Tamped Ablator Pressure Dependence on Intensity and Tamper

NIF/JLF user meeting

11 February 2026

M. R. Armstrong[1], M. Bally-Grandvaux[2], S. Bolanos[2], J. Dominesey[1,2], J. E. Garay[2], S. M. Maricle[1], A. Mondai[2], O. Culfa[2], P. LaChapelle[2], F. N. Beg[2], H. B. Radousky[1]

[1]LLNL [2]UCSD

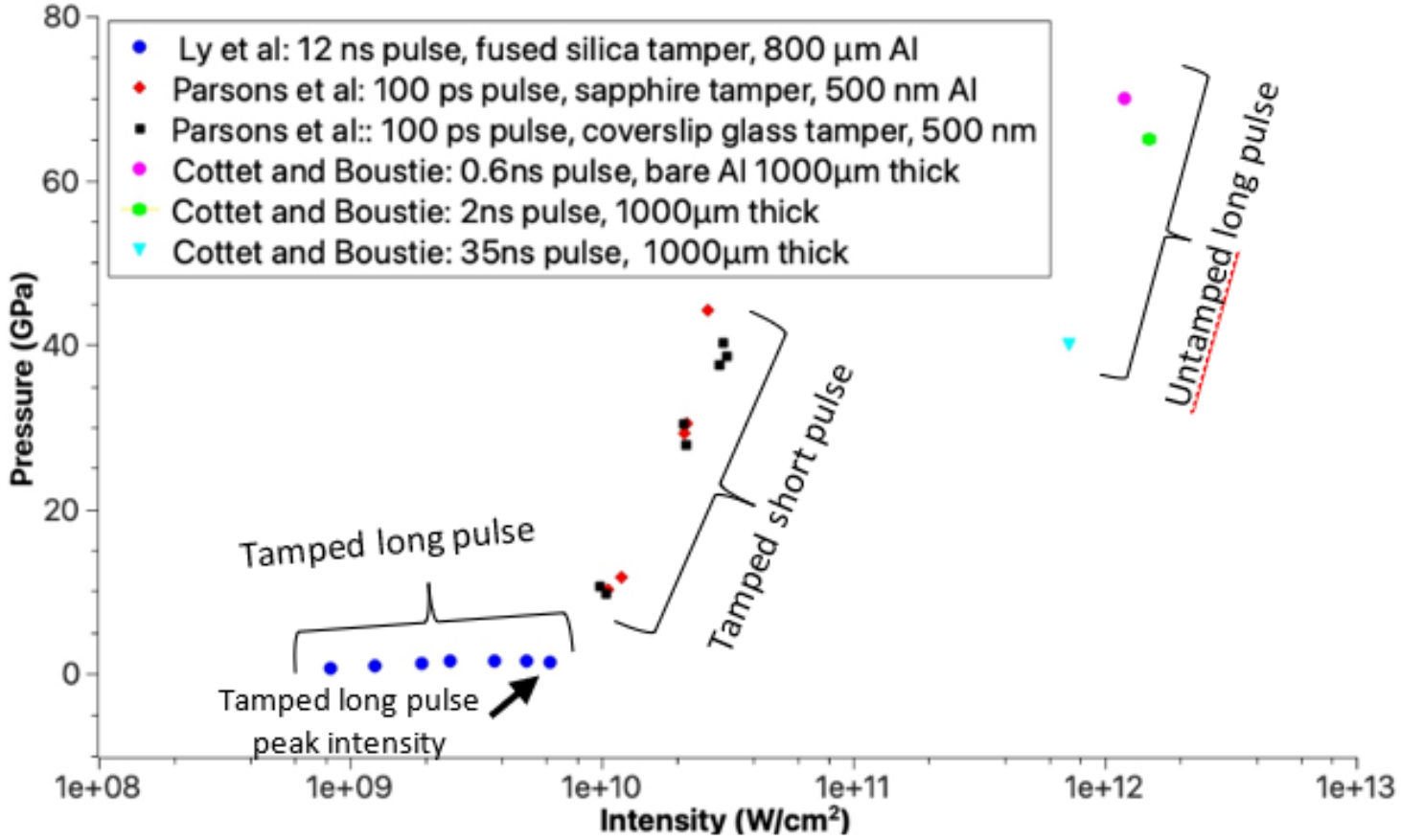
This work was supported by the U.S. DOE Office of Science, Fusion Energy Sciences under Field Work Proposal No. SCW1836-1: LaserNetUS: Discovery Science and Inertial Fusion Energy research at the Jupiter Laser Facility, and Lawrence Livermore National Laboratory, under Contract No. DE-AC52-07NA27344.

MSEE
MATERIALS SCIENCE IN EXTREME ENVIRONMENTS UNIVERSITY RESEARCH ALLIANCE

Drive side tampers can substantially increase pressure

Complex non-linear processes govern the pressure generated using tamped ablators.

For tamped ablation, pulses with duration greater than the ns range can generate at most 5-10 GPa pressure for intensity less than 10^{10} W/cm^2 , but sub-ns pulse generate many 10s GPa pressure at intensity up to 10^{11} W/cm^2

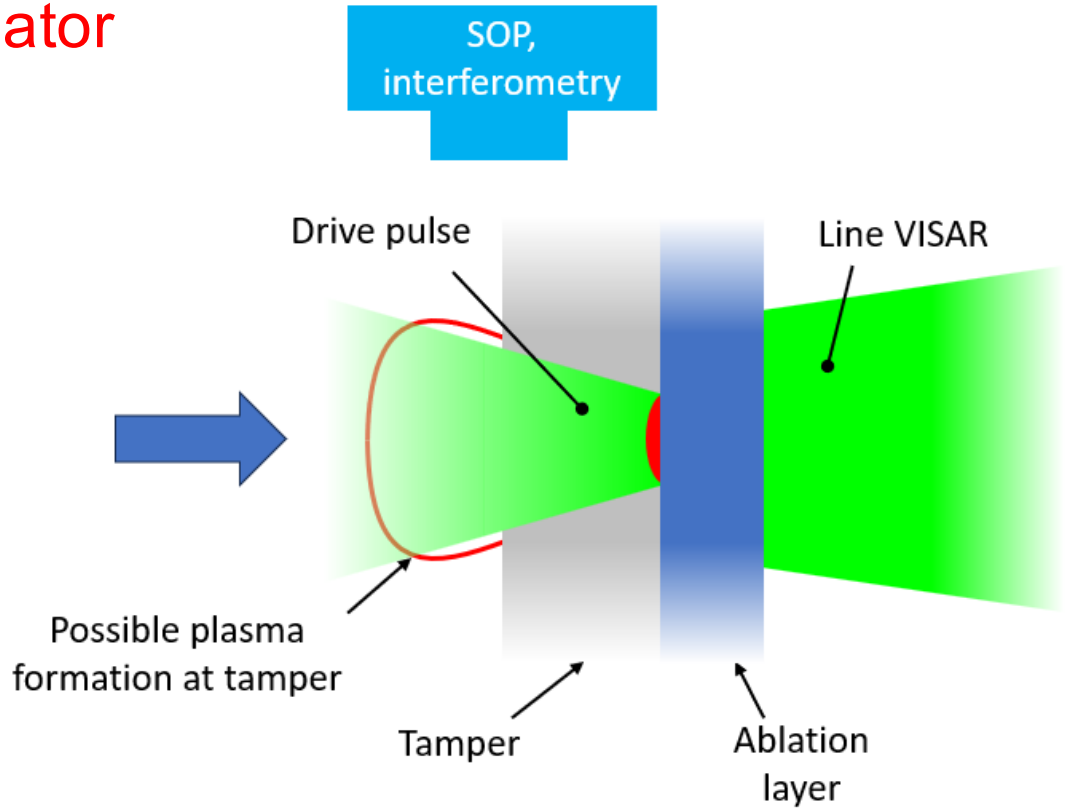


Prepared by LLNL under Contract DE-AC52-07NA27344.

