Laser-Fuel Coupling Studies for MagLIF with Z-Beamlet

SAND2015-7959C

Exceptional service in the national interest

Sandia National Laboratories

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Sandia National Laboratories

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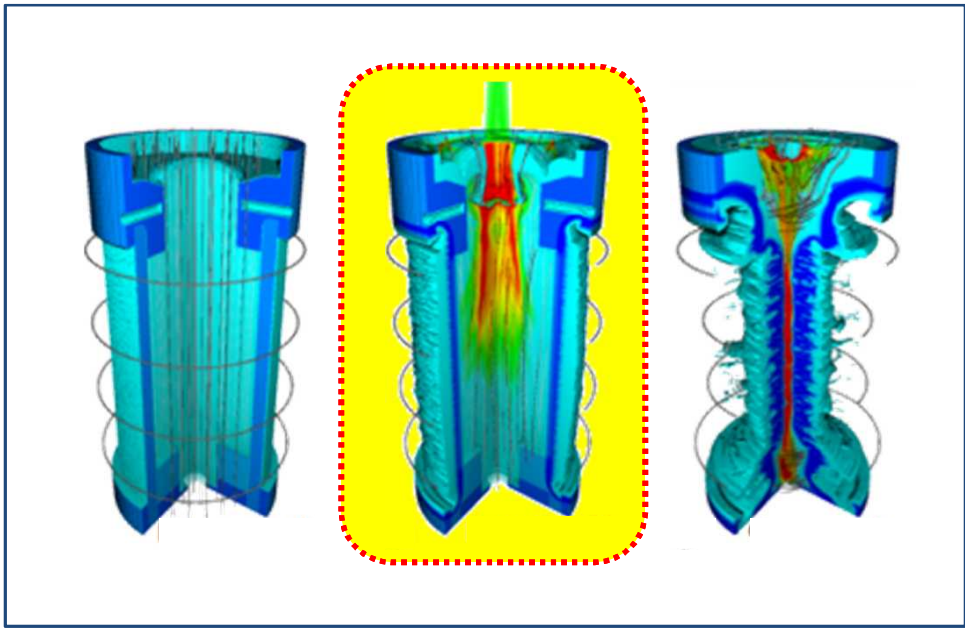

Inertial Fusion Sciences & Applications

IFSA SEATTLE 2015

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

Z Backlighter

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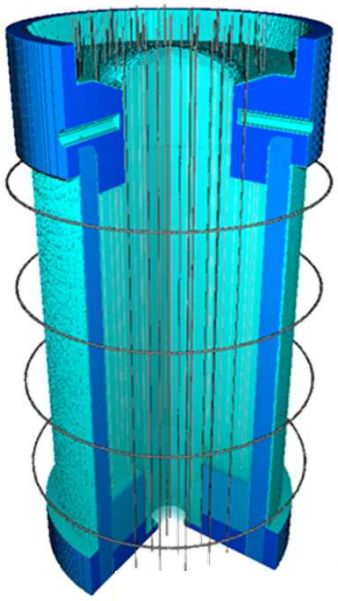
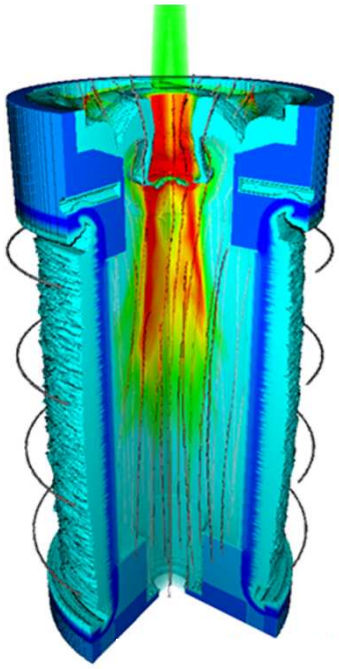
Motivation: Magnetized Liner Inertial Fusion:

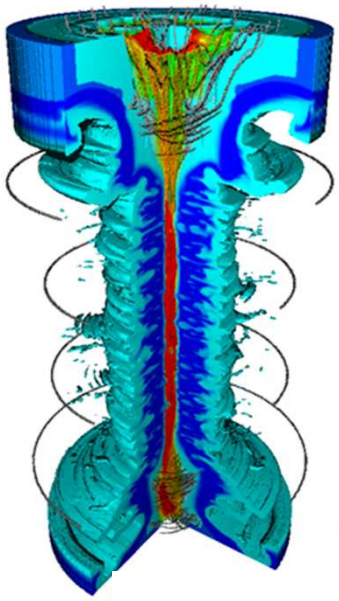
MagLIF



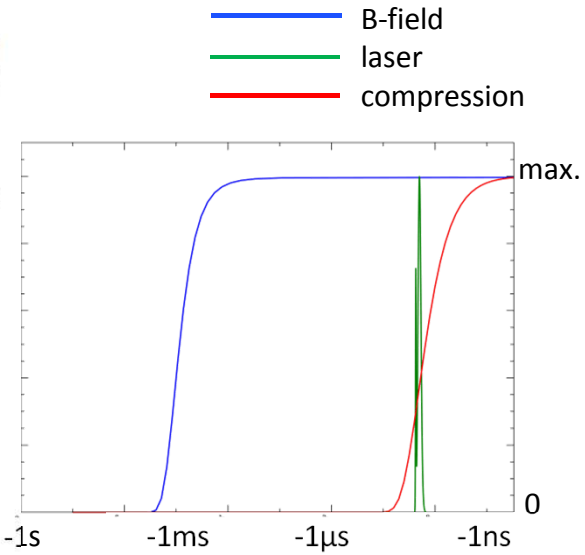
Magnetization with external B-Field (10-30T)

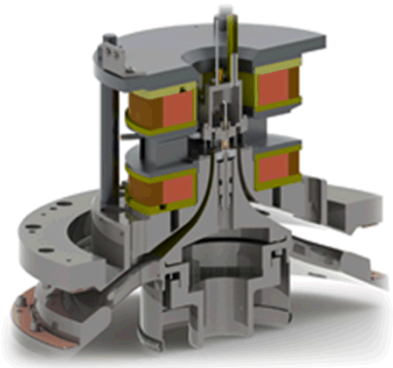


Laser heating with Z-Beamlet (2-6kJ @ 2-6ns)



Compression with 'Z'

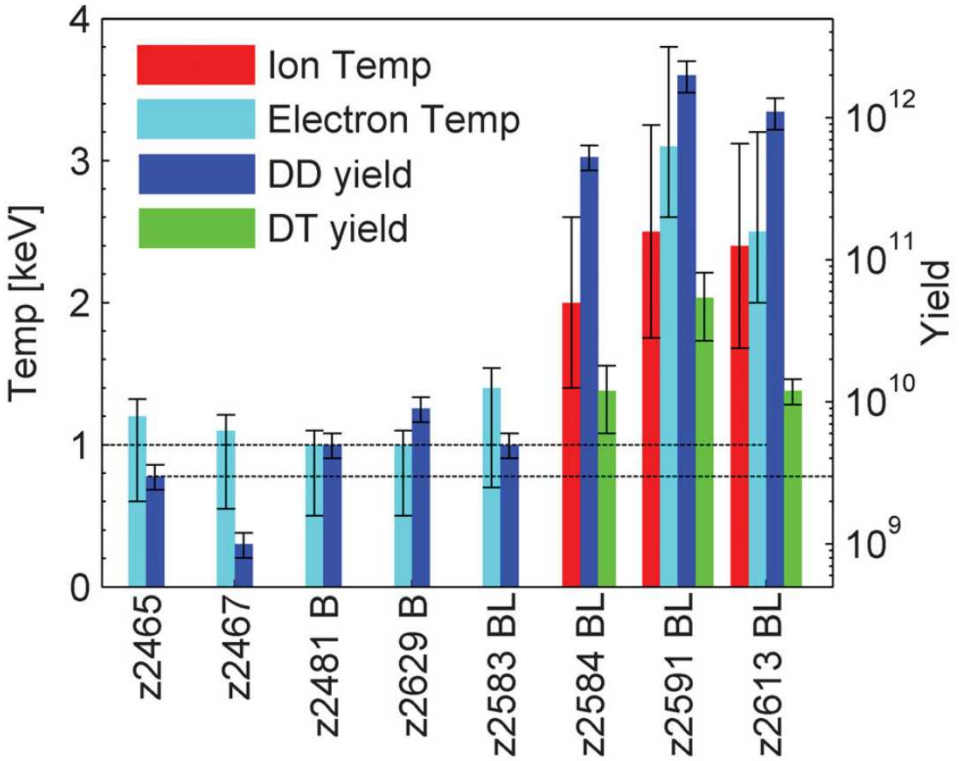




S. Slutz et al.: Physics of Plasmas **17**, 056303 (2010)

A. Harvey-Thompson: (next talk), **S. Slutz**: Tu.O.3.3 (11:20AM), **A. Sefkow:** Tu.O.3.4 (11:40AM)
D. Sinars: We.P.4 (9:40AM), **K. Peterson:** Fr.O.4.3 (2:10PM)

MagLIF (continued)



- 2E12 neutrons in 2014 were short of modeling predictions, but highly encouraging.
- Suspicion of poor laser coupling and potential fuel contamination.
- Initial measures to improve coupling lead to LOWER yields.
- A pre-conditioning task group now investigates laser pre-heat and its impact on the target!

