Exceptional service in the national interest

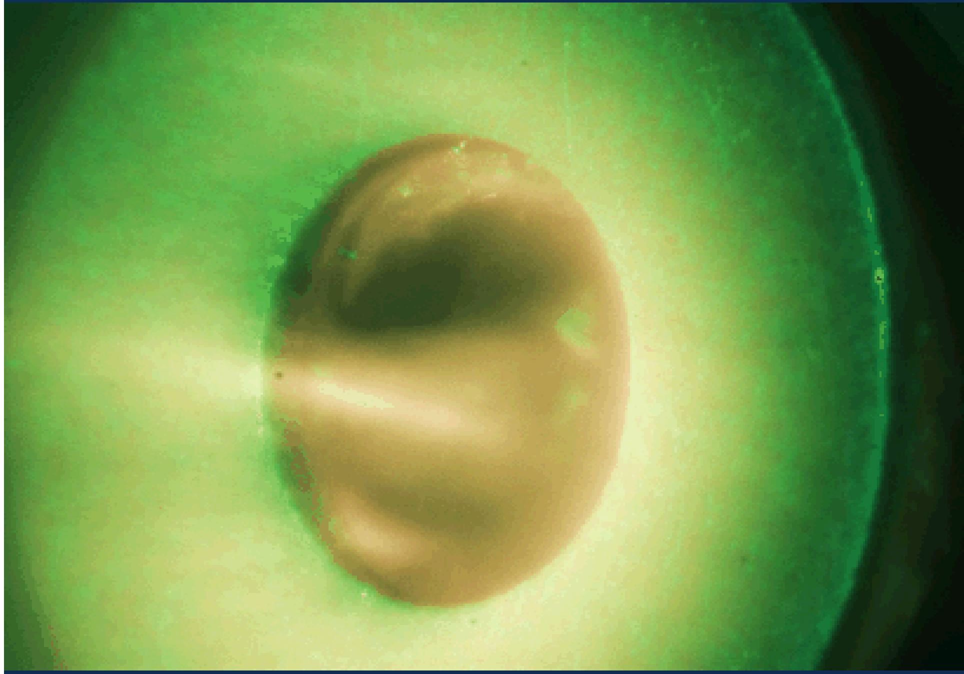
Sandia National Laboratories

SAND2014-19658C

Adaptive Beam Smoothing with Plasma-Pinholes for Laser-Entrance-Hole Transmission Studies

The American Physical Society's
56th Division of Plasma Physics Meeting
New Orleans, October 28, 2014

GO4.00011



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C. Jennings, M.W. Kimmel, S.M. Lewis*,
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A.B. Sefkow, J.E. Shores, D.B. Sinars,
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SAND2014-.