We did experiments on the effects of varying laser and target parameters on tamped ablation at Janus/JLF

We will correlate plasma formation related to the tamper to the generation of pressure in the ablator

- Laser Parameters
  - Pulse durations 350 ps to >10 ns
  - Wavelength 1 mm and 0.532 mm
  - Intensity ~ 10^{9} to 10^{11} Wcm^{-2}
  - Energies from ~30 mJ to ~30 J
  - Laser spot ~ 2 mm
- Target parameters
  - Aluminum or titanium ablator
  - Tamper materials sapphire, LiF, and fused silica

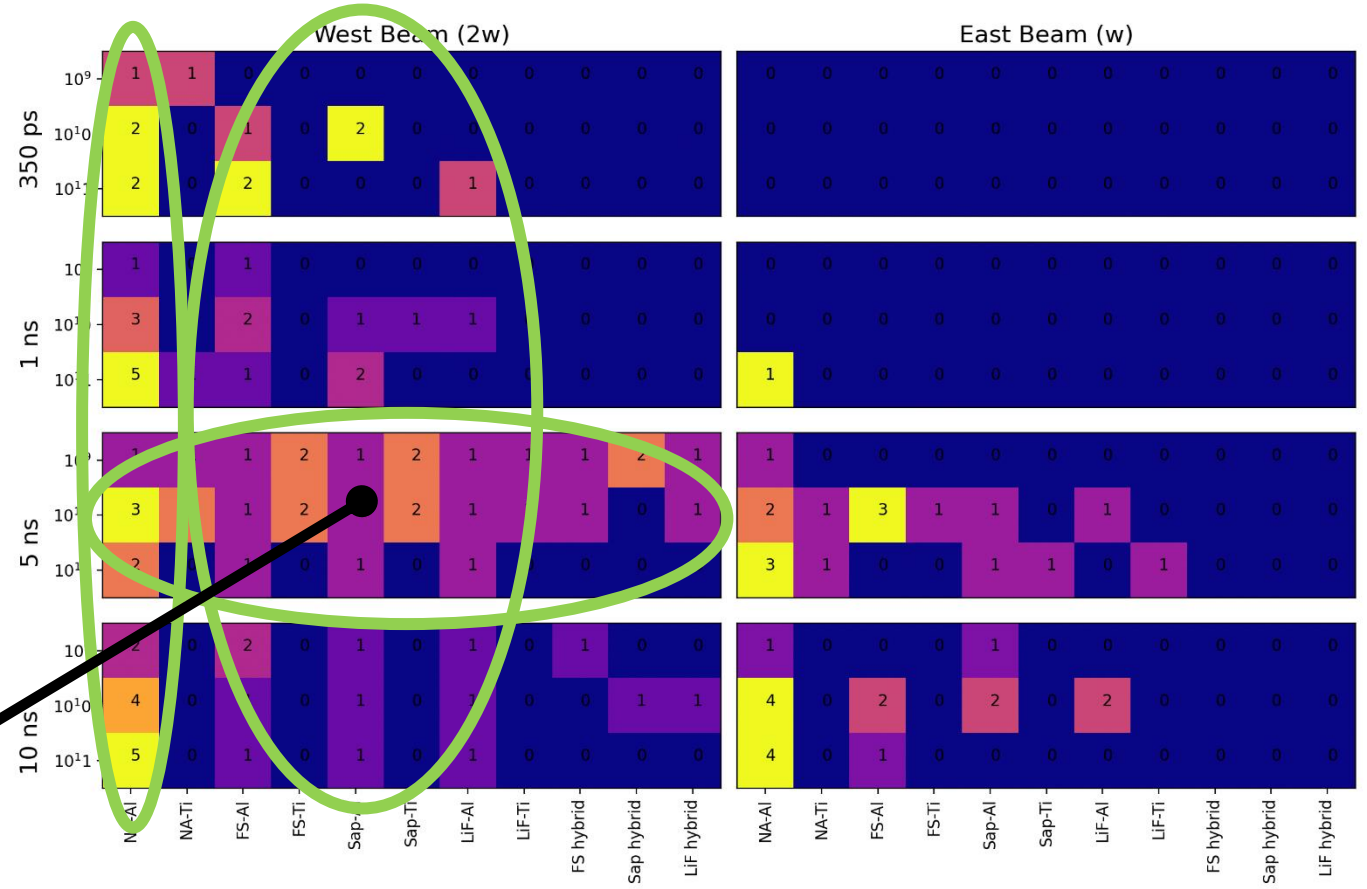


Since ablation can depend on many parameters, it can be challenging to connect results from different studies which may not overlap in experimental conditions

Prepared by LLNL under Contract DE-AC52-07NA27344.

We likely have enough shots to cover variation over several parameters

- ***5 ns green vs. tamper materials and intensity***
- Bare Al for variation in pulse duration and intensity
- Tampers vs intensity and pulse duration



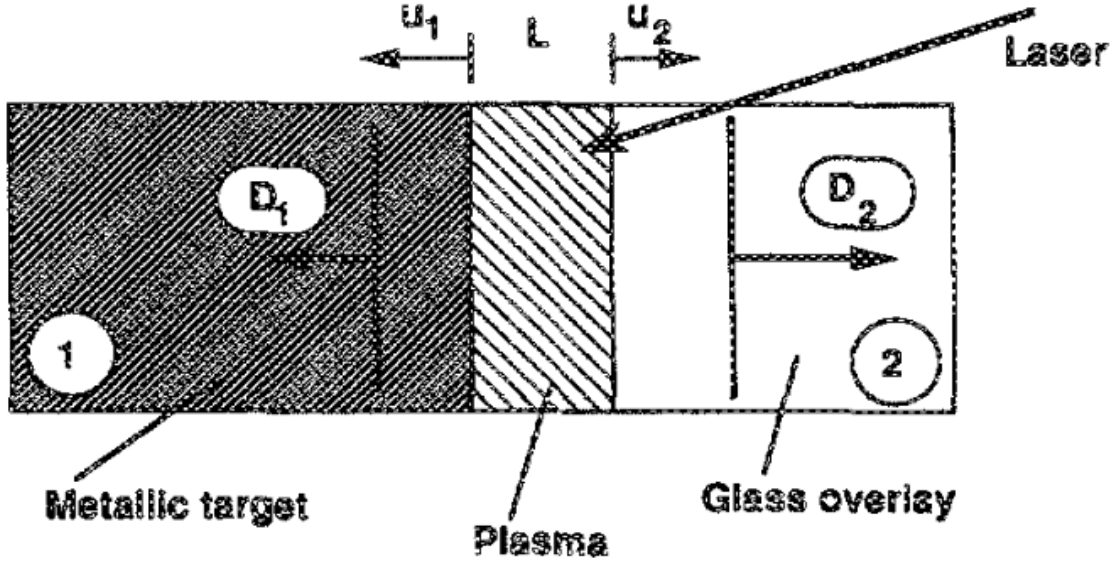
The data of this talk

We planned on 60-100 shots and took >130! 11-12 shots per day at the end of the campaign.