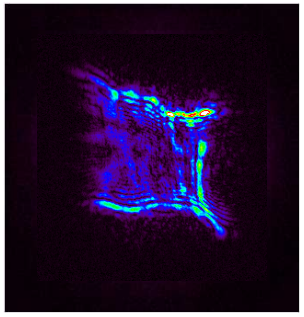
M.R. Gomez et al.: PRL **113**, 155003 (2014)

Pre-Heat Challenges

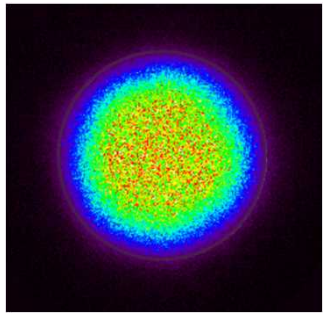
- ***High initial energy density requires high gas density***
  - *High pressure at room temperature*
  - *Thick window: 180 psi D_2 requires 3.5µm kapton across 3mm*
  - *Very high laser absorption and back-scatter in the window*

- ***Laser spot size is always a compromise***
  - *Small spots burn easily through Laser-Entrance-Hole (**LEH**)*
  - *Large spots are more efficient in fuel heating*

- ***Laser Plasma Instabilities (LPI): SBS, SRS, TPD, …***
  - *Hard to correctly predict or simulate*
  - *Lead to redirection and loss of energy*
  - *Caused by high intensities, inhomogeneities (laser spot!!), high densities.*



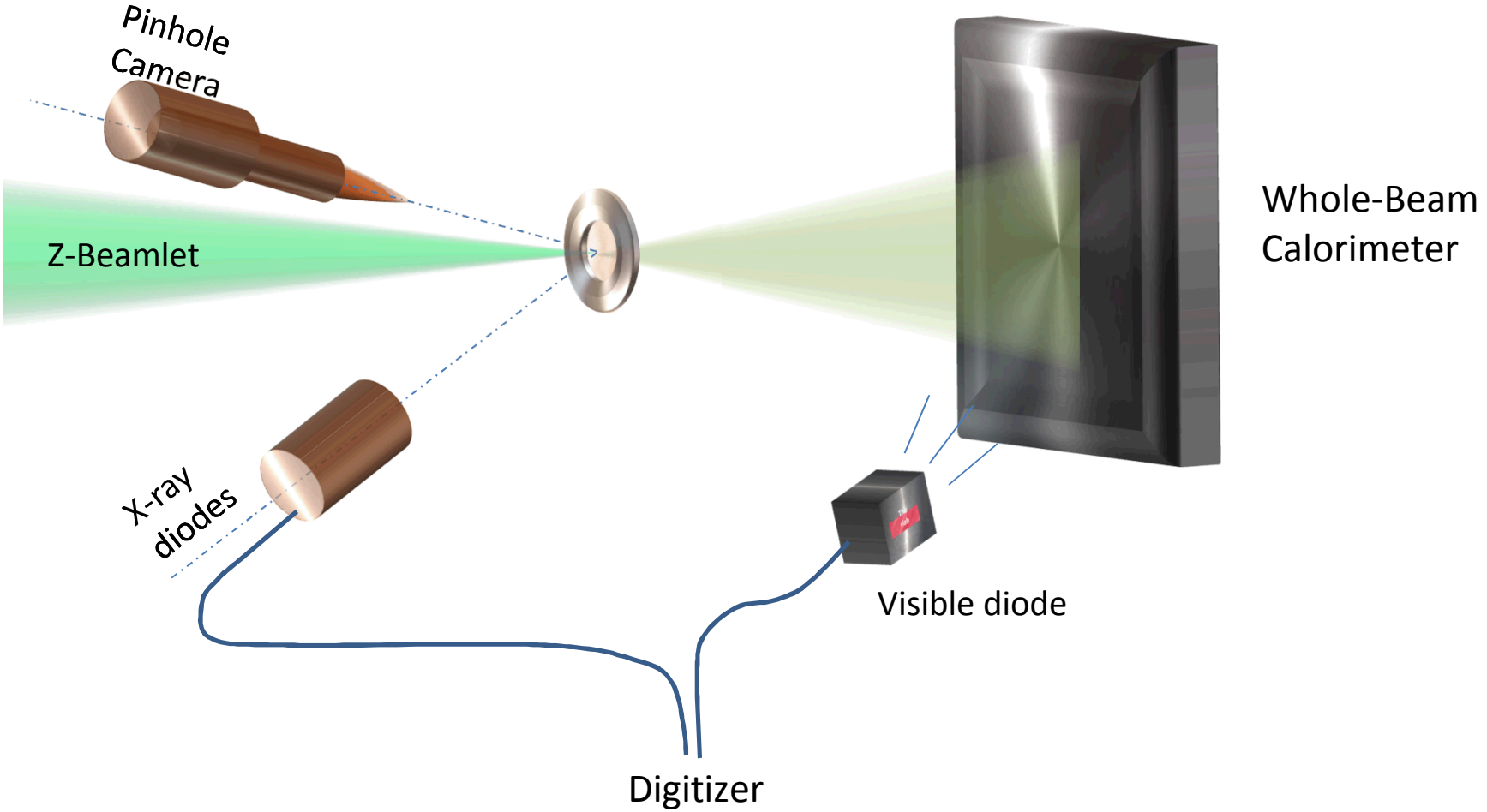
Current ZBL-spot, defocused:
Poor illumination, modulated.



Better: with phase plate
(ideally + pol. smoothing
and temporal smoothing)