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Motivation: MagLIF

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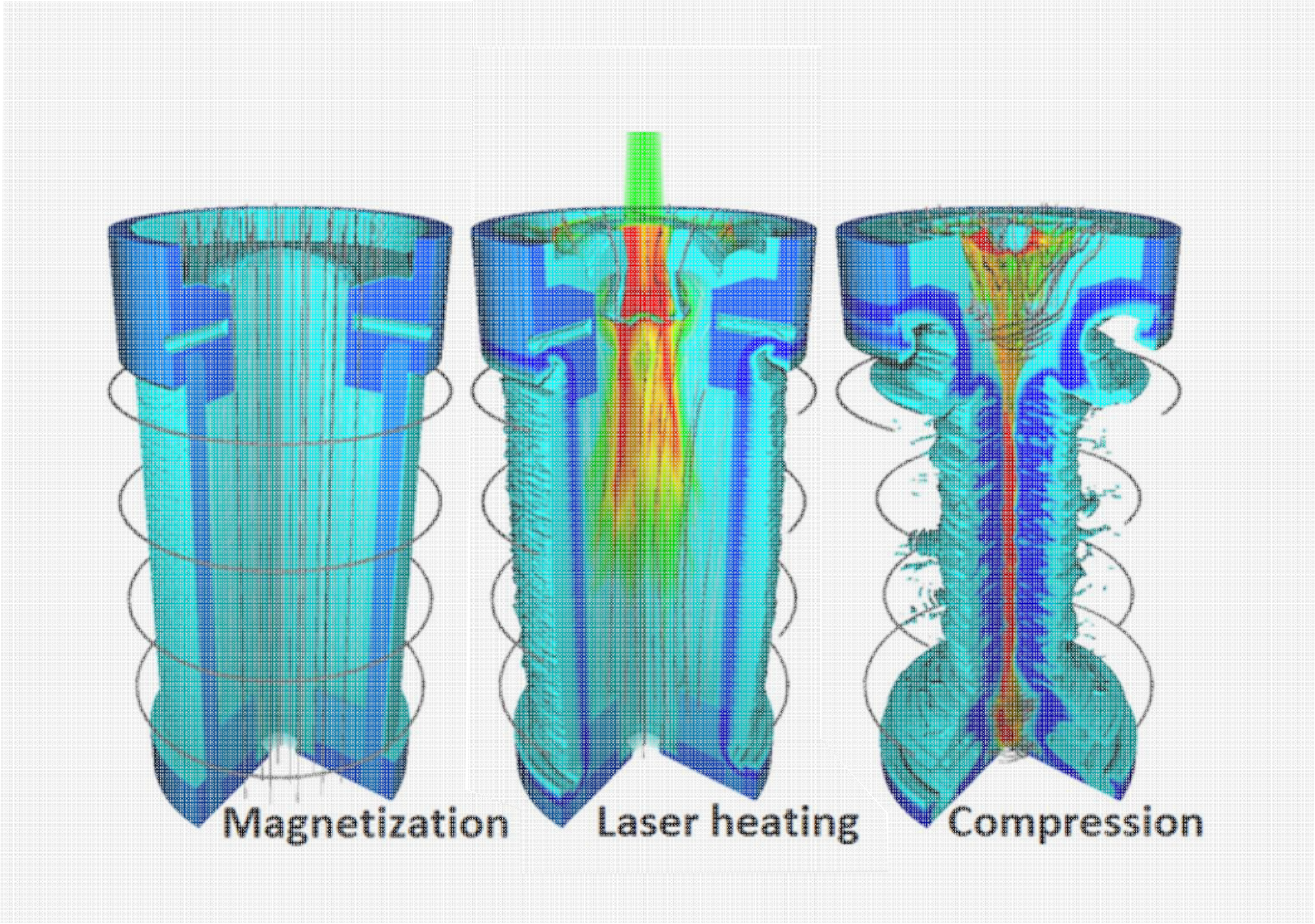
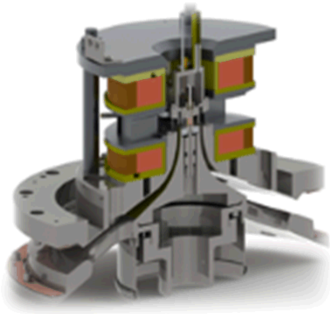
Preheat for Magnetized Liner Inertial Fusion



S.A. Slutz et al.:
Phys. Plasmas 17, 056303 (2010)

This session:

A.B. Sefkow: GO4.00005
S.A. Slutz: GO4.00007



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Penetrating the Laser-Entrance-Hole (LEH)

Considerations for efficient laser coupling

The Foil Aspect:

- High intensity improves ease of penetration.
- Thin LEH windows absorb less laser energy.
- Defocused laser beam exhibits strong hot spot features.
- SBS/SRS get worrisome for 'large filaments' (hot spots).

The Gas Aspect:

- Low intensity couples better into fuel.
- High density absorbs laser better, needs thicker LEH window.

The Computational Aspect:

- Experiments are guided by simulations.
- Beams with highly irregular features are hard or impossible to model.

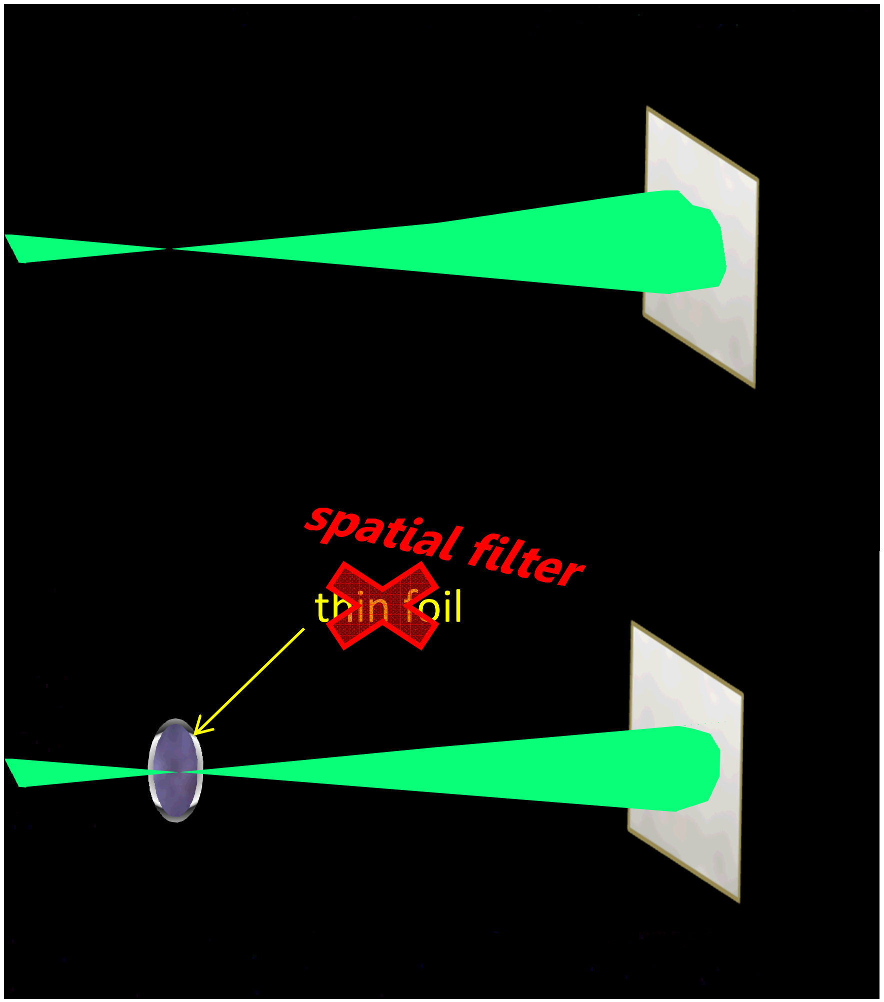
SMOOTH LASER BEAM!