Prepared by LLNL under Contract DE-AC52-07NA27344.

Tamped ablators generate more pressure because the ablation plasma is confined

The ablation pressure increases with shock impedance and intensity, assuming light can reach the ablation plane



$$P(kbars) = 0.1\left(\frac{\alpha}{2\alpha+3}\right)^{1/2} Z^{1/2} I^{1/2}$$

$$Z\left(\frac{g}{cm^2 s}\right) = \frac{2}{\frac{1}{Z_{ablator}} + \frac{1}{Z_{tamper}}}$$

$$I\left(\frac{GW}{cm^2}\right)$$

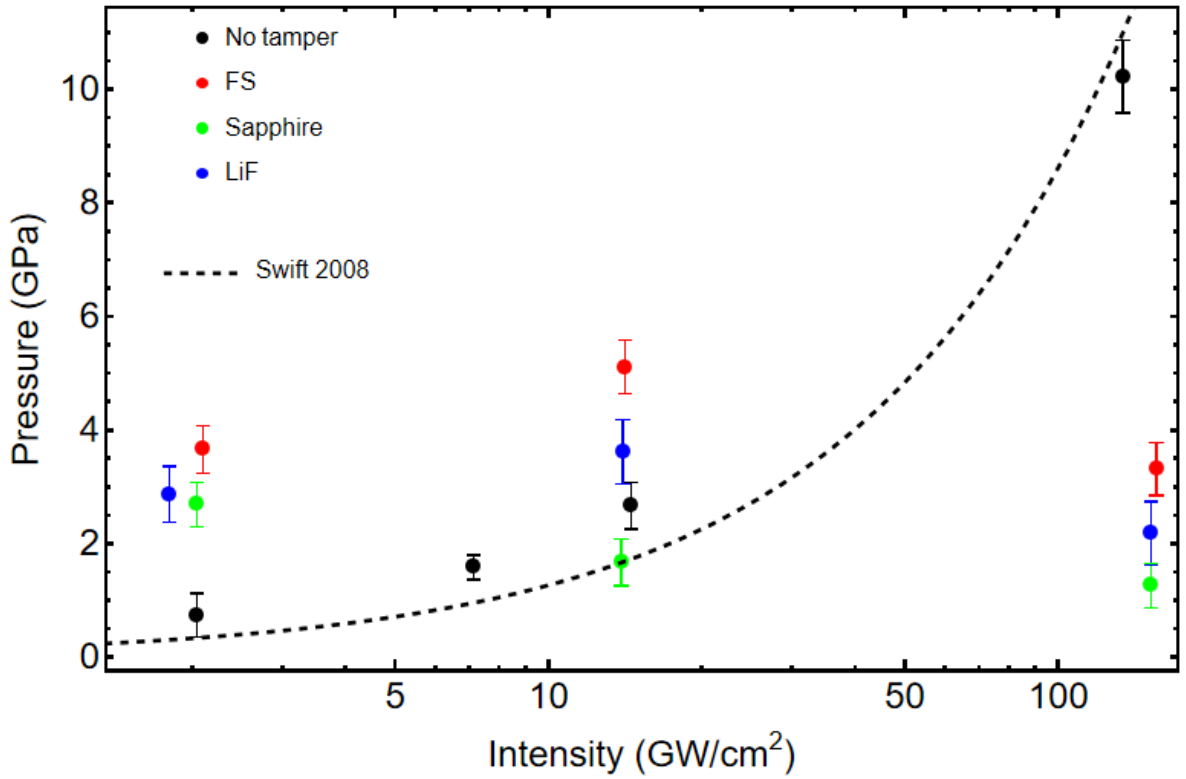
Fabbro, R.; Fournier, J.; Ballard, P.; Devaux, D.; Virmont, J. Physical Study of Laser-produced Plasma in Confined Geometry. *Journal of Applied Physics* **1990**, *68* (2), 775–784.

α is a unitless constant that specifies the fraction of thermal energy in the plasma

Prepared by LLNL under Contract DE-AC52-07NA27344.

A clear difference in pressure with tamped and untamped targets was observed

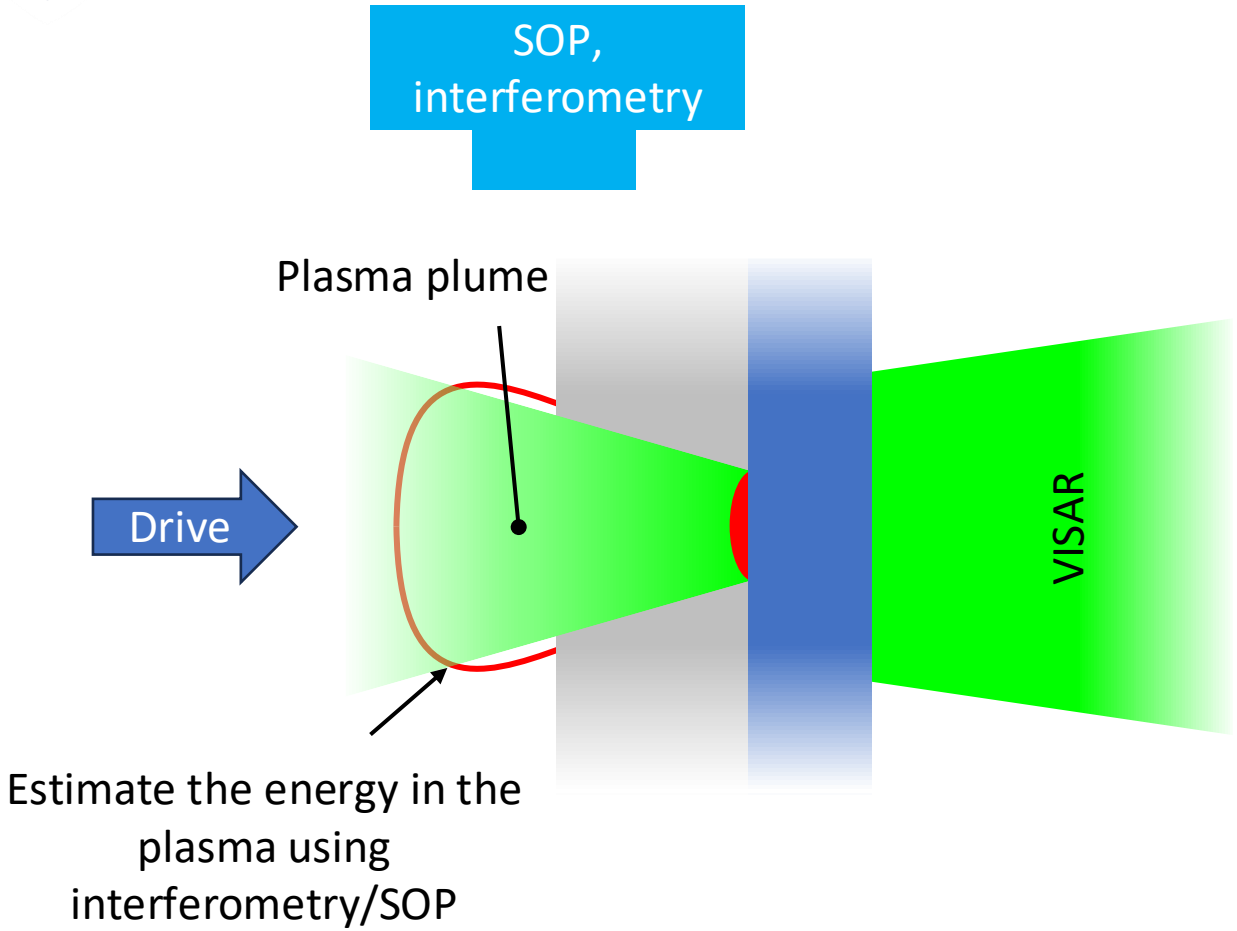
Tamped ablation generates higher pressure than untamped, until the intensity is high enough to be absorbed in the tamper