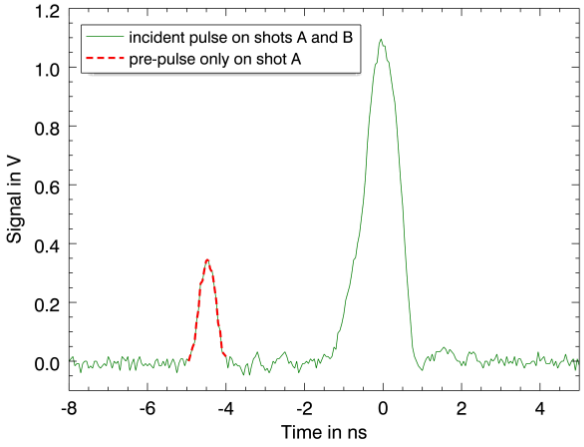
PECOS Chamber Experiments

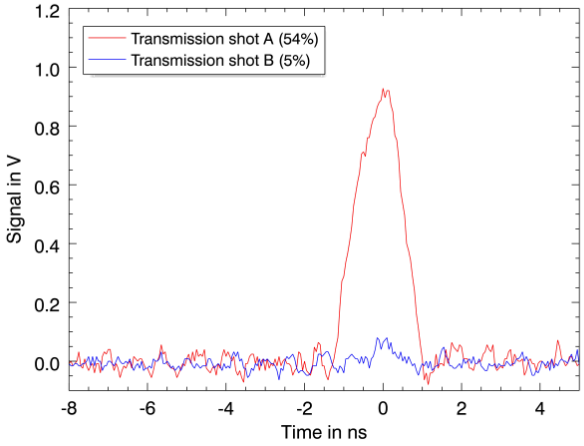
LEH Transmission



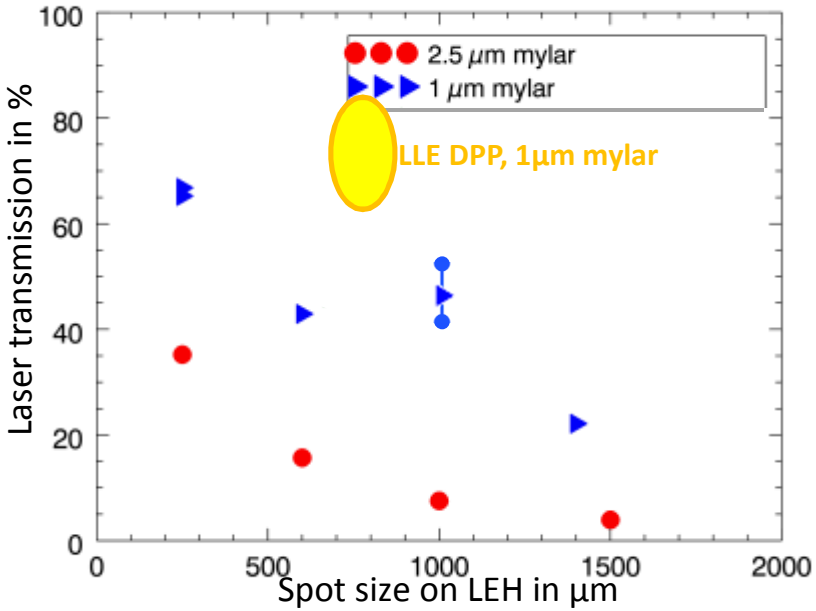
Transmission Studies

Importance of a Pre-Pulse





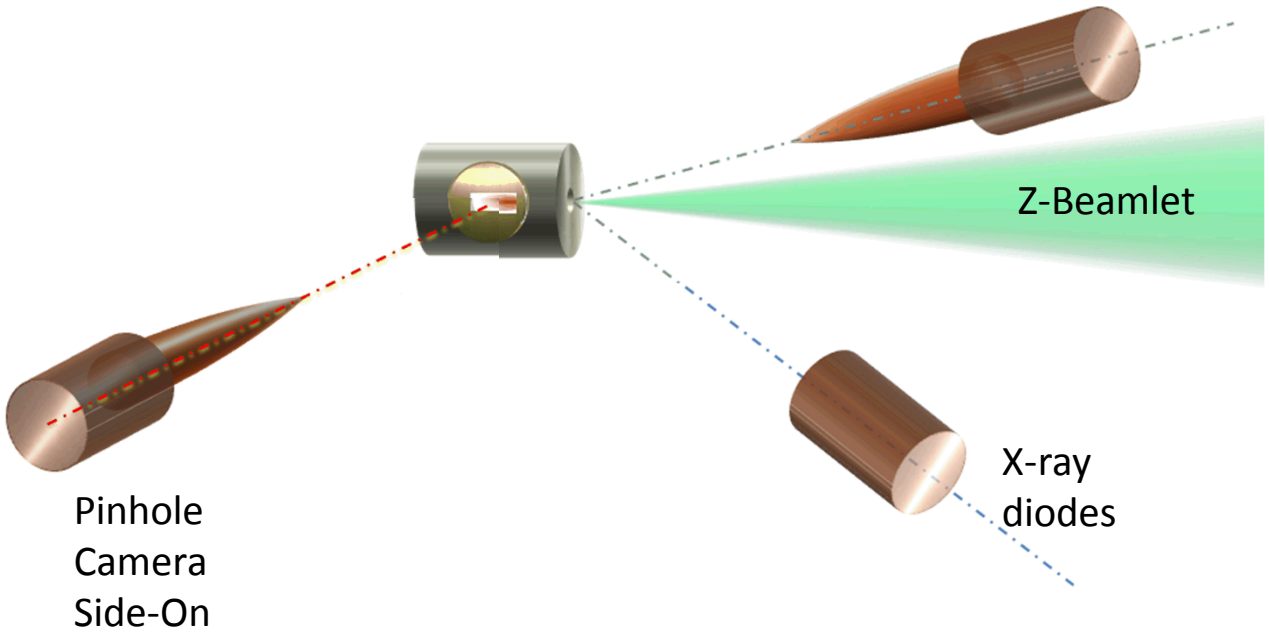
Importance of LEH Thickness



(0.5 + 2) kJ pulse energies,
1μm mylar window,
No phase plate.

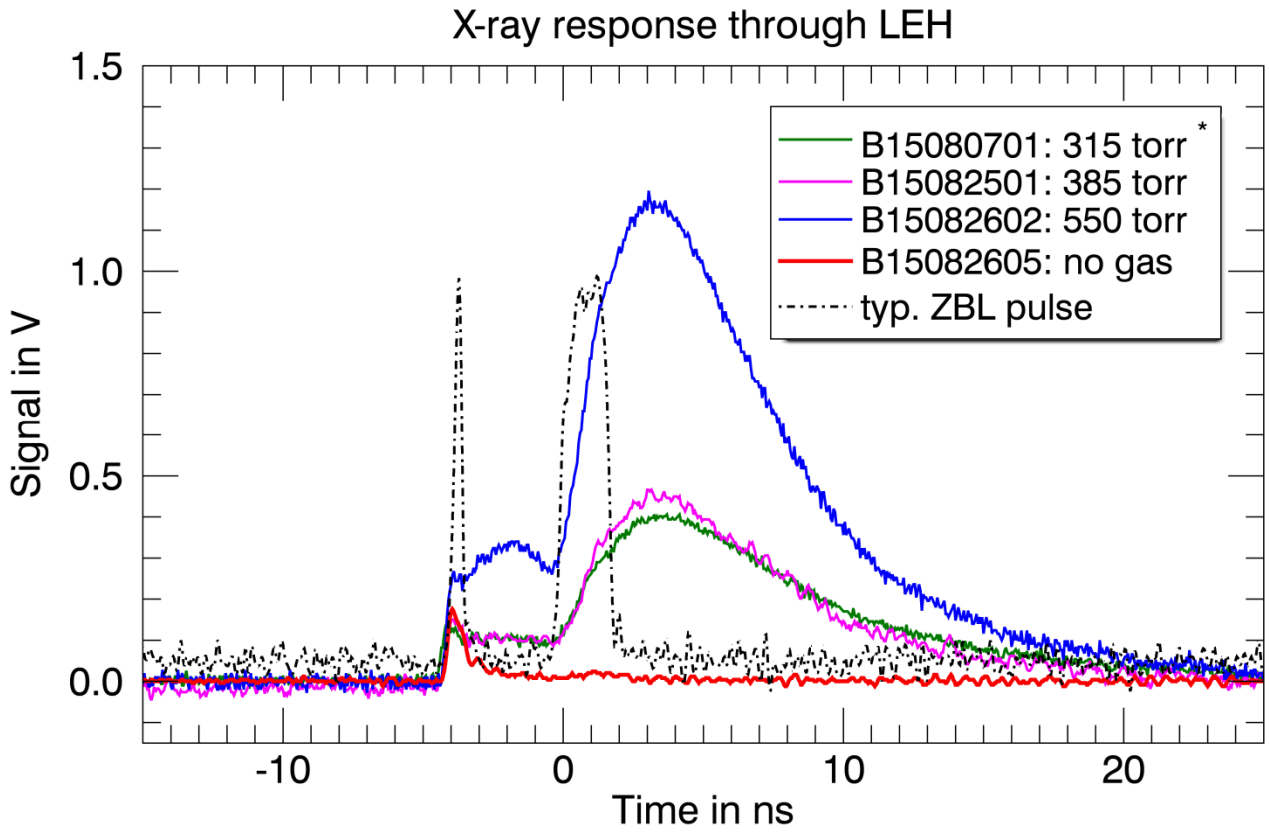
PECOS Chamber Gas Cell Experiments

Neon dopant (~1 keV K-shell):
Effective for low temperatures and
long time scales. Observable through LEH!



Pecos X-ray Diode Measurements

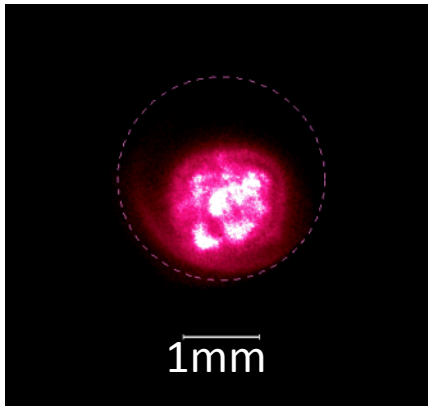
Ne X-ray output versus pressure with 1µm mylar LEH



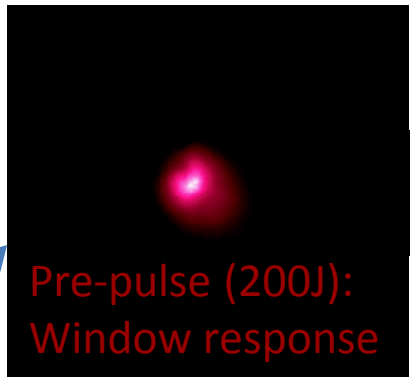
*: Shot with phase plate

Ne-Emission through LEH

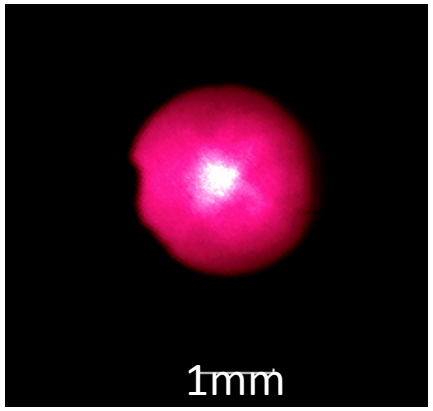
No gas fill



Only area irradiated by the laser lights up.

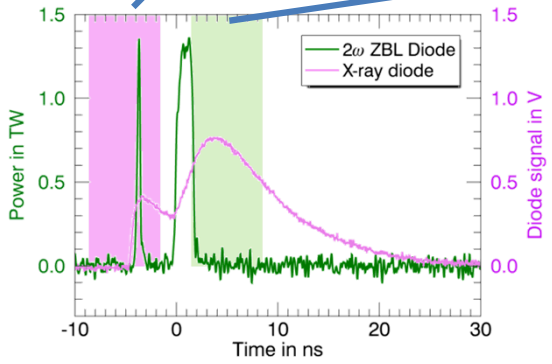


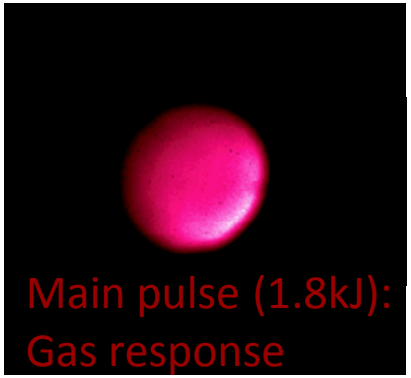
250 torr Ne



Neon emission fills entire LEH.

