SAND2015-4867C

LEH Transmission and Early Fuel Heating for MagLIF with Z-Beamlet

Exceptional service in the national interest

Sandia National Laboratories

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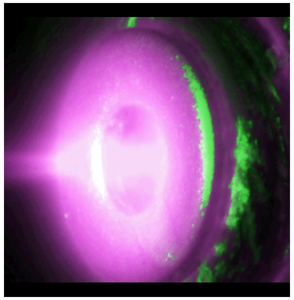

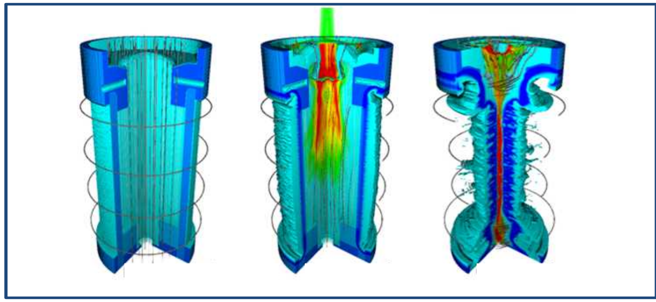

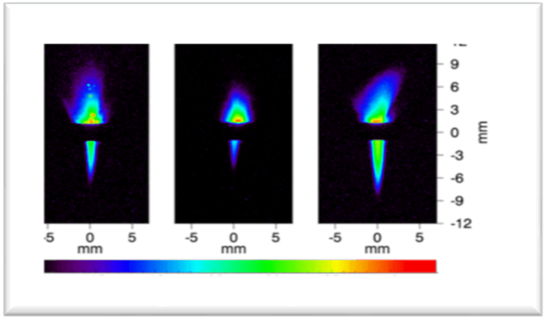

ANOMALOUS ABSORPTION 2015

Ventura, CA

45th Anomalous Absorption Conference
Ventura Beach, CA
June 19, 2015

U.S. DEPARTMENT OF ENERGY

NNSA

National Nuclear Security Administration

Z Backlighter

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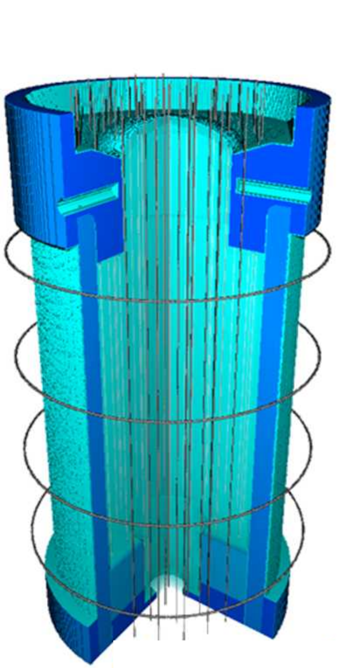
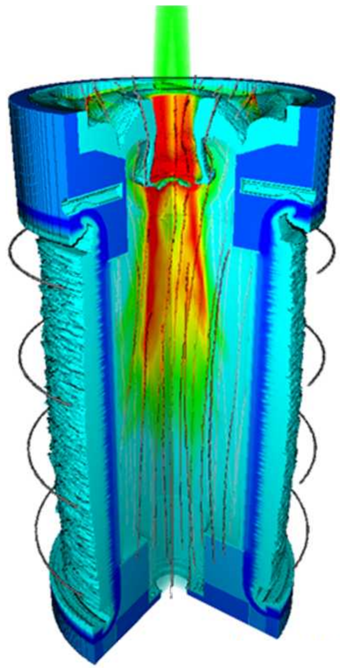
Square 1: Magnetized Liner Inertial Fusion:

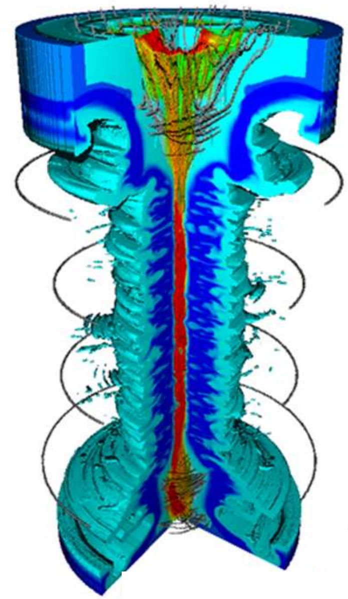
MagLIF



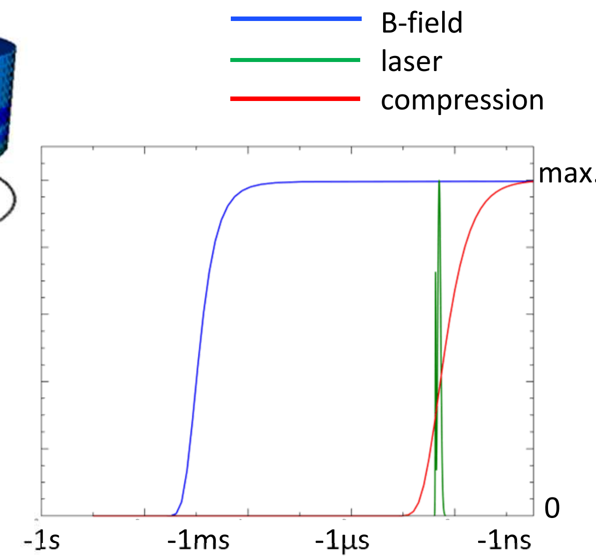
Magnetization
with external B-Field
(10-30T)

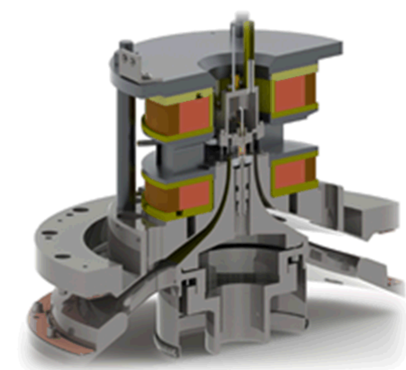


Laser heating
with Z-Beamlet
(2-6kJ @ 2-6ns)



Compression
with ‘Z’





S.A Slutz et al.: Physics of Plasmas **17**, 056303 (2010)
A.B. Sefkow: “Adventures in ICF with magnetic fields” (Wednesday)

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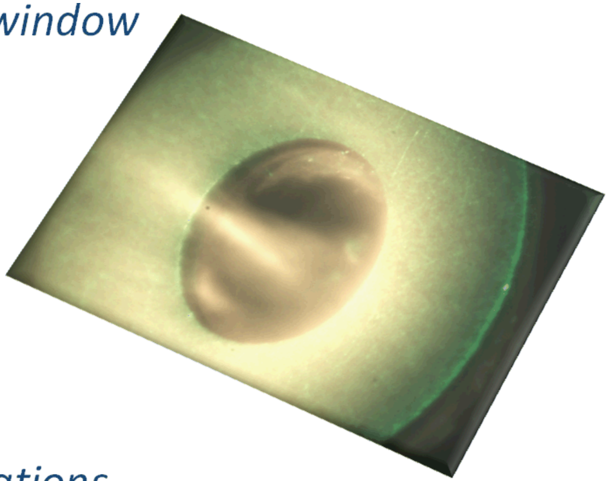
The Problem with Having Windows

- ***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 LEH*
  - *Large spots are more efficient in fuel heating*
  - *Laser must not hit bottom of fuel container*
- ***Ideal laser profiles cannot be 'dialed in' by defocusing***
  - *Unconditioned laser spots have detrimental modulations*
  - *Unconditioned laser are hard or impossible to model*
  - *Dedicated experiments are needed to determine best initial conditions for laser and window.*

Objectives:

1. ***Measure Transmitted Laser Light in Dependence of:***
   a. *Focus size*
   b. *Foil thickness*
   c. *Focus quality (defocus vs. phase plate)*
   d. *Evaluate requirement of advanced smoothing*