- At intensities <10^{10} W/cm^2, the pressure is highest for FS tamped Al targets, then LiF and Sapphire tamped Al targets, and finally bare Al foil targets.
- As the intensity approaches 10^{11} W/cm^2, the pressure in tamped samples drops below that in bare Al foil
- LiF and sapphire tamped Al targets obtain lower pressure?
- LiF and sapphire tamped Al targets also seem to fall off with intensity more than FS

Prepared by LLNL under Contract DE-AC52-07NA27344.

We want to quantify changes in the ablation pressure due to upstream absorption in the tamper

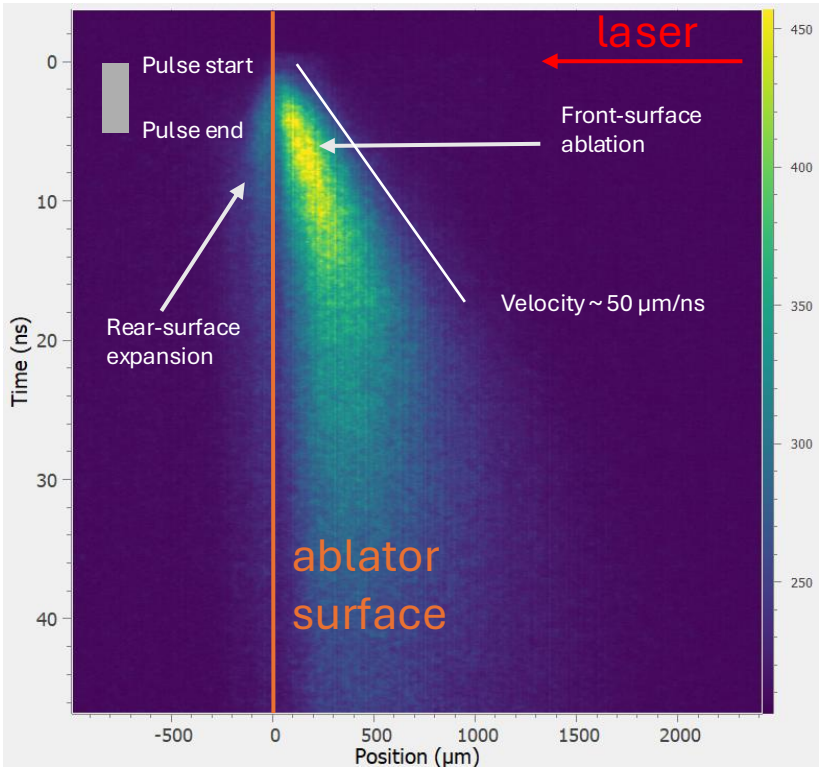


Can we subtract the energy in the plasma plume from the drive energy to obtain the pressure in the ablator?

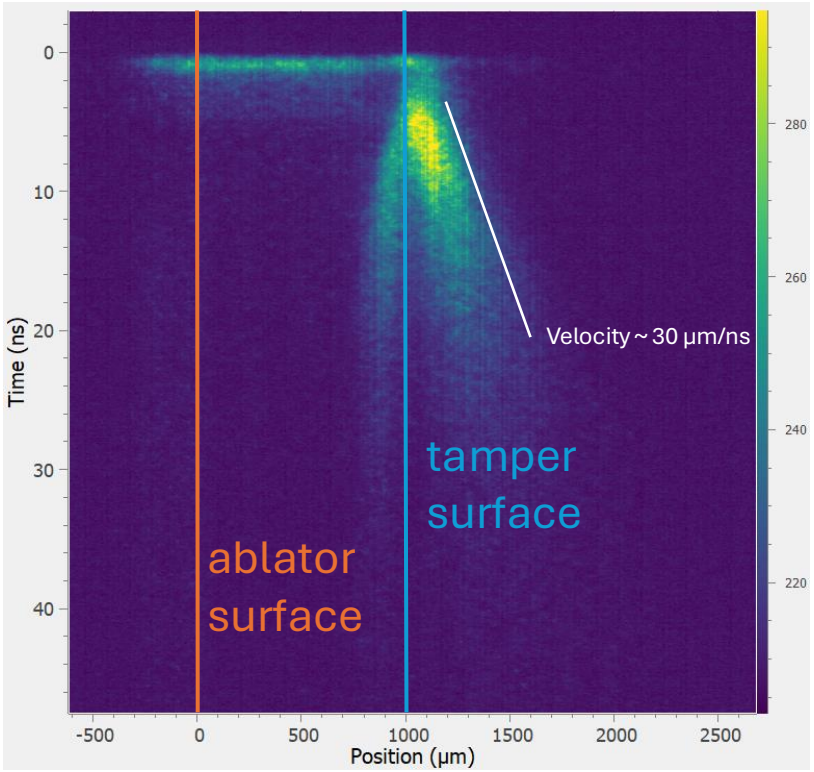
Prepared by LLNL under Contract DE-AC52-07NA27344.

The better performance of FS+Al at 10^9 W/cm^2 correlates with less optical emission from the tamper

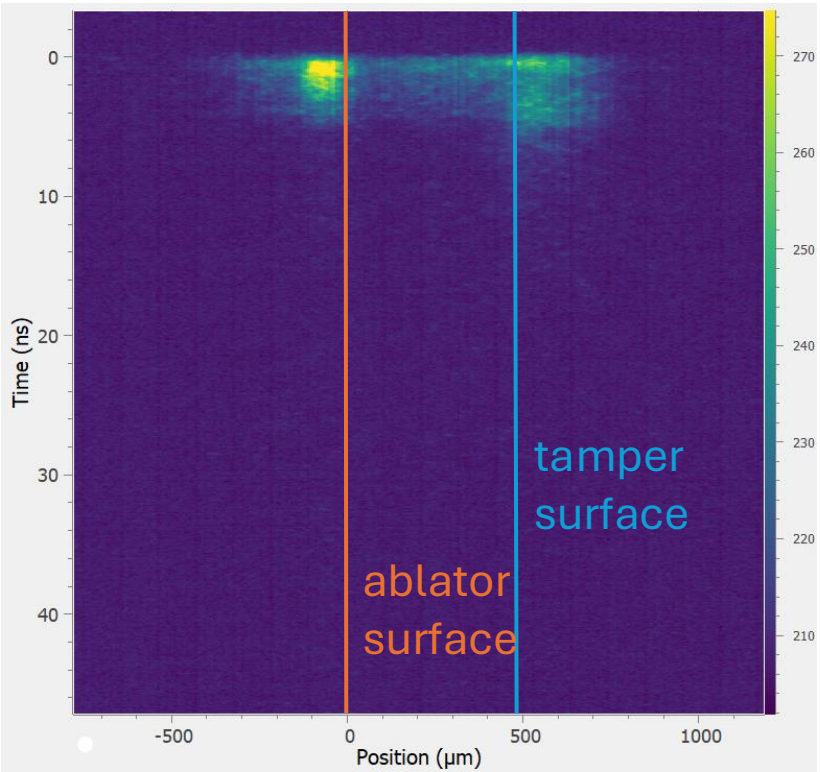
SOP for 5 ns pulse duration, 2x10^9 W/cm^2@2ω



Bare Al



Sapphire + Al



FS + Al

The sapphire tamper absorbs more laser light than the FS tamper, which likely explains the higher pressure observed with FS+Al at this intensity.