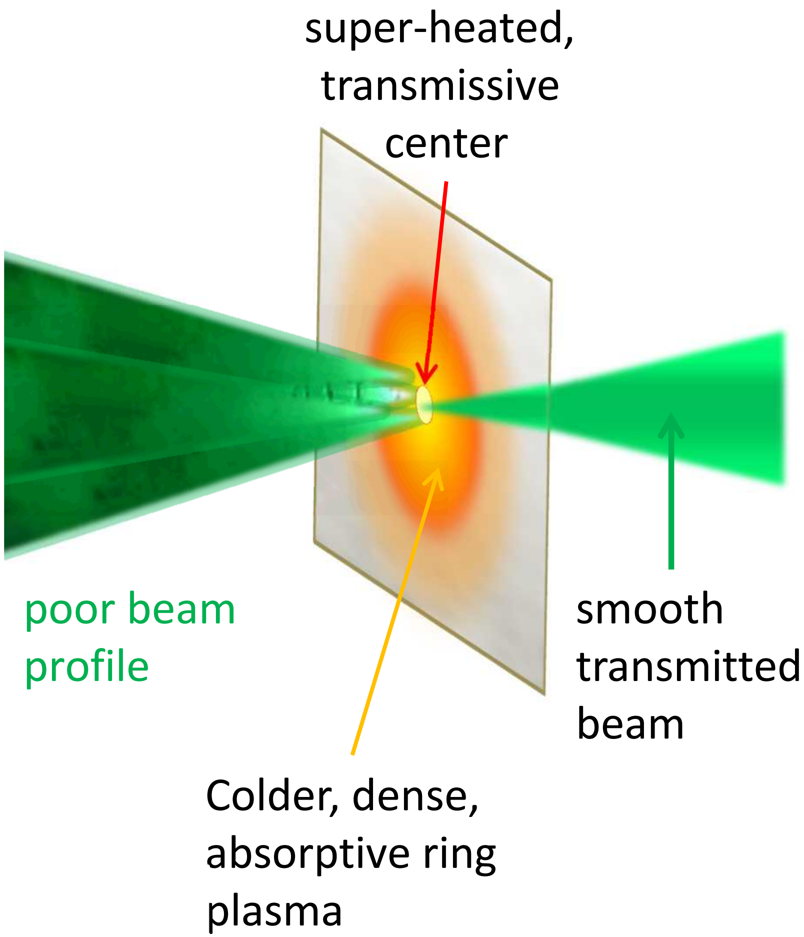
SPOT SIZE Compromise!

Window Thickness Compromise

Adaptive Smoothing

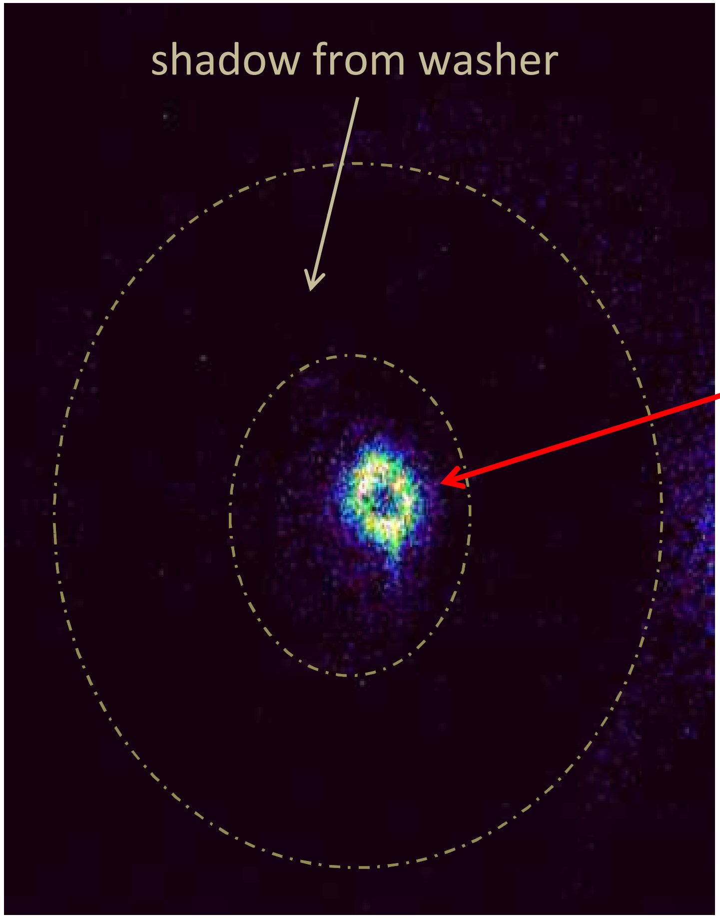
Smoothing a Laser Beam with Selectable Spot Size