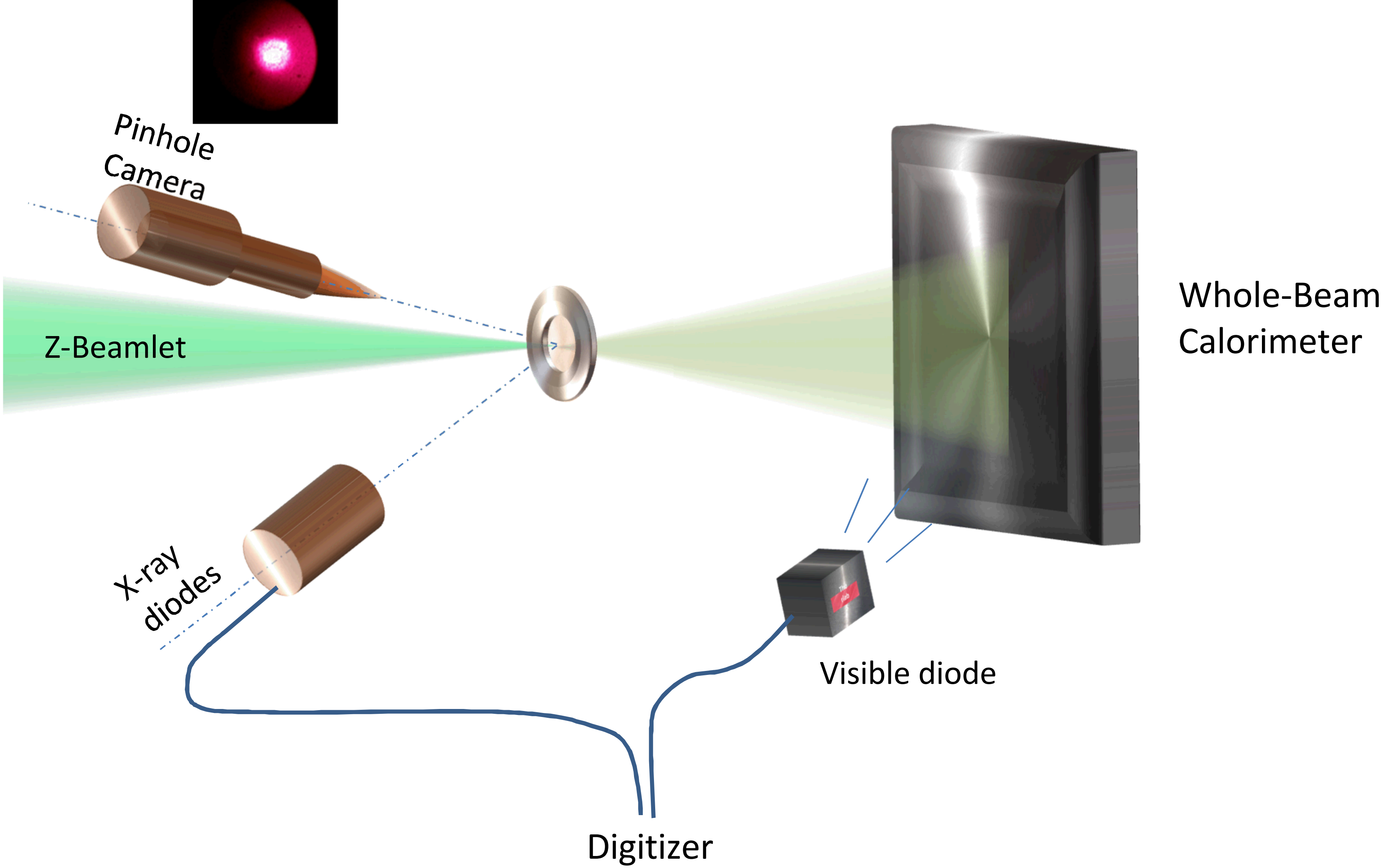
2. ***Measure Energy Deposition in Gas:***
   a. *Measure laser driven blast waves in fuel*
   b. *Measure X-ray emission from fuel*
   c. *Measure cooling rate*
   d. *Measure potential LPI losses (SBS, SRS, TPD, etc…)*