Prepared by LLNL under Contract DE-AC52-07NA27344.

Interferometry shows significant ablation of tamper surfaces at intensity greater than 10^{10} W/cm^2

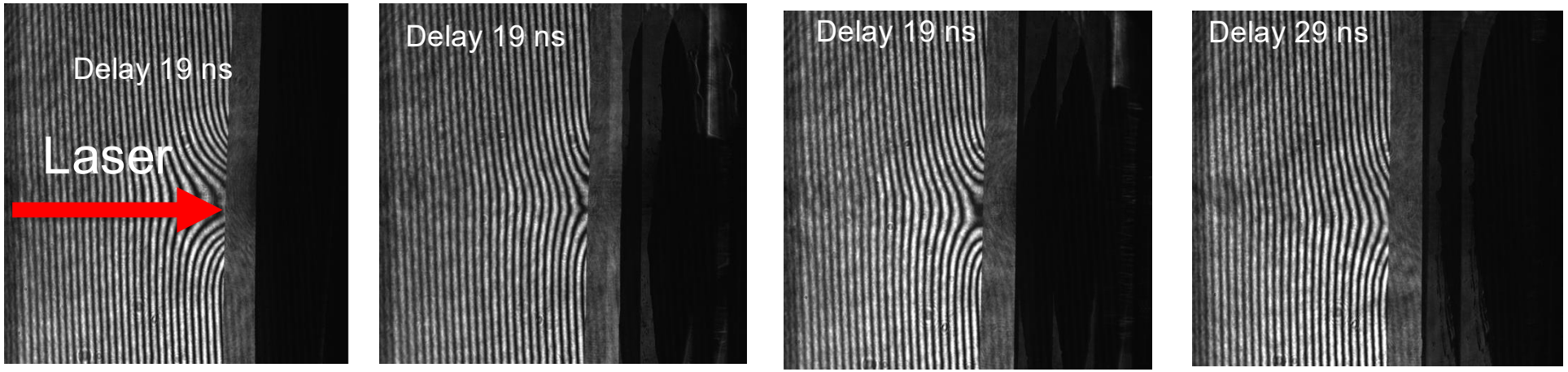
Interferometry gives detailed information about density