Smoothing with 0.5 µm Foil

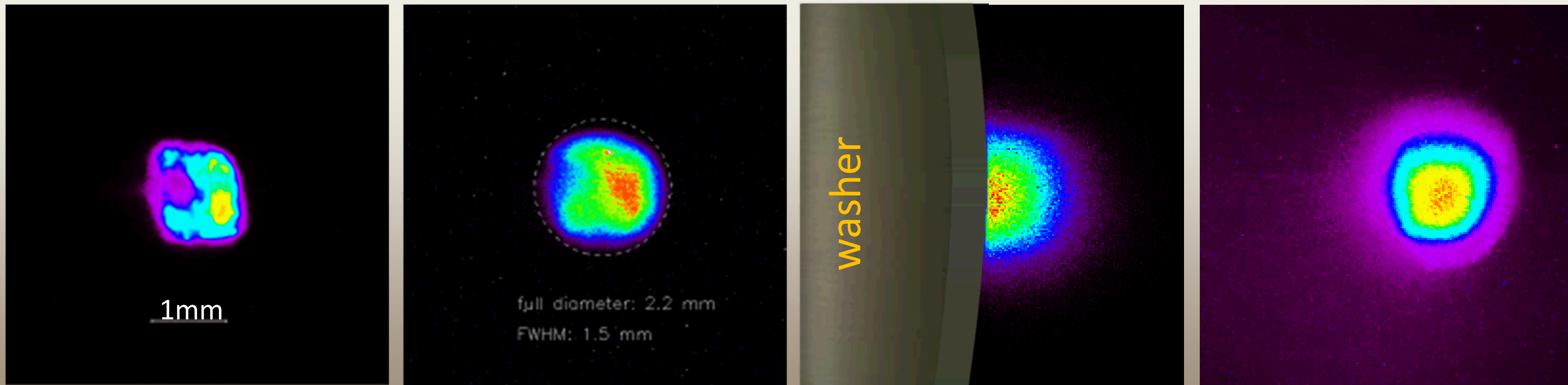
Pinhole Evidence



Donut-shaped plasma ("spatial filter pinhole")

Adaptive Smoothing

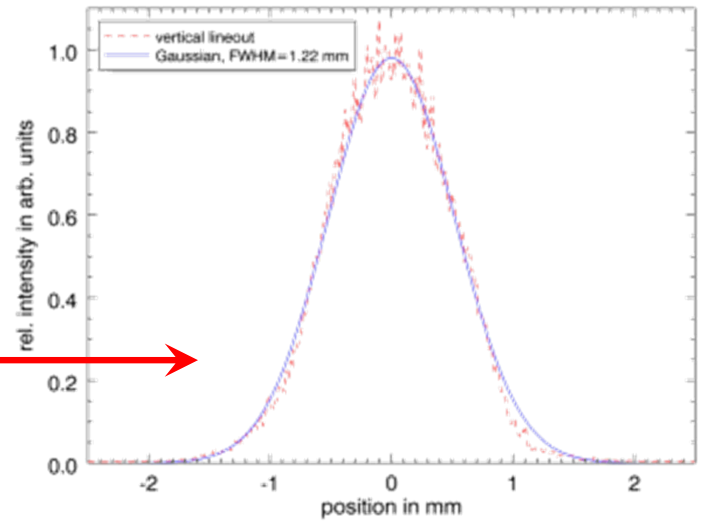
X-ray Pinhole Camera Images 12 mm Behind Focus



no smoother | 100 nm parylene | 250 nm parylene | 500 nm mylar

Parylene-N	Pre-pulse transmission	Main pulse transmission
0 nm	100%	100%
100 nm	90%	>90%
250 nm	50%	>80%
500 nm*	9%	>80%