3. ***Develop In-situ Diagnostics for Integrated Experiments***
   a. *The value of surrogate experiments*
   b. *Looking along the laser's line of sight*

4. ***Take Lessons Learned to Prepare Ideal Target***
   a. *Cryo-cool target to enable tolerable window thickness*
   b. *Buy adequate Phase-Plate for Laser*

PECOS Chamber Experiments

LEH Transmission



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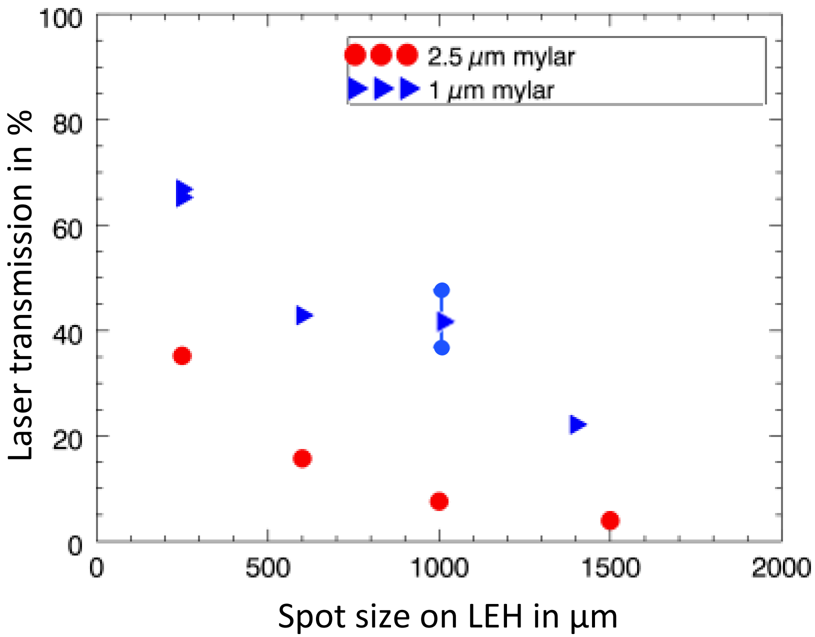
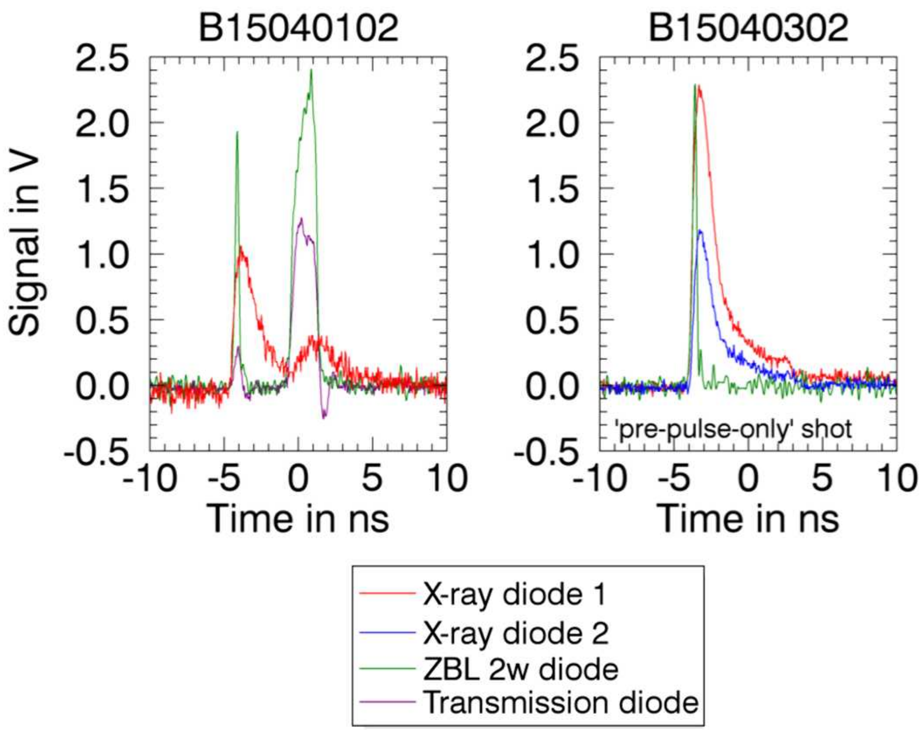
Transmission Comparison Graph