temporally resolved

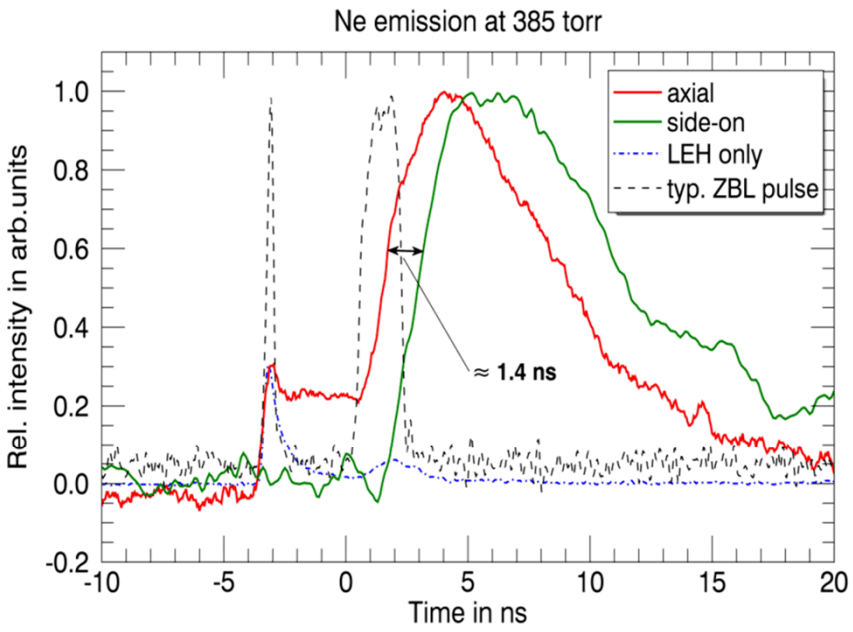


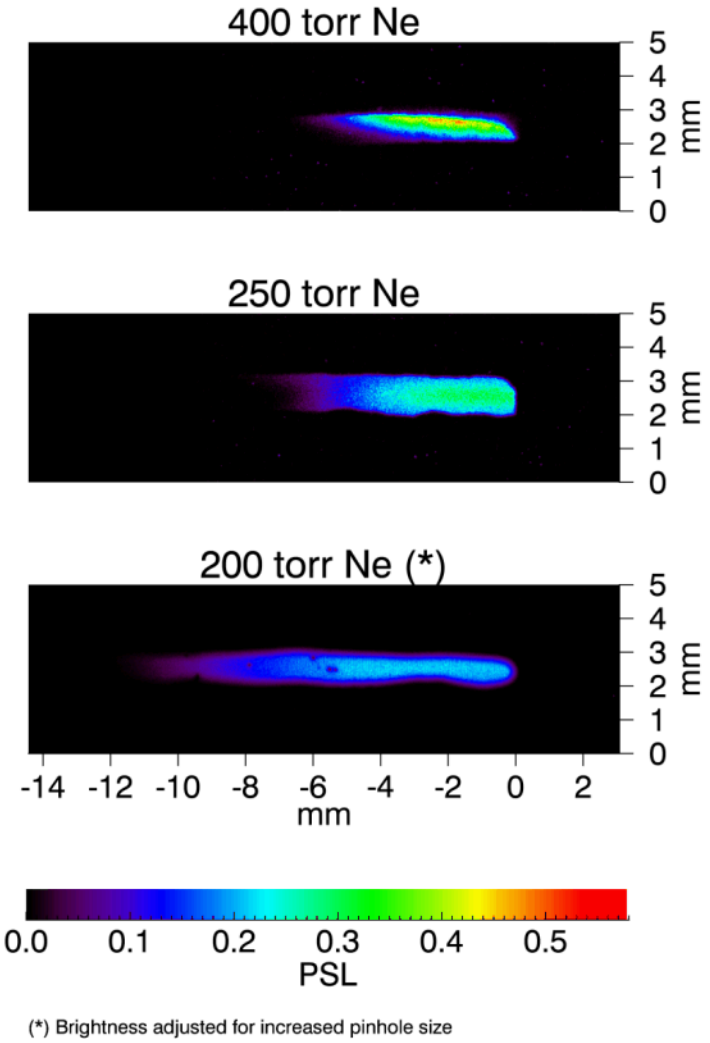


See G. Rochau, We.S.4 (5PM) for techn. details

Ne-Emission

Side-On





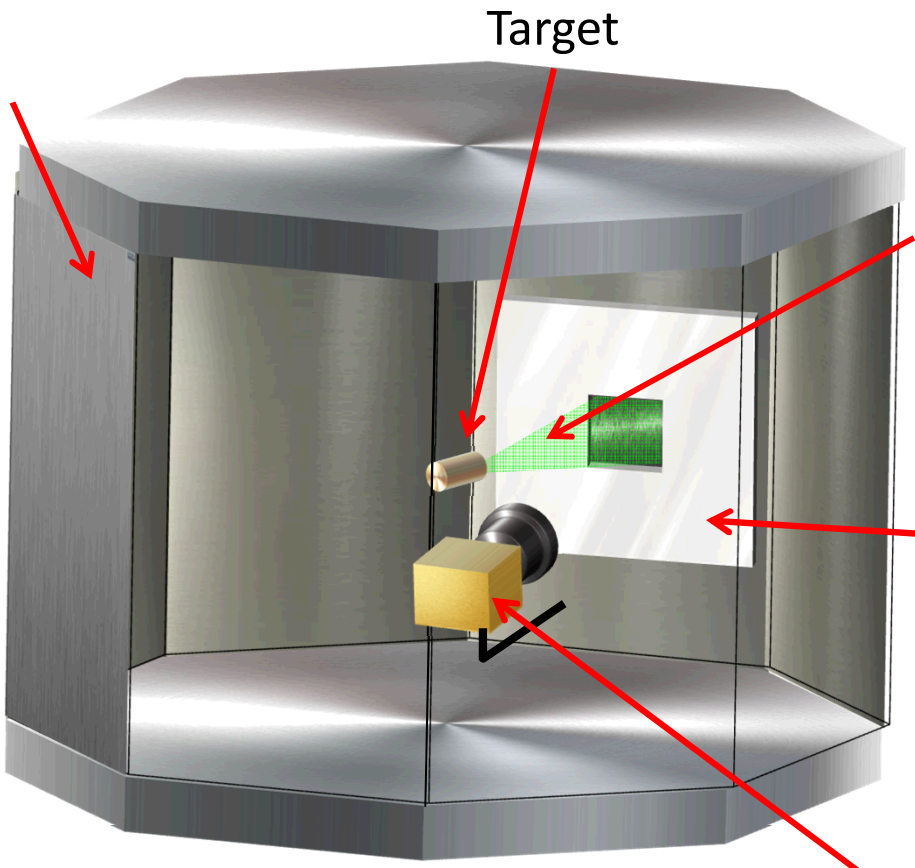
The side-on window's field-of-view starts 4-5 mm behind the LEH. Therefore the laser drills into gas at around 3000 km/s!

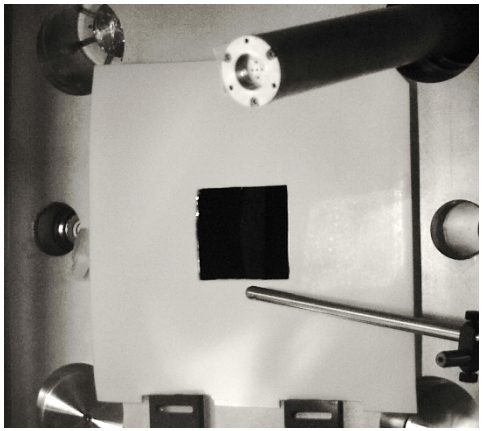
(*) Brightness adjusted for increased pinhole size