*mylar



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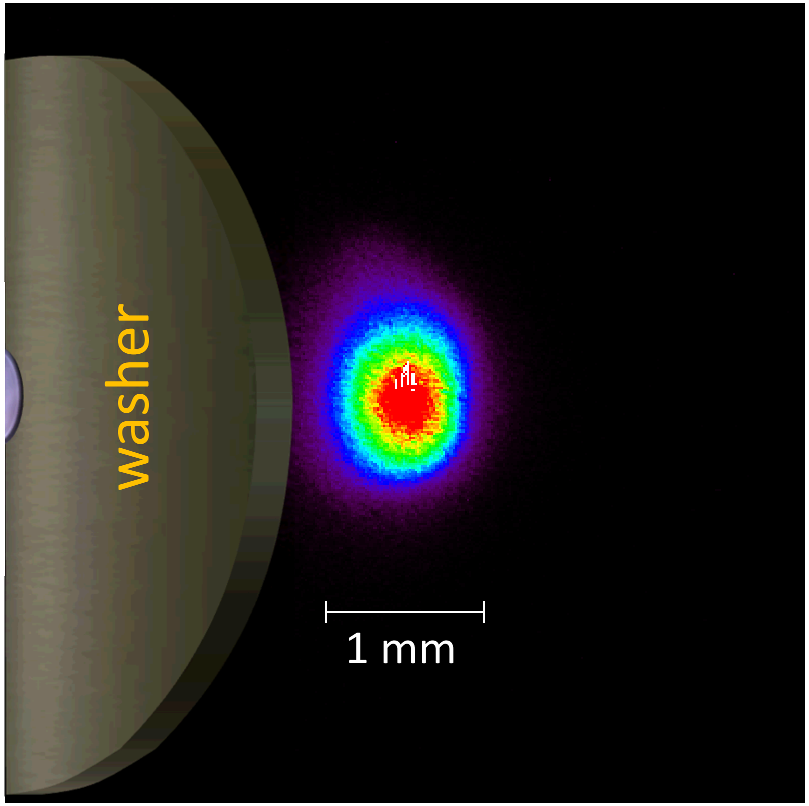
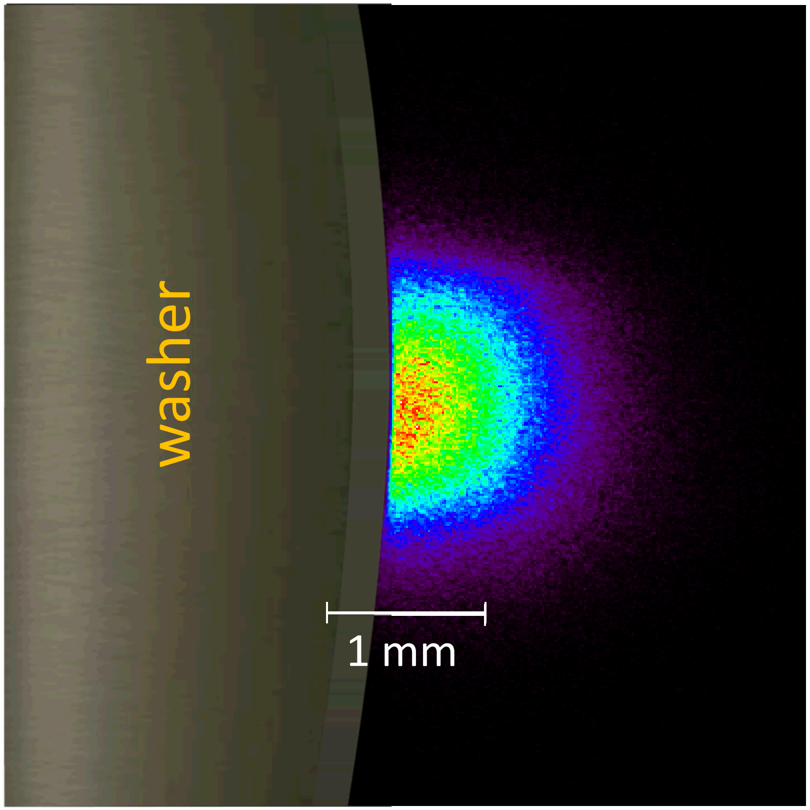
Adaptive Smoothing

Distance Variations (250 nm Parylene-N)