Calorimeter Data, Energy and Power

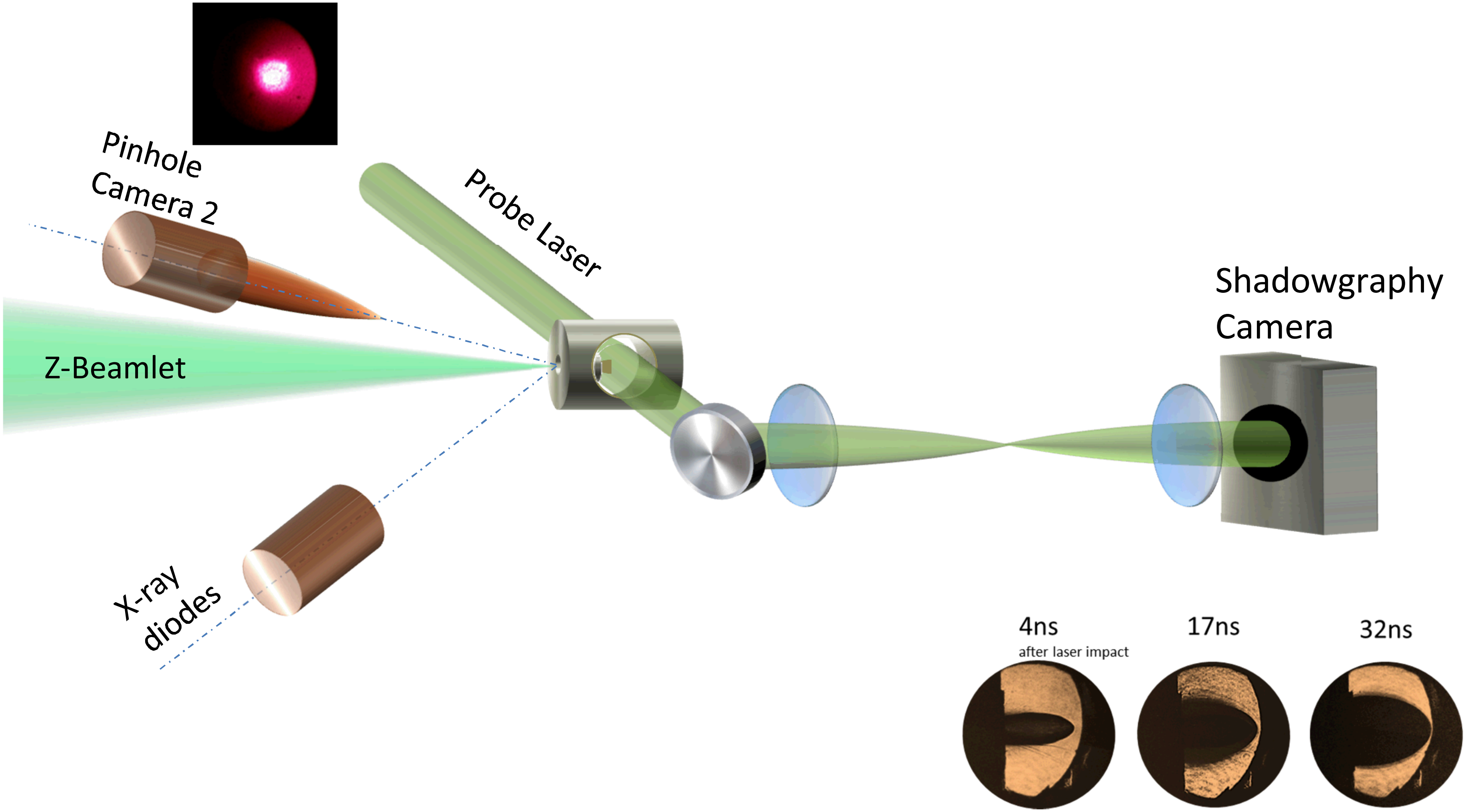
2 kJ laser pulse, no smoothing





(0.5 + 2) kJ pulse energies, 1µm mylar window.