Backscatter Measurements

SBS Near Beam Imaging Measurements

Pecos
target chamber

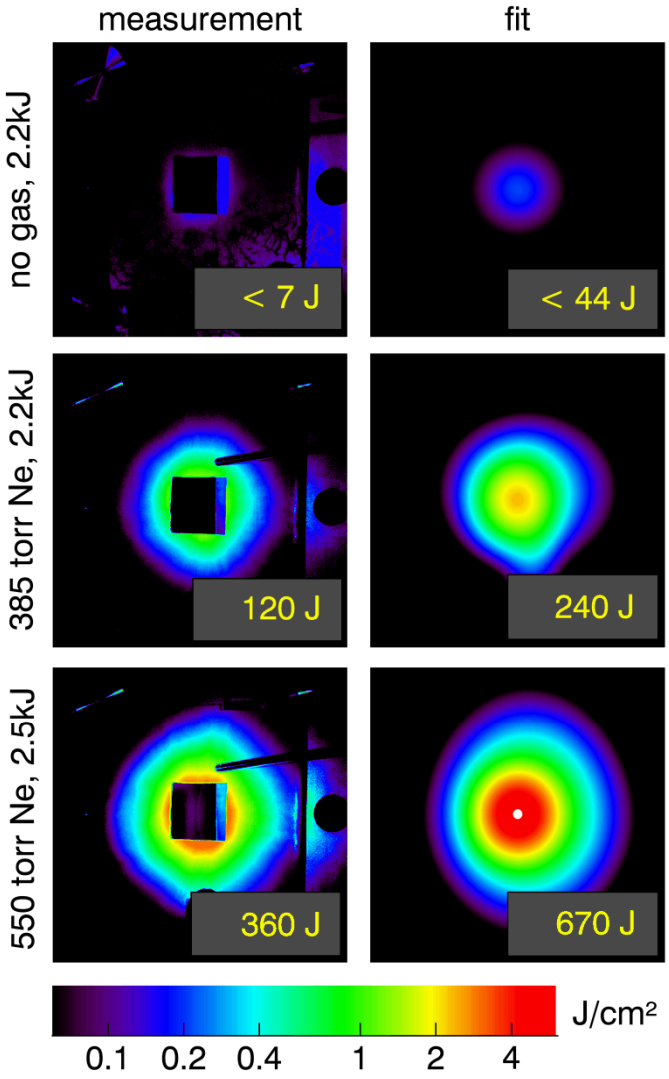


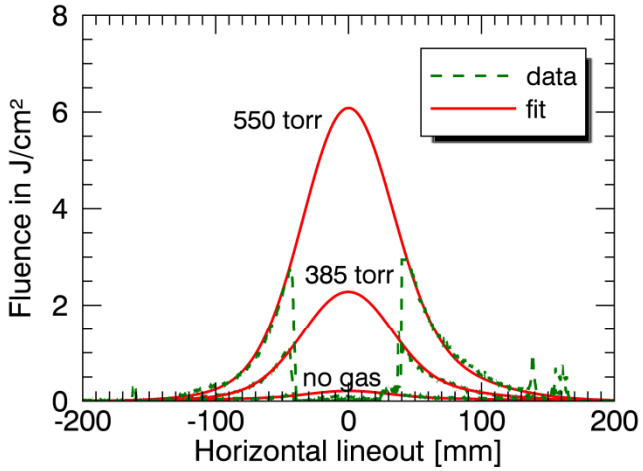


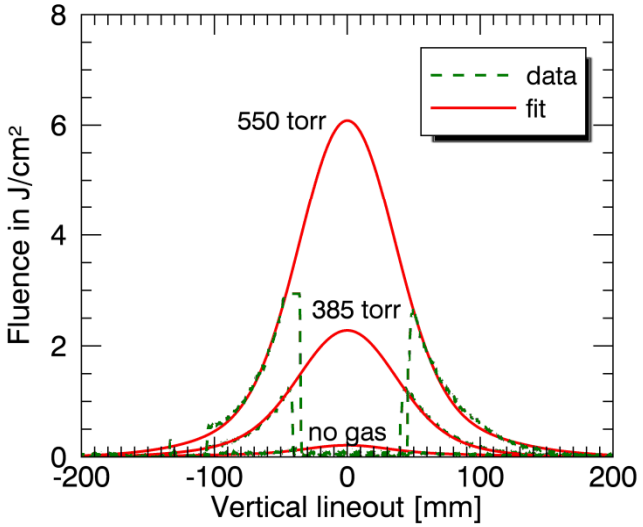
SBS camera
- Green filter
- ND filters
- GigE (triggered)
- 8- or 12-bit

Backscatter Measurements

SBS Near Beam Imaging Measurements

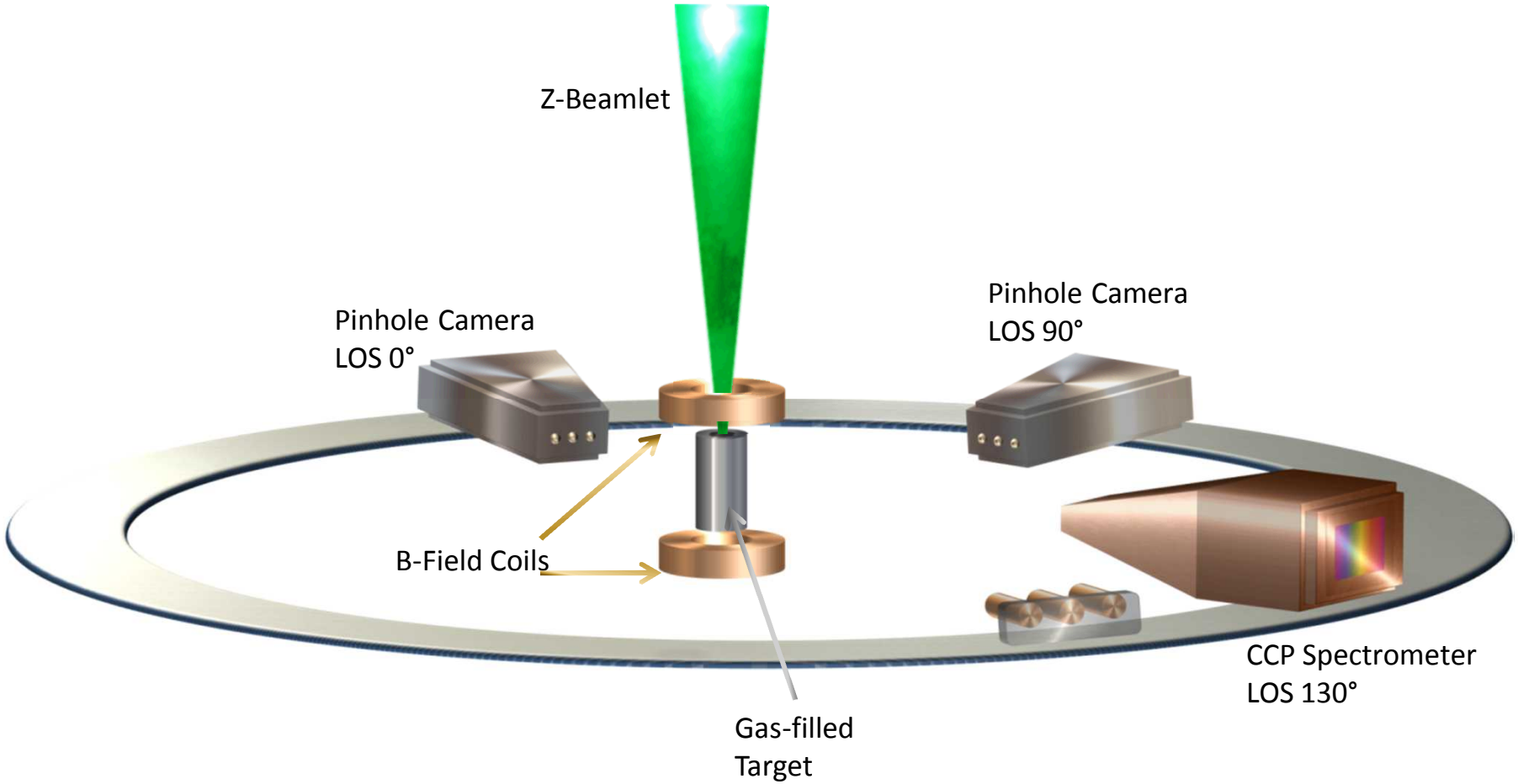






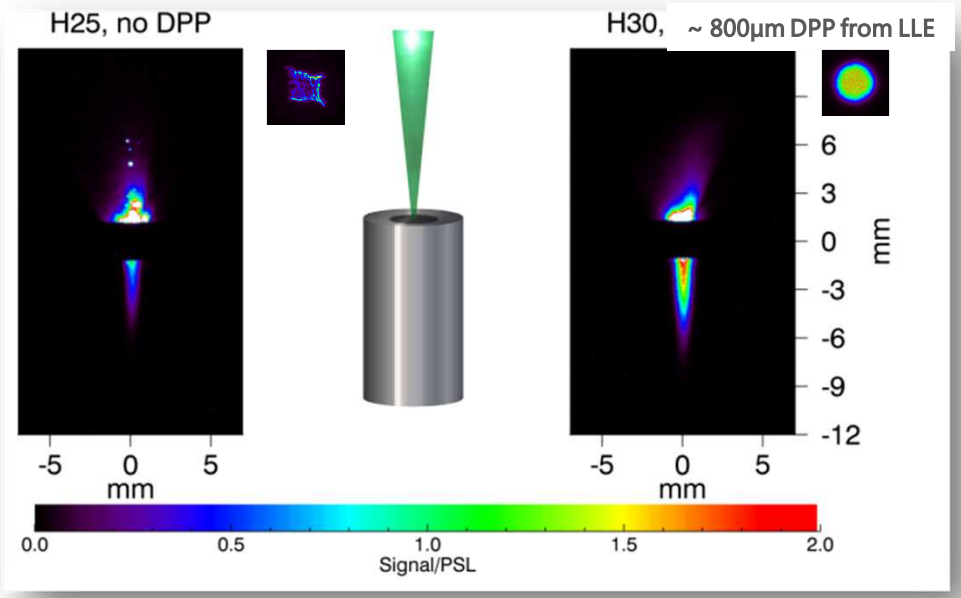
Experiments in Z Center Section

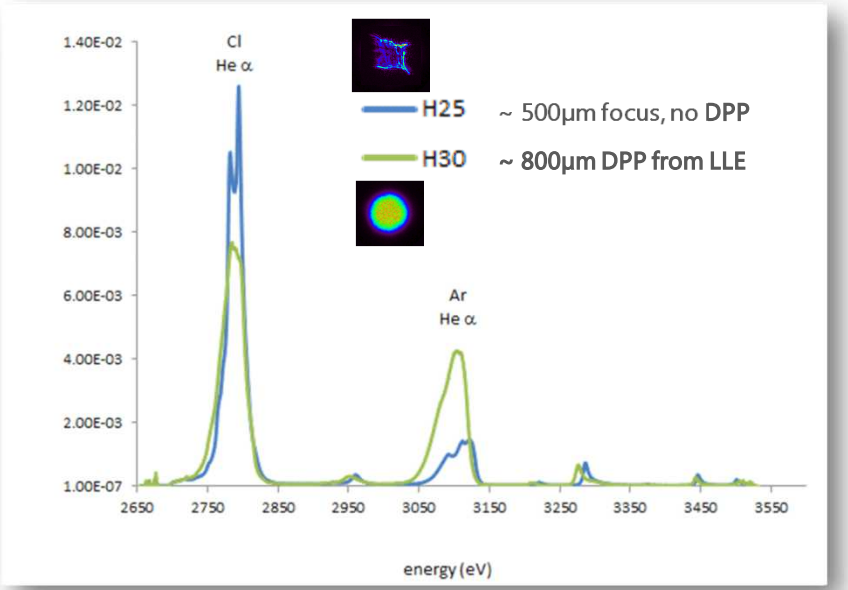
Diagnostic Configuration (not to scale)



