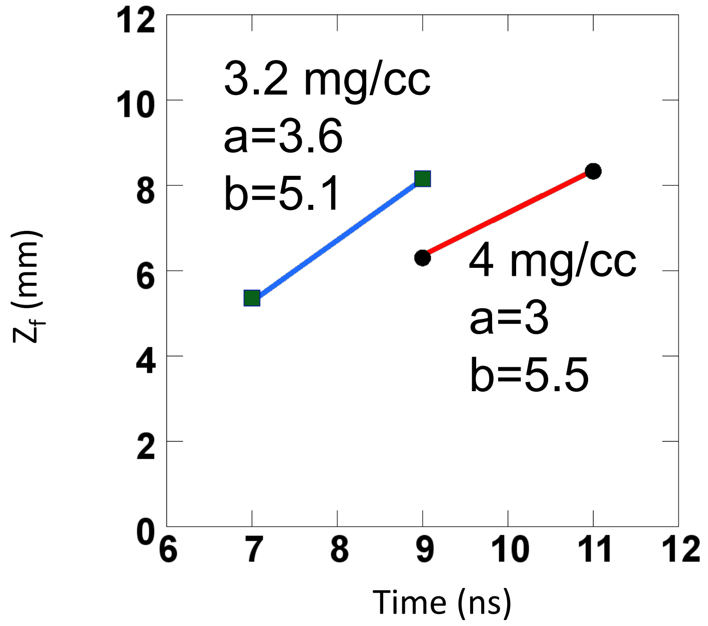
Pollock et. al. submitted to PoP

17.1% nc D2: a=3.9

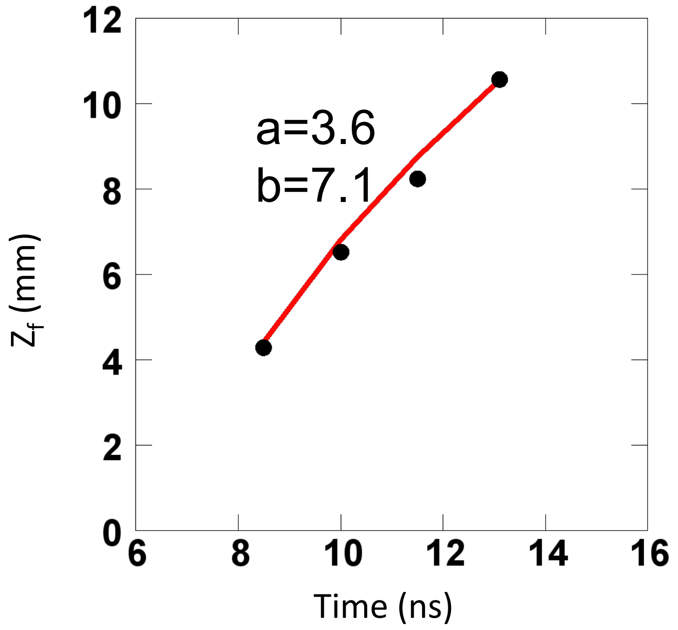


Applying the same methodology to the 3.2 and 4 mg/cc fills, the fit disagrees with the model

Model a: 10.7% nc=7.3, 12.3% nc=5.6

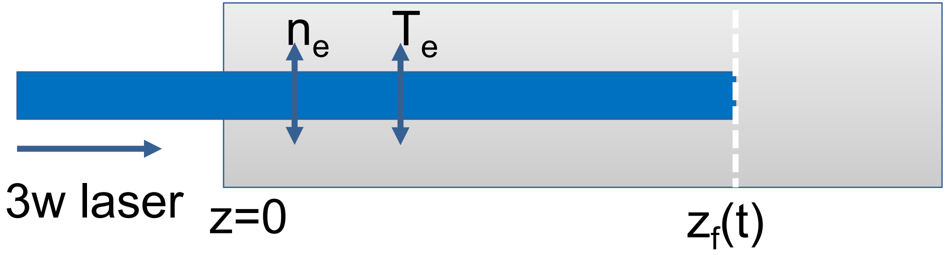


17.1% nc D2: a=3.9



The balance between hydro expansion and thermal conduction is complex and matters to the propagation

Hydro expansion is driven by pressure (P=nkT) and reduces density on axis

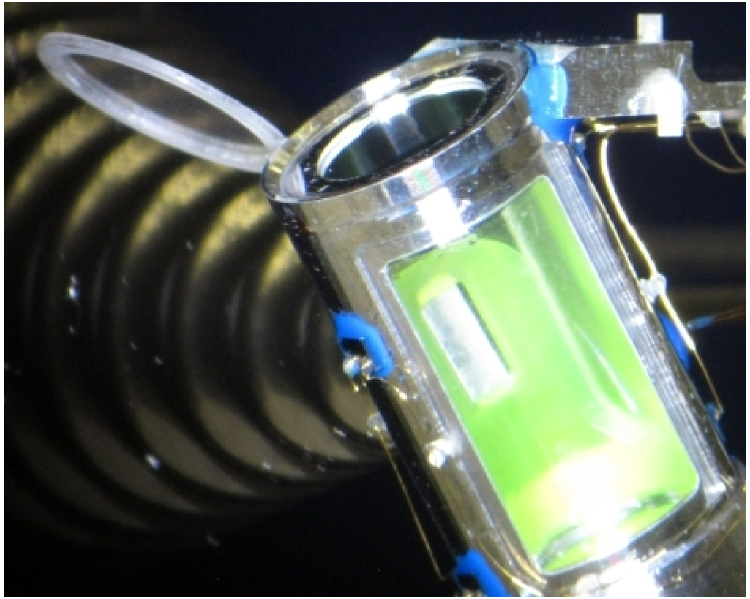


Thermal conduction ($\kappa \sim T^{5/2}$) heats a larger effective spot size

- The Denavit and Phillion model relates T_e and n_e near the target entrance as $T^{5/2} \sim n_e$
- This suggests $P \sim n^{7/5}$, and $\kappa \sim n$
- Reducing density reduces impact of hydro more rapidly than conduction
- If conduction effects are dominant the laser propagation will be slower and energy coupling higher than modeled

Future experiments with the D2 fills will measure energy coupling to the plasma using Visar and will magnetize the targets

- The current energy coupling at 5.1 mg/cc is >20 kJ, and consistent with the design space of future MagLIF designs
- The data are being compared with Hydra simulations, and additional experiments will provide better statistics
- NIF is modifying its pulsed power system to accommodate magnetized cryo targets in FY24



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