PECOS Chamber Gas Cell Experiments



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X-Ray Diode Measurements

1 Mylar, 2.5kJ laser energy, 1 mm defocus

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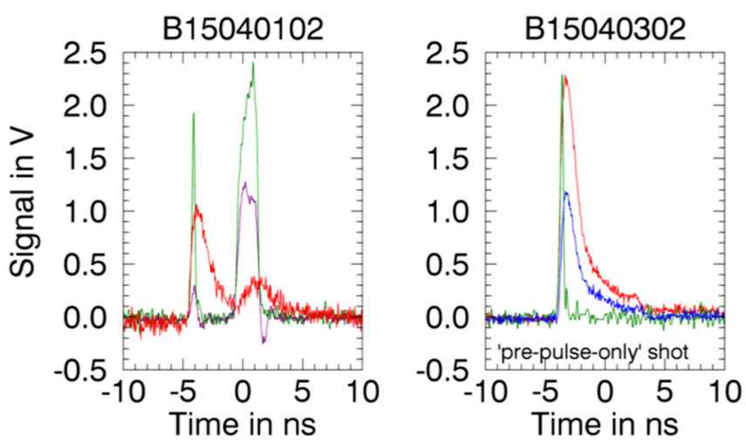
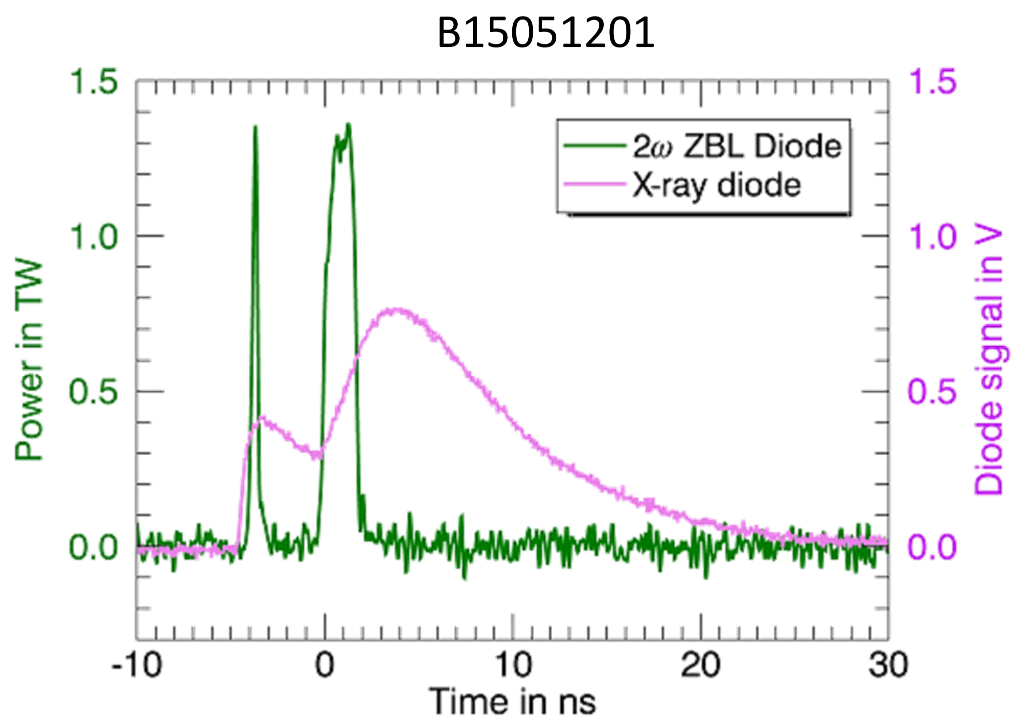


No Gas Fill



GAS CELL, 400 torr Ne

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