Phase Plate / No Phase Plate

60 psi D_2 with 0.1% Ar-dopant, Cl-doped LEH





Data analysis:
Stephanie Hansen

- **1.6 mm depth increase**
- **2x emission from gas for argon K-shell radiation**

- **Phase plate reduces window contamination**
- **Increases gas emission**

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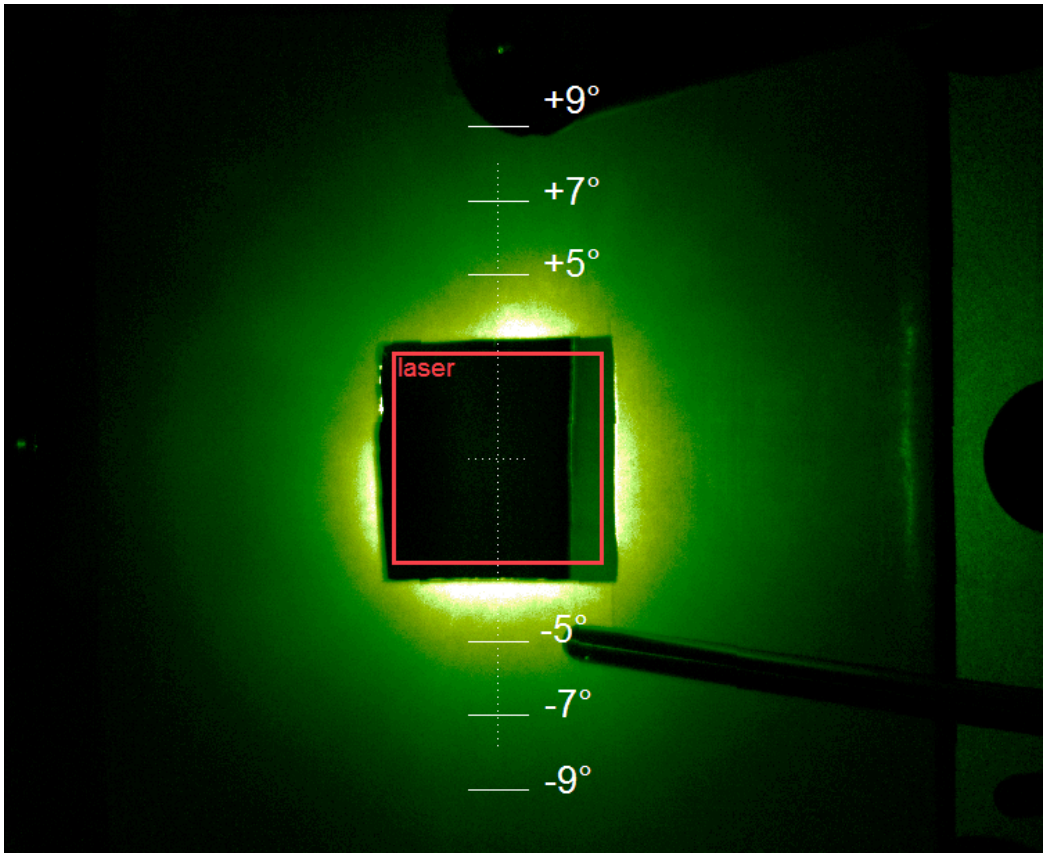
Summary

- *Pre-pulse is important. Potential to optimize (timing, energy).*
- *Phase plate is important!*
- *Neon is promising as dopant for axial diagnostic.*
- *Significant difference between pre- and main pulse interaction!*
- *Use < 1µm LEH (cryogenic campaign with 400nm LEH on Z this week).*
- *Check for - and stay away from - LPI such as SBS (possibly ~1kJ), SRS, TPD, etc…*

- *To do:*
  Characterize mix, optimize diagnostics, SRS, analyze, analyze, analyze…

Extras

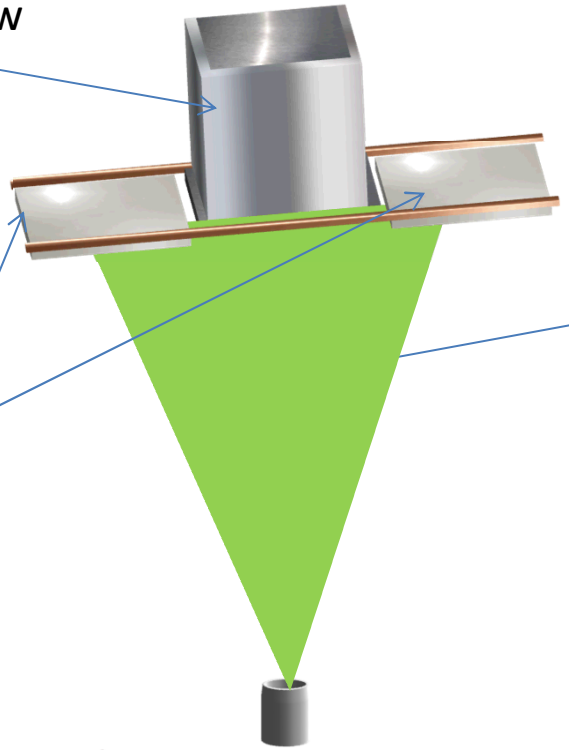
Pecos Backscatter Measurements



SBS measurements

Near Angle Backscatter Measurements

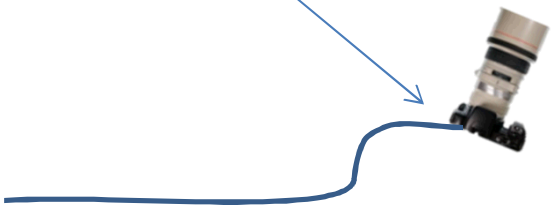
Re-entrant vacuum window of ZBL FOA in Z



Backscattered Light

PTFE scatter plates (attached to window rim)

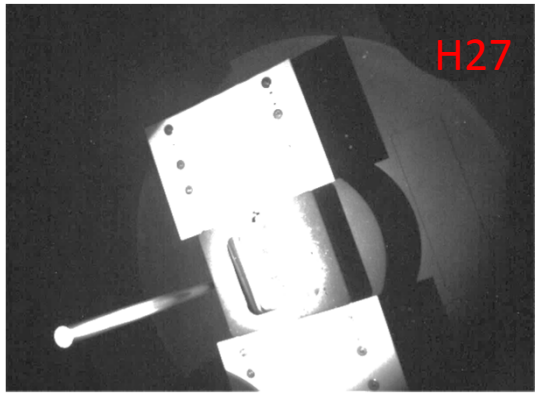
IEEE1394 camera used in AXIAT 1.



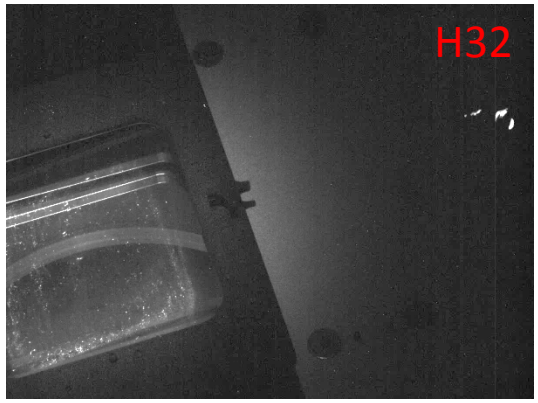
SBS Measurements

Camera: Evaluation pending

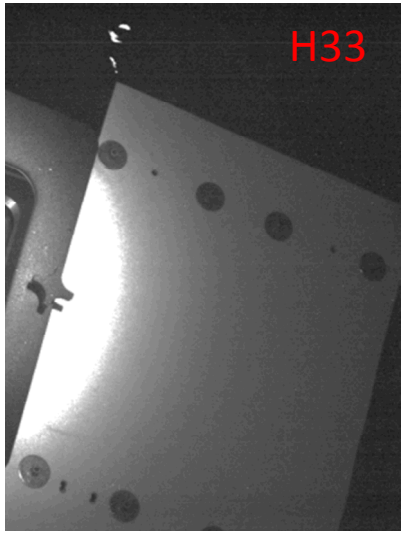
LASPE2 (no phase plate. ND4)



AXIAT2 (LLE phase plate, ND5)