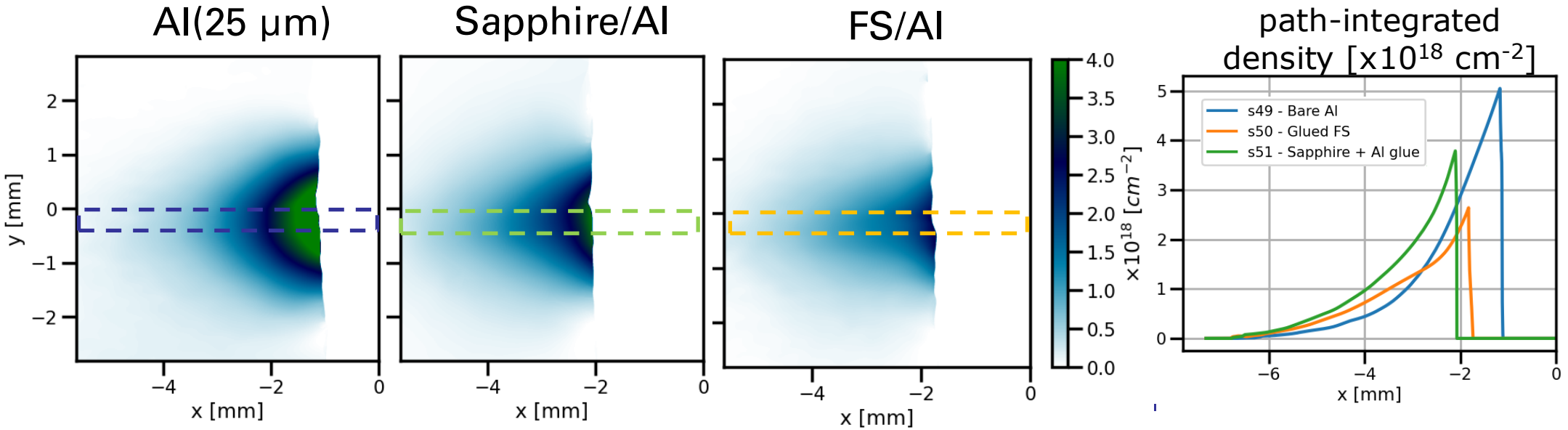
Pulse Duration 5 ns

Laser Energy ~2.3 J

Laser Intensity

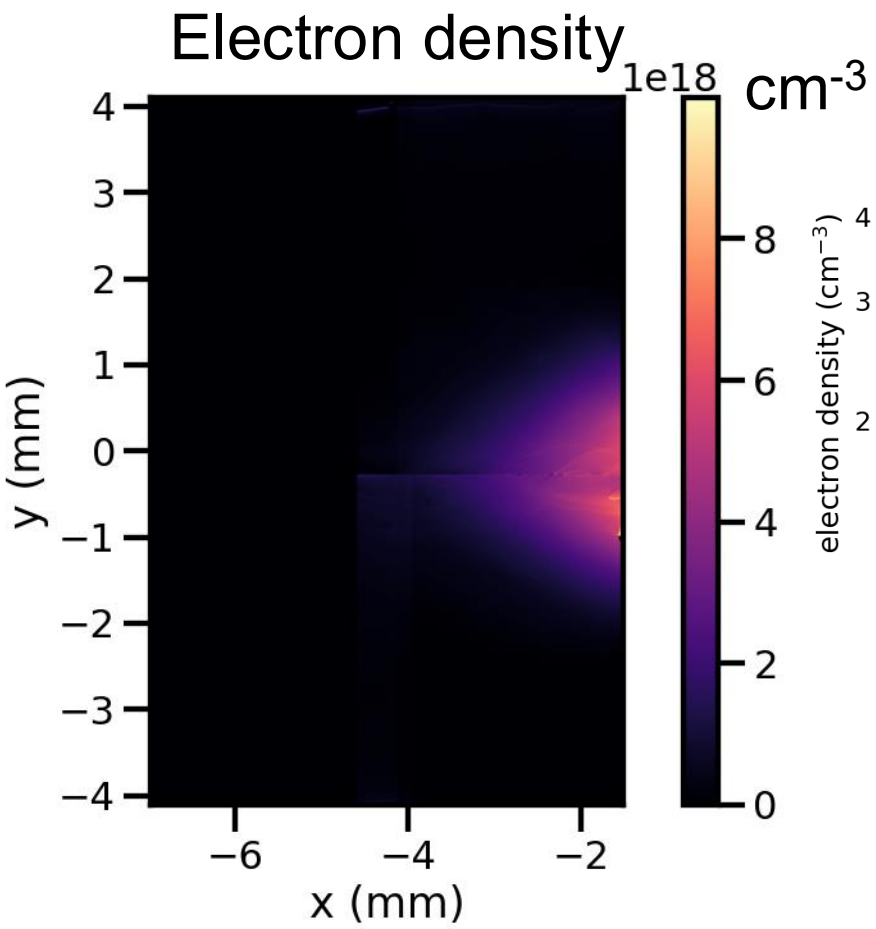
1.4 x10^{10} W cm^{-2}

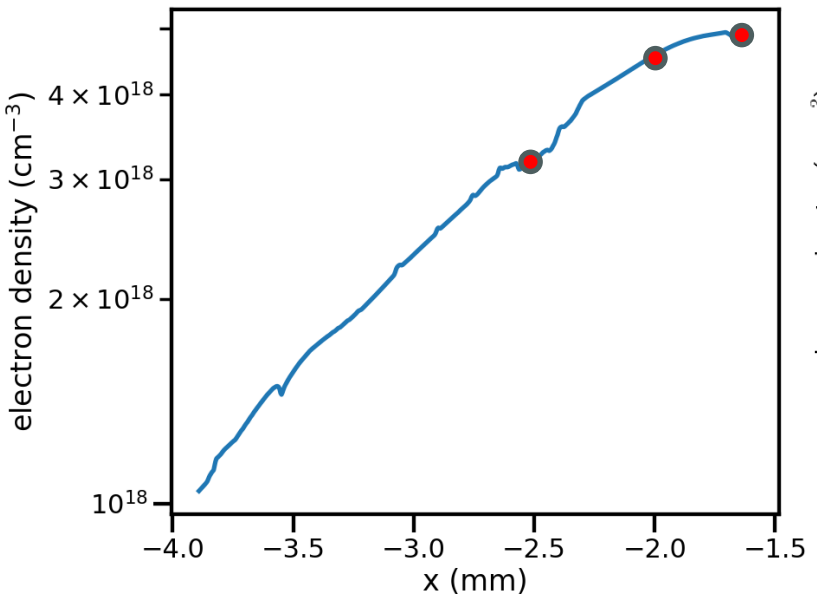


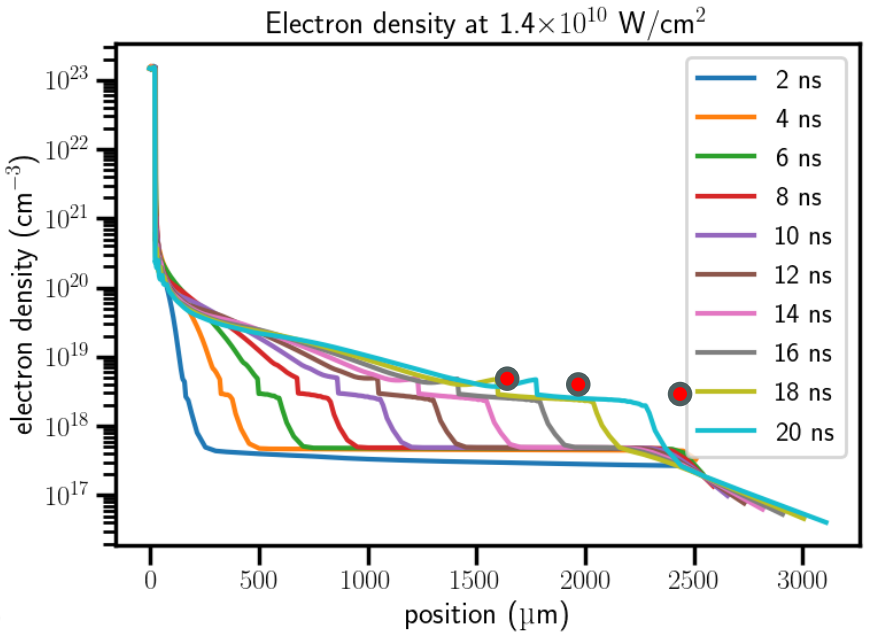


Prepared by LLNL under Contract DE-AC52-07NA27344.

The plume electron density for bare Al at $1.4*10^{10}$ W/cm^2 is consistent with expectations from HELIOS simulations



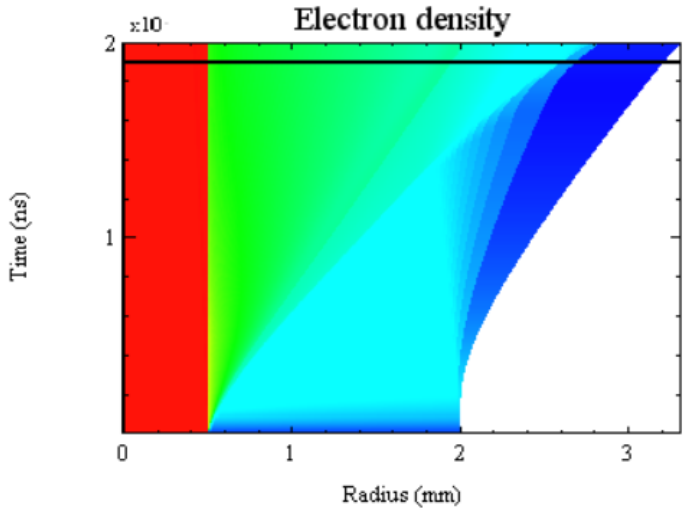


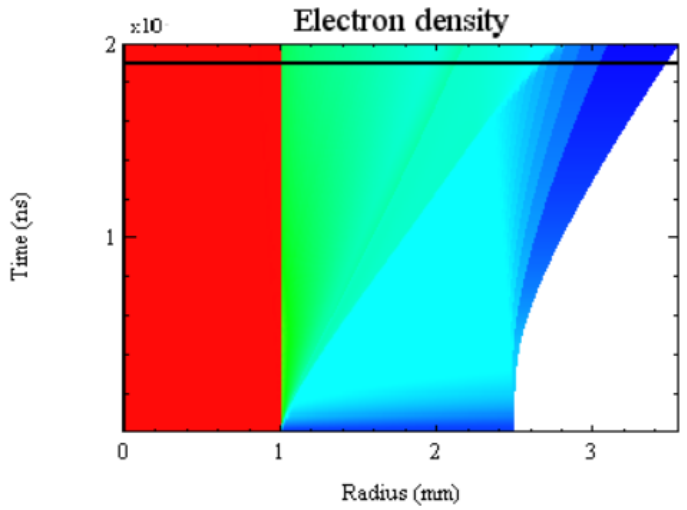


We obtain good agreement for bare Al.

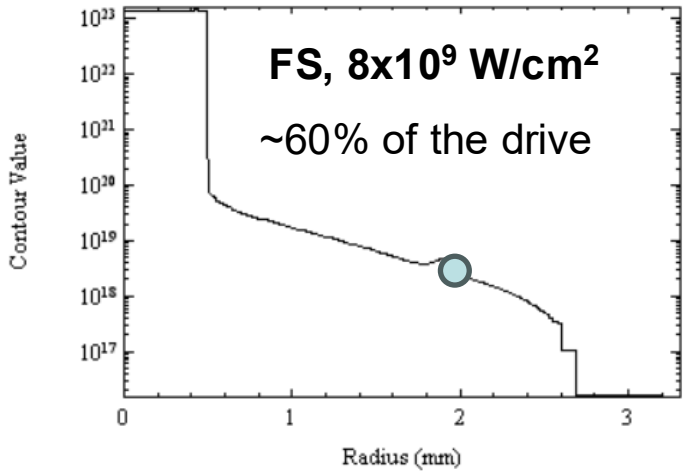
Prepared by LLNL under Contract DE-AC52-07NA27344.