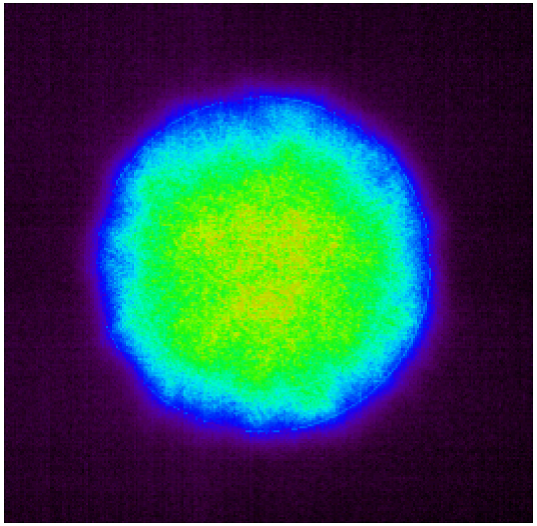
Screen 4.5 mm from smoothing foil



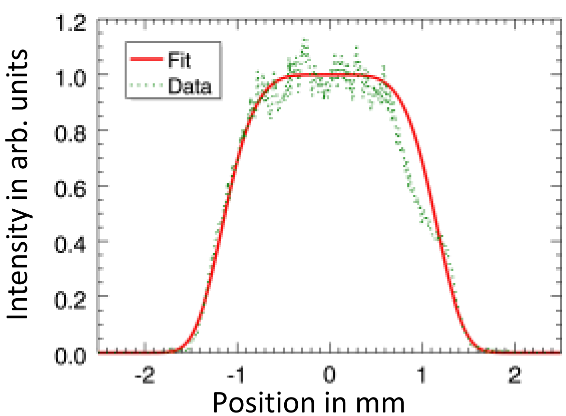
Screen 14 mm from smoothing foil

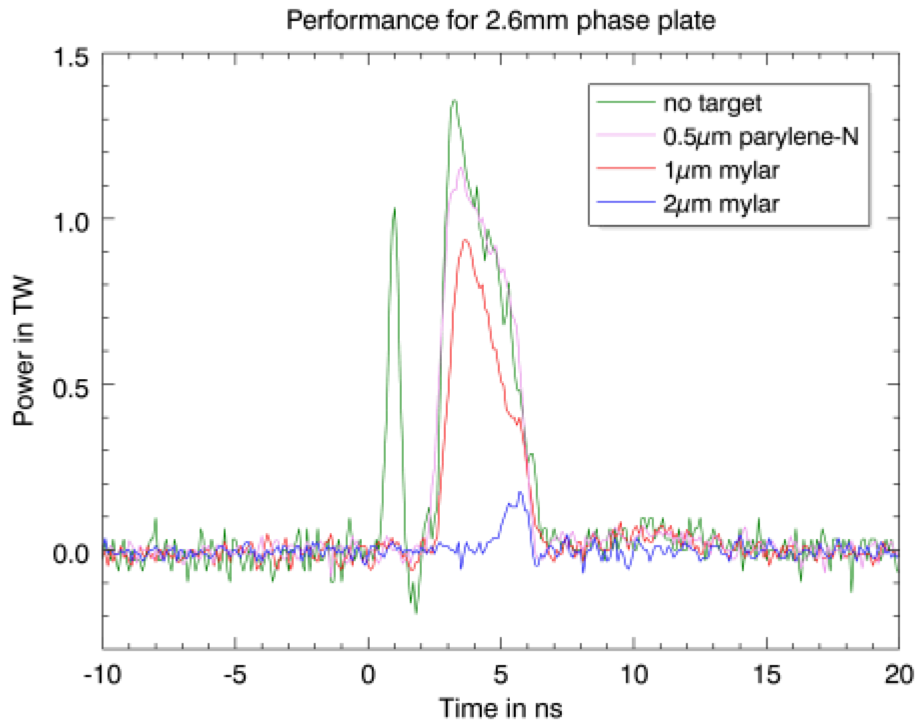
Ideal Case: Phase Plate

Continuous Phase Plate with r=1.3 mm



CPP:
Laser spot measurements:
95% of energy within r=1.3 mm
FWHM = 1.94mm
5[th] order SG



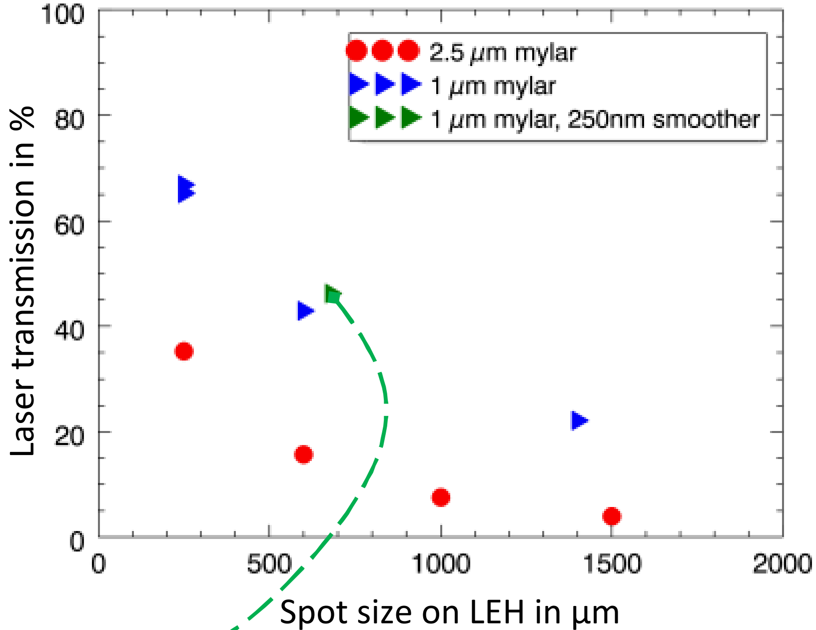


Supergauss of order ‘n’: $F(x) = EXP\left\{-\sqrt{\left(\frac{x-x0}{\sigma}\right)^{2n}}/2\right\}$