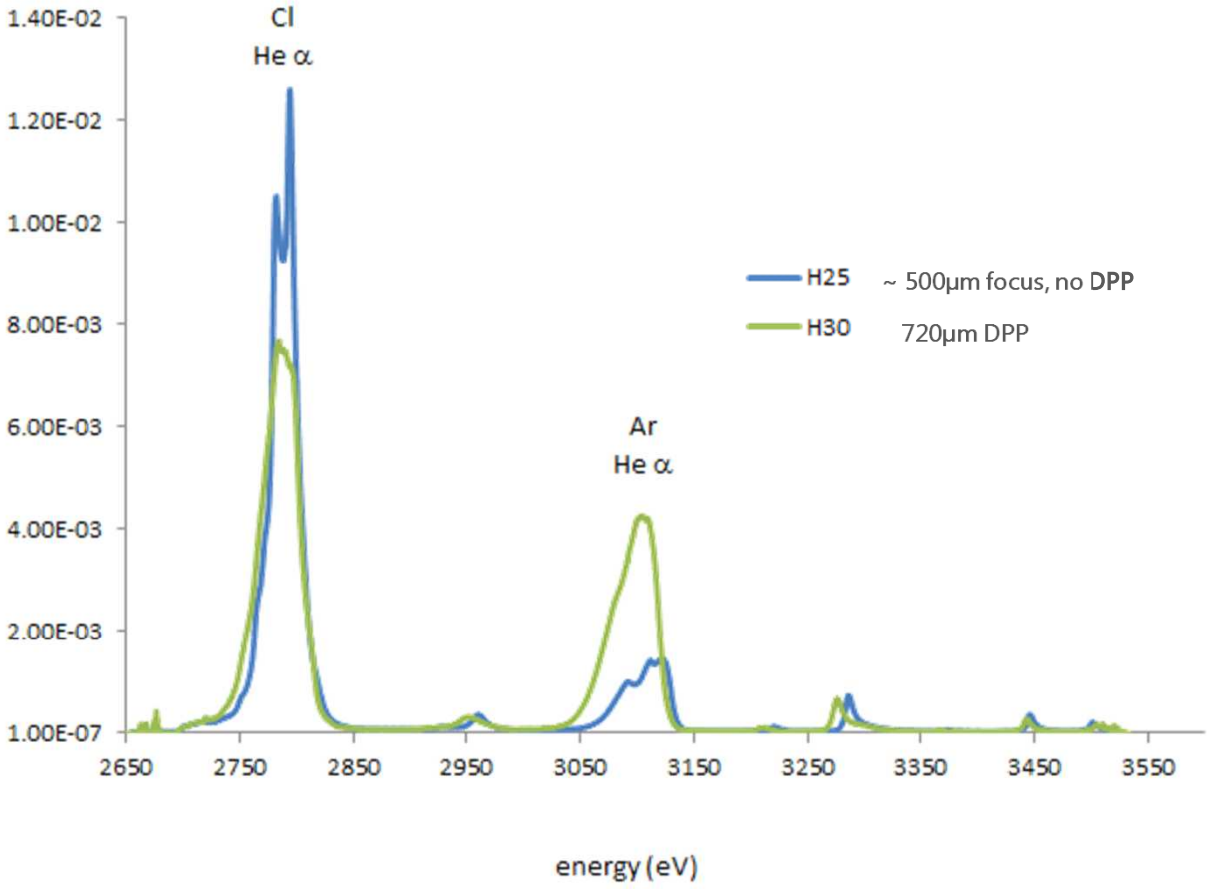
0.5µm kapton, 15 PSI Ne



1.6µm kapton, 60 psi D_2

CCP Spectrometer

60 psi D_2 with 0.1% Ar-dopant, Cl-doped LEH



Data analysis:
Stephanie Hansen

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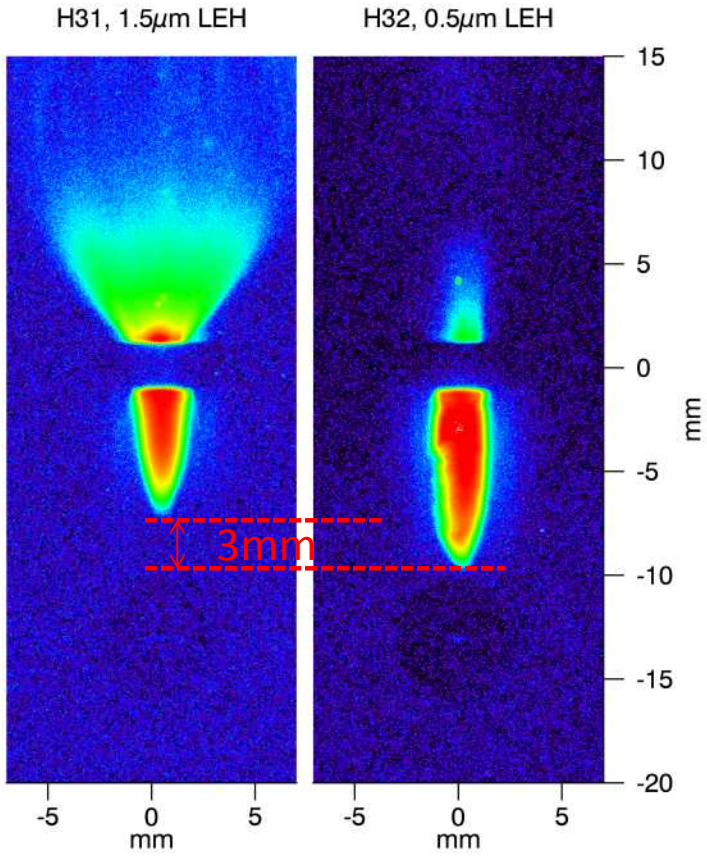
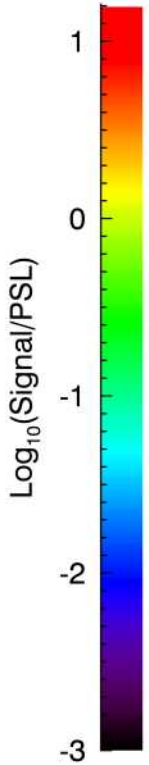
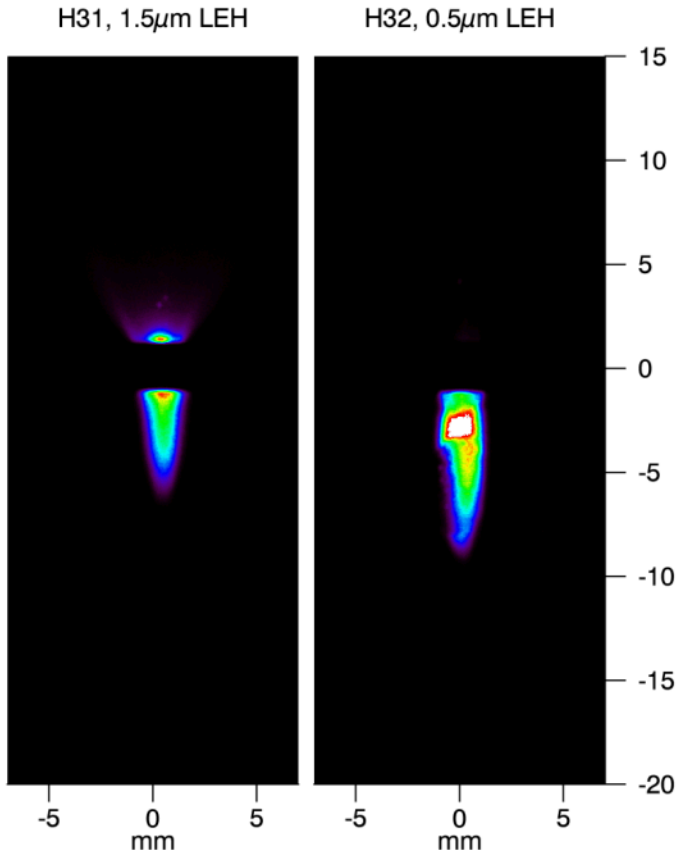
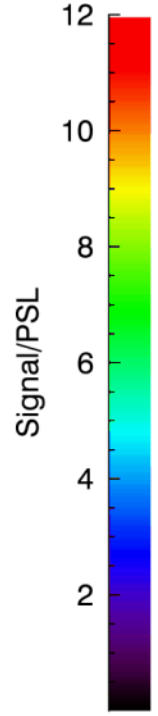
Why we like thin windows:

Aperture Ring Camera, 15 psi neon, LOS 90









Logarithmic scale

Linear scale

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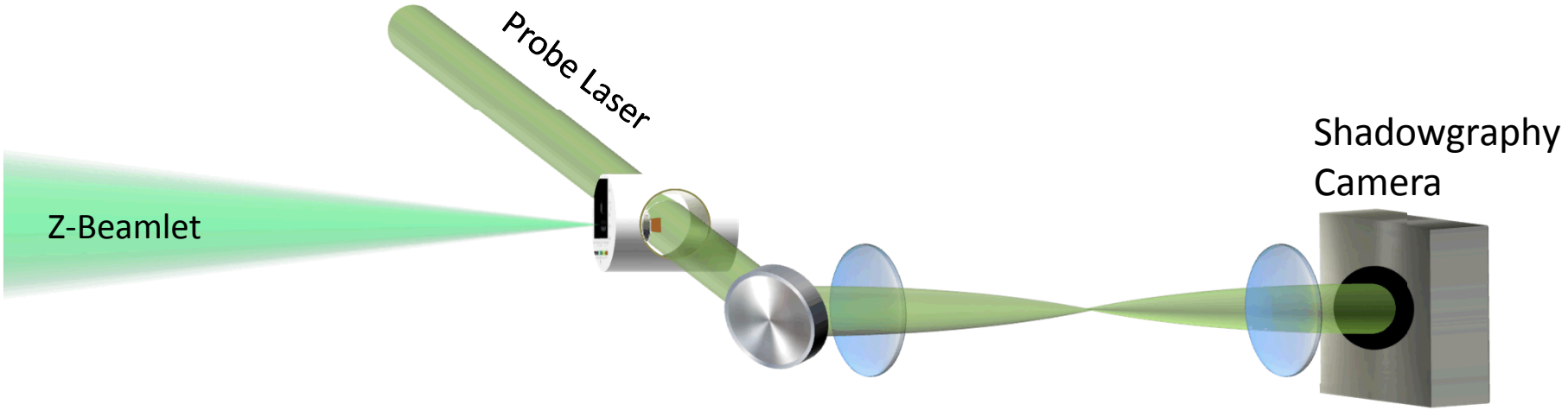
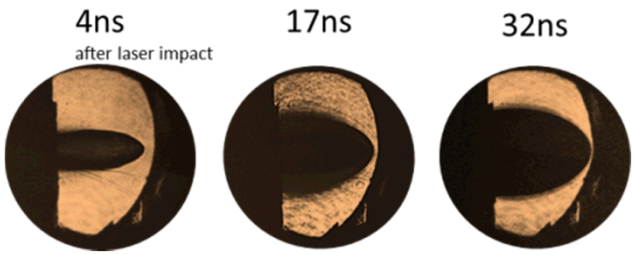
PECOS Chamber Gas Cell Experiments