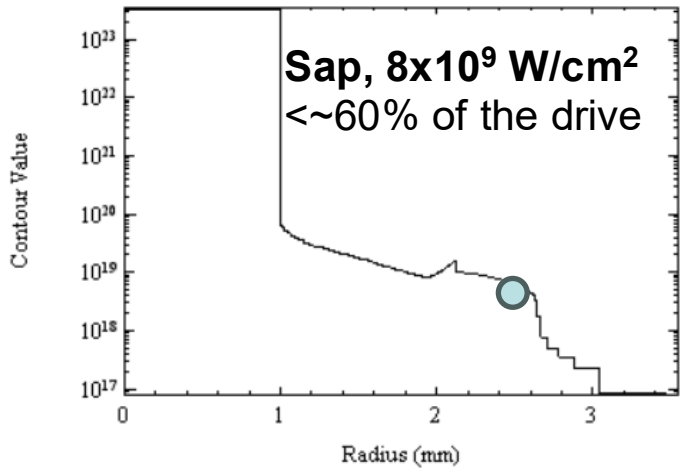
We match the measured plume electron density to reduced intensity simulations to obtain the absorbed energy

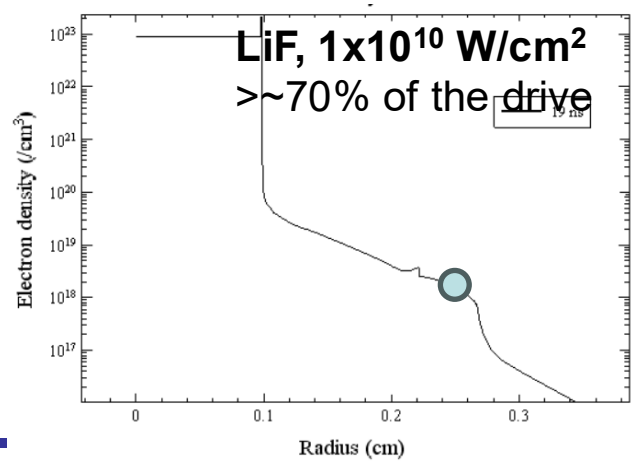




To match interferometry results, the absorption in the tampers are around 60% of what it is for bare Al, with a marginally reduced absorption for Sap compared to FS, and noticeably higher absorption for LiF

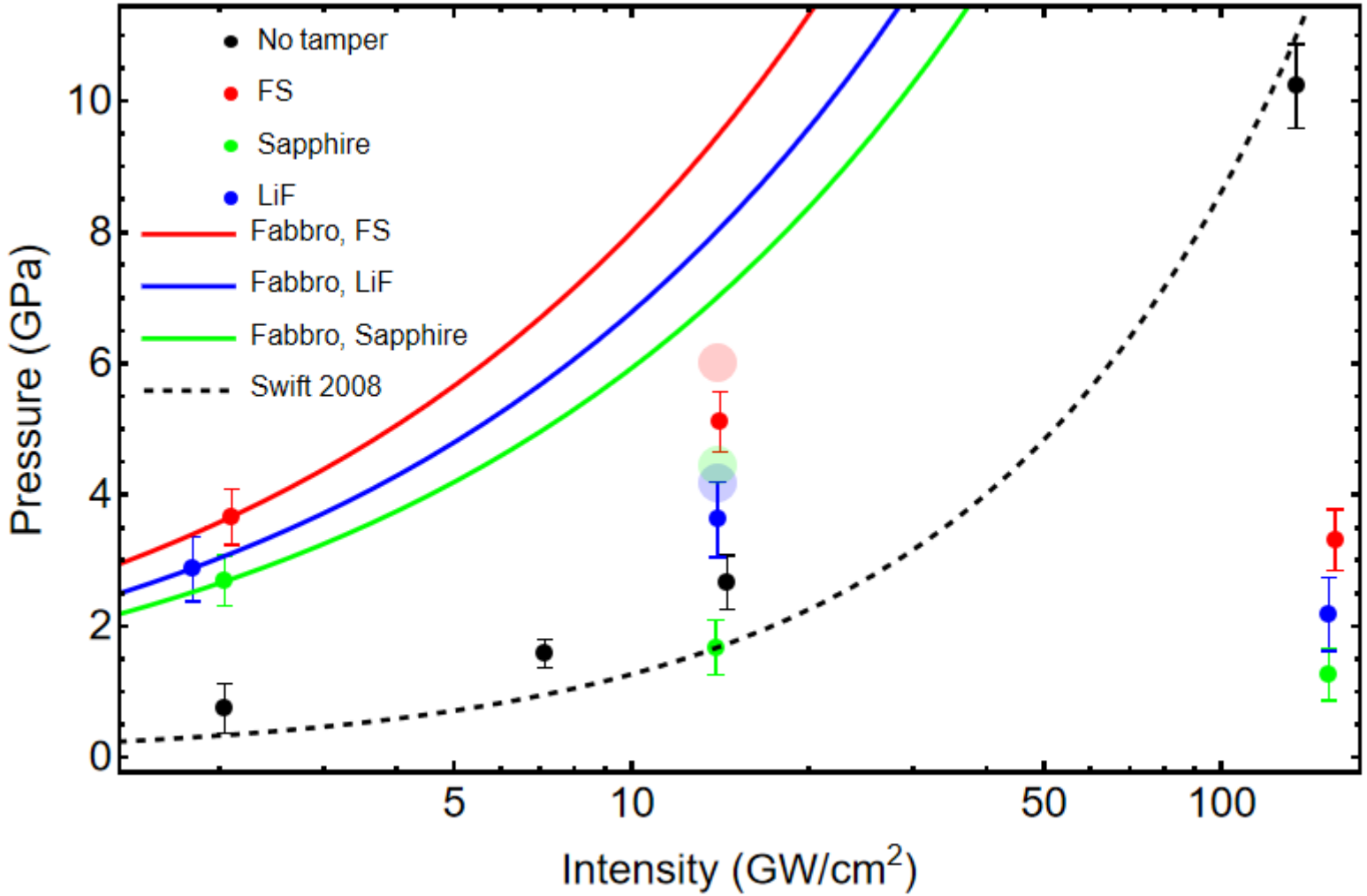






Prepared by LLNL under Contract DE-AC52-07NA27344.

A clear difference in shock velocities with tamped and untamped targets was observed



The estimated pressure (light colored disks) at ~10^{10} W/cm^2 are within 12% of the measured pressure for LiF and FS, but significantly off for sapphire.

Generally, we expect to overestimate the pressure, since the ablation plume may not be the only source of energy loss.

Prepared by LLNL under Contract DE-AC52-07NA27344.