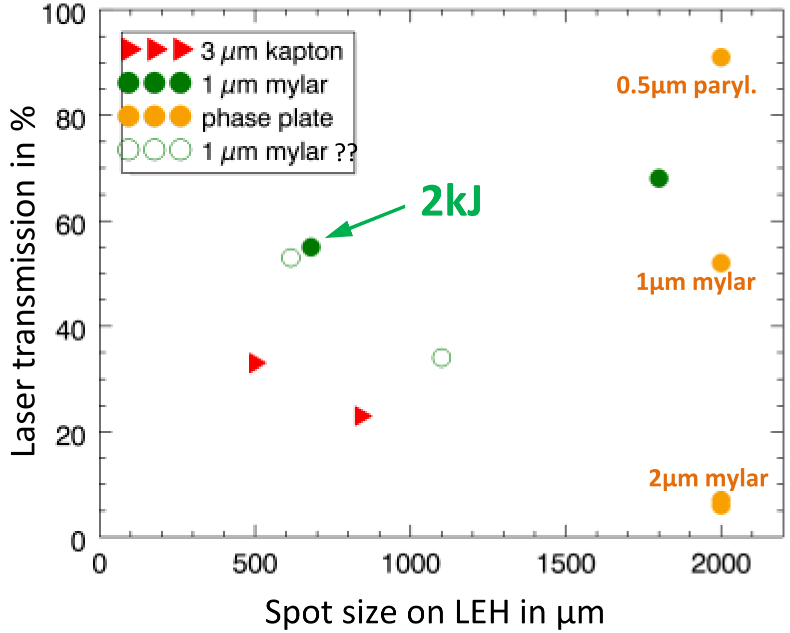
Comparison Graphs

Summary of Results

2 kJ laser pulse, no smoothing



4 kJ laser pulse, smoothing



Result was reproduced with HYDRA by A.B. Sefkow using experimental observation of smoothing foil output!!

SUMMARY

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- **Thin polymer foils (< 250 nm) in best focus can efficiently smooth a transmitted laser beam with little energy loss.**
- **Smoothing foils can produce a continuously variable spot size.**
- **Smoothing foils are affordable (~$50 per shot).**
- **The plasma-pinhole smoothing process should eliminate all small scale modulations.**
- Minimum spot size for smoothing foils in not yet determined.
- **Smoothing foils are less likely to have a featureless ‘flat top’ profile.**
- **Phase Plates (RPP, CPP, DPP) are less flexible but have steeper slopes and ‘flatter top’: Less clipping and more evenly distributed intensity.**
- **Phase plates don’t require target modifications.**

GOOD

Unknown

Not so good

EXTRAS

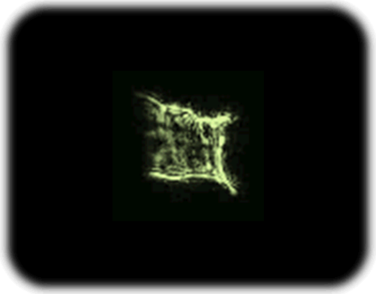
Heating Magnetized Fuel

Where we started

Z-Beamlet (ZBL) prior to MagLIF campaigns:

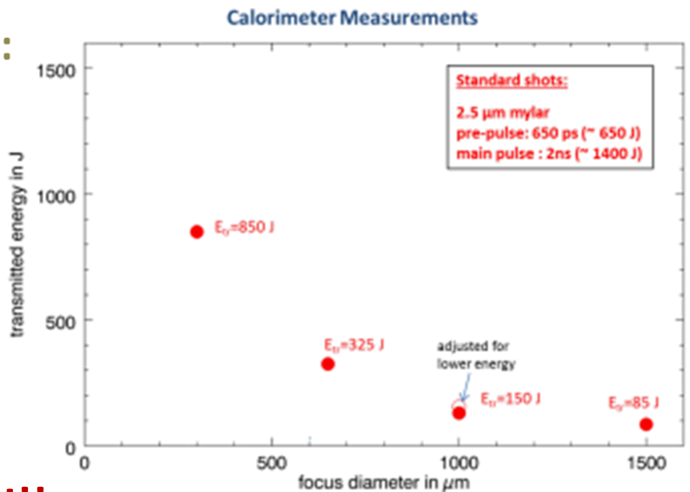
<u>Operation with emphasis on Backlighting</u>