"Hippogriff" Hybrid CMOS Camera (J. Porter)



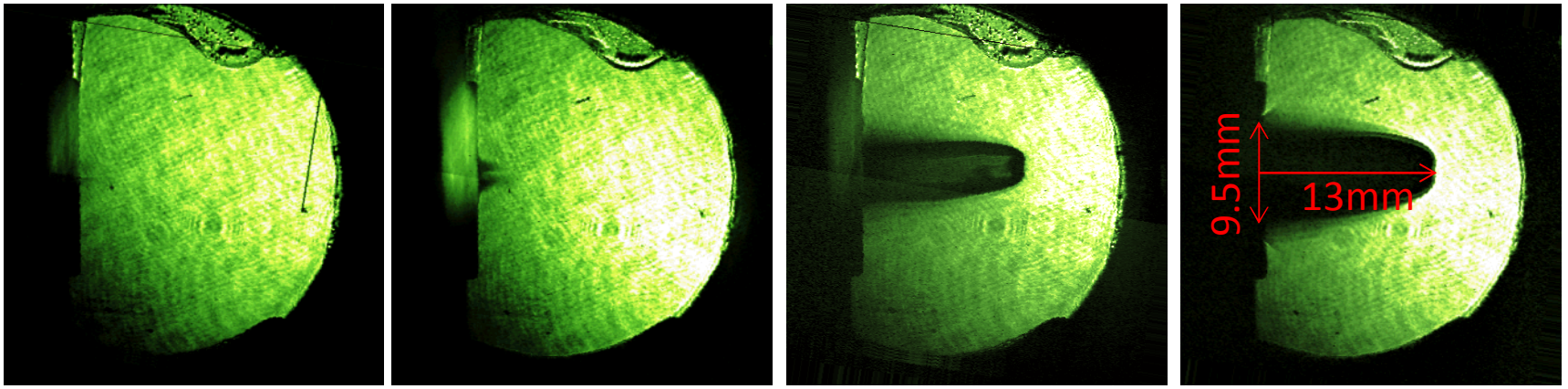


8-frame* probe beam B14121104

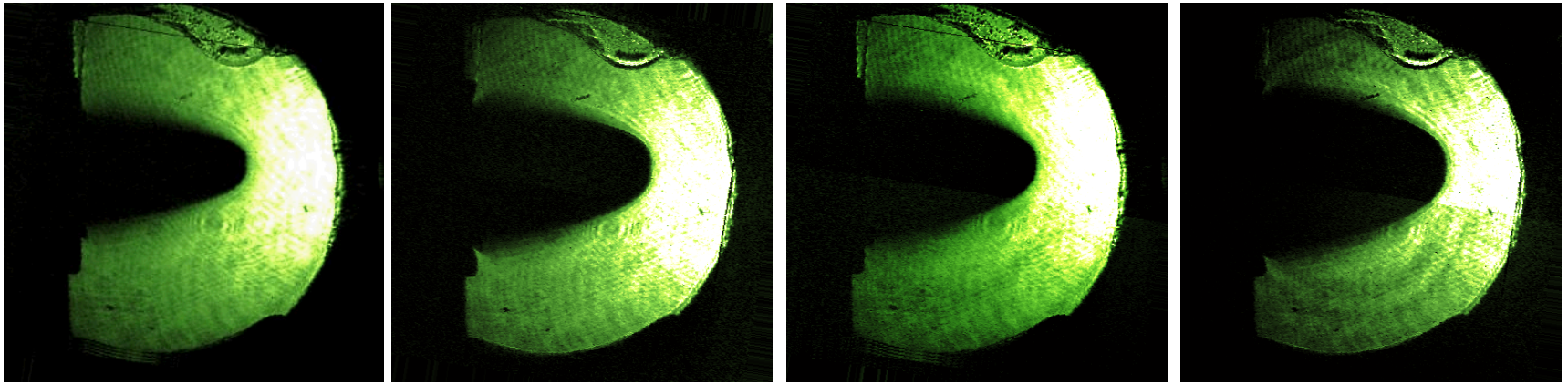
1µm LEH, ~2kJ

Pre-Pulse

Duration of Main Pulse



-2 ns | 0 ns | 2 ns | 4 ns



6 ns | 8 ns | 10 ns | 12 ns

*: 2x interlaced Hippogriff with polarization multiplexing

Courtesy: John Porter, Mark Kimmel, Sean Lewis

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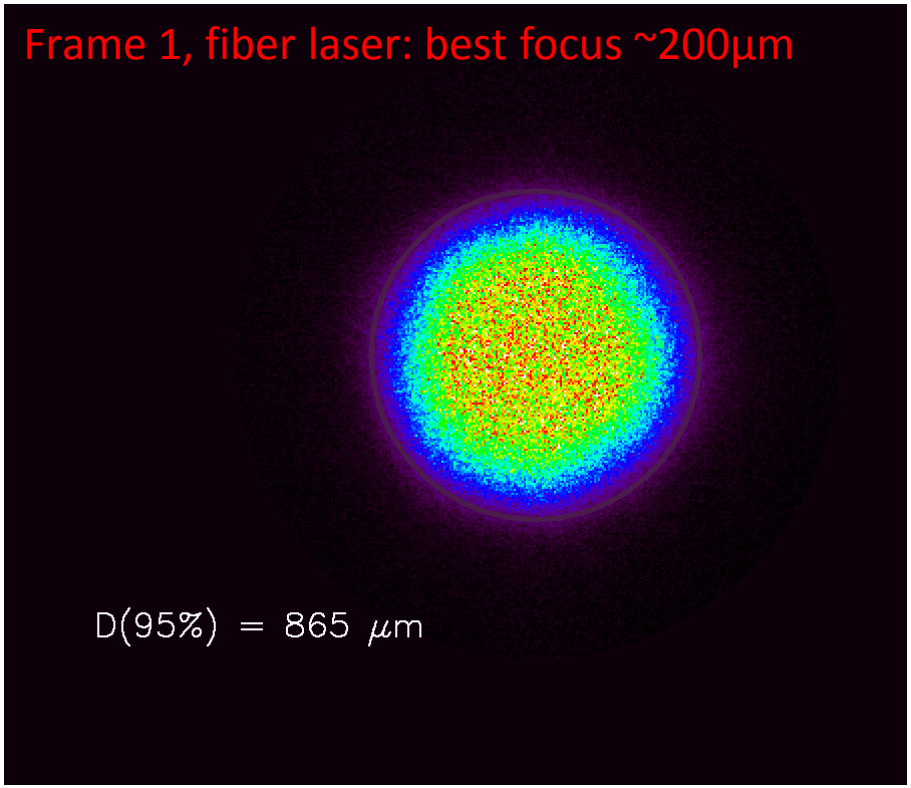
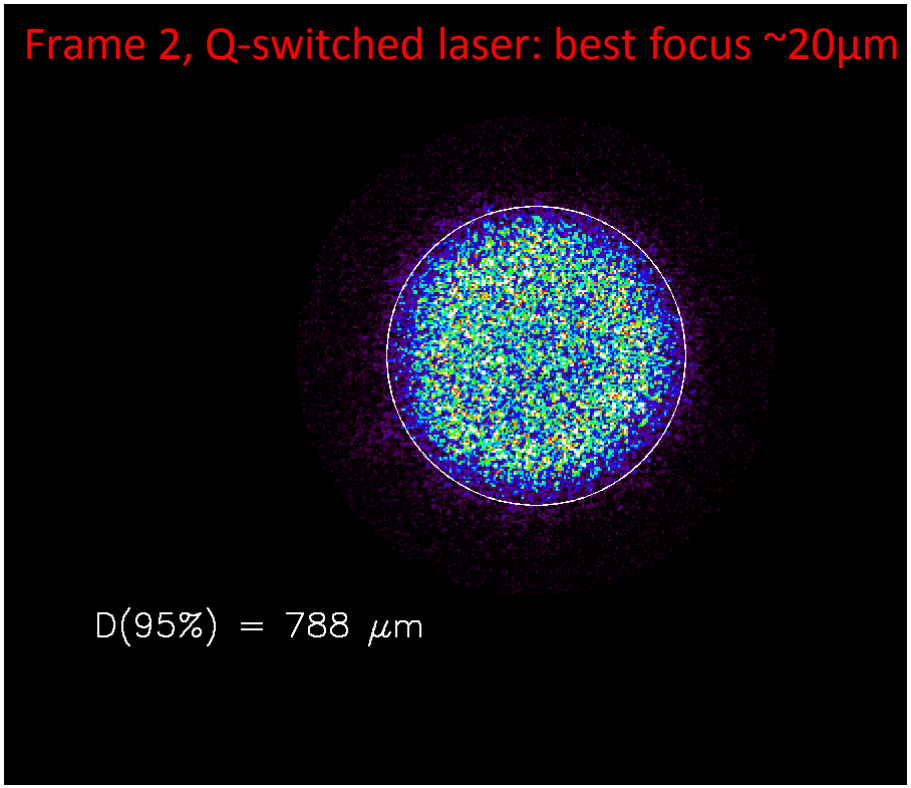
LLE '800 µm' Distributed Phase Plate

Measured Alignment Beam Foci





Measurements were slightly compromised by high frequency pointing instabilitiy