Conclusions and TBD

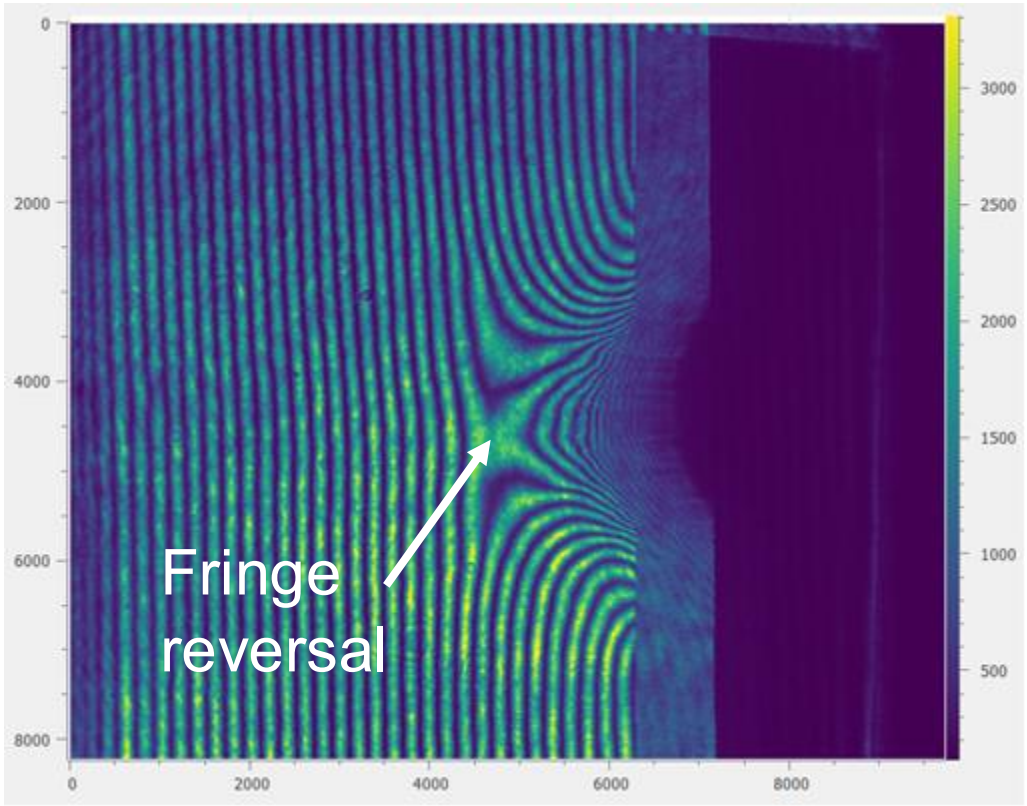
- Simulations and interferometry analysis on higher intensity shots is ongoing
- Better characterization of the UV absorption of tampers
- Estimate the nonlinear bulk optical absorption
- Based on our analysis so far, the drop in pressure can be mostly accounted for by energy loss from an upstream tamper ablation plume
- Sapphire results are not fully explained
- We expect to have this submitted for publication soon and move on to analyzing other shots from this campaign

Thanks to the staff at Janus/JLF for making this experiment possible!

We're currently working on remaining interferometry analysis and simulations

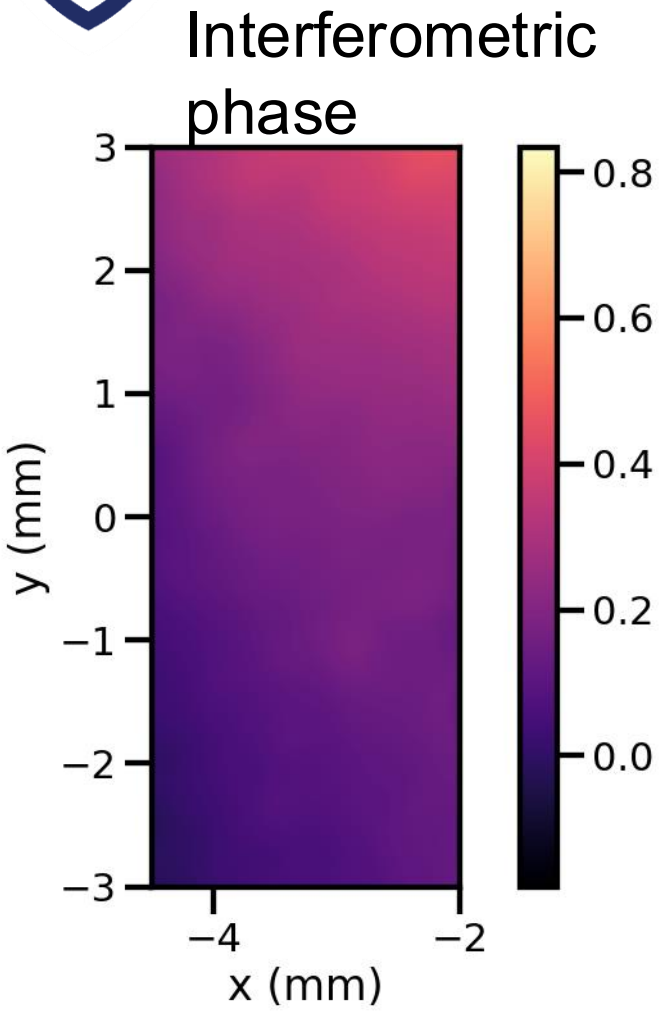
- Correlate absorbed energy with pressure
- Analysis for fringe reversed data
- LiF plasma expansion EOS
- LiF surface plasma simulations for comparisons to interferometry
- Tamp/ablator internal simulations for pressure
  - Since we can use Fabbro expressions for these, I tend to see these as more optional

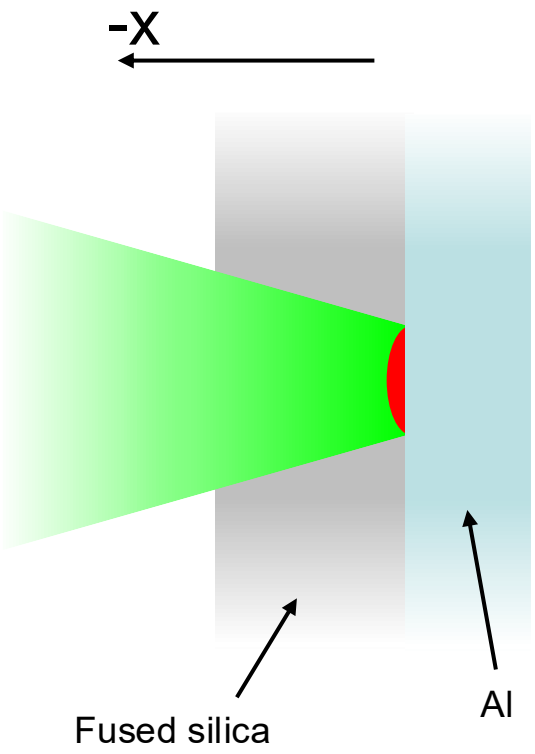
10^{11} W/cm^2 Al



Prepared by LLNL under Contract DE-AC52-07NA27344.

The plume induced interferometric phase from fused silica+Al at $2*10^9$ W/cm^2 is negligible





In this case, we observe a negligible plasma plume.

This is consistent with our expectations for the absorption on the front FS surface.

Prepared by LLNL under Contract DE-AC52-07NA27344.

The better performance of FS+Al at 10^9 W/cm^2 correlates with less optical emission from the tamper

- The sapphire tamper absorbs more laser light than the FS tamper, which explains the higher pressure observed with FS+Al at this intensity.
- This trend does not seem to hold at higher intensities, where the relationship between intensity and deposited energy may depend on the tamper material