- 1ns pulse width
- 1kJ pulse energy (plus pre-pulse of ~ 0.5 ns / 350 J)
- Multi-Frame option introduced some optics with poor wave-front transmission.
- No beam smoothing techniques needed.
- No SBS suppression needed (i.e. phase modulation/high bandwidth)



ZBL for early MagLIF design and first campaign (2013):

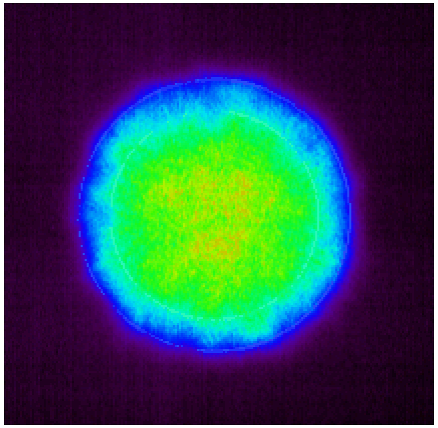
- 2.5 ns
- 2.5 kJ pulse energy
- LEH with 3.5µm polyimide window
- Beam defocused to ~600µm diameter

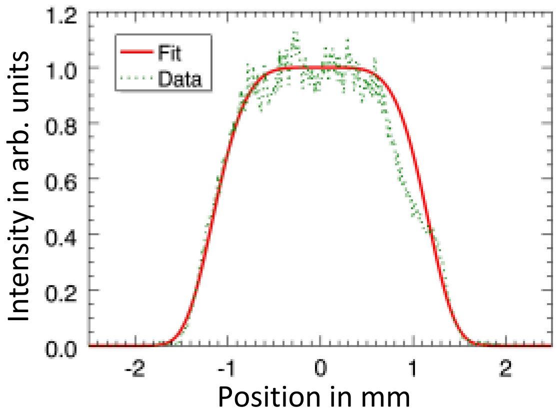


Lesson learned: Experiment does not reproduce LASNEX and HYDRA predictions for LEH transmission. LPI!!

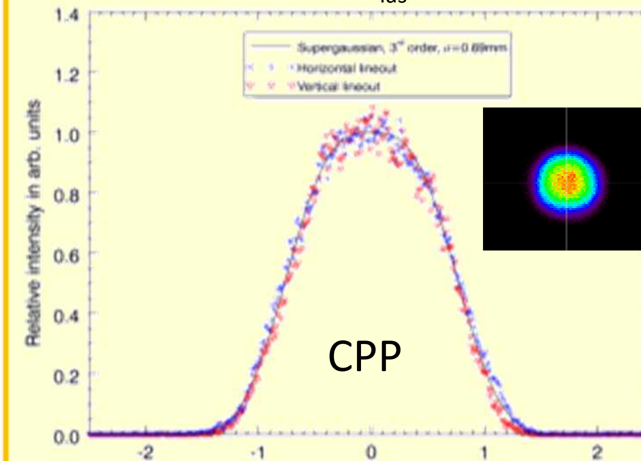
Comparison: Phase Plate

Continuous Phase Plate with r=1.3 mm

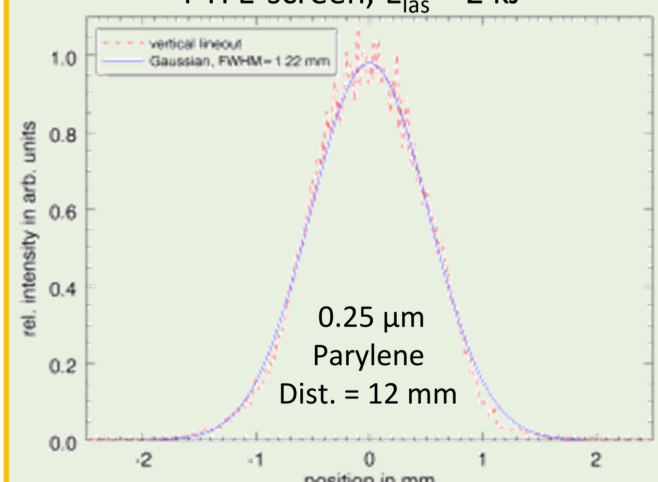




Ti-screen, E_{las} = 4 kJ



PTFE-screen, E_{las} = 2 kJ



CPP:
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5^{th} order SG

X-ray screen image
CPP
3^{rd} order SG

X-ray screen image
Smoothing foil
1^{st} order SG (Gauss)

Supergauss of order ‘n’: $F(x) = EXP\left\{-\sqrt{\left(\frac{x-x0}{\sigma}\right)^{2n}}/2\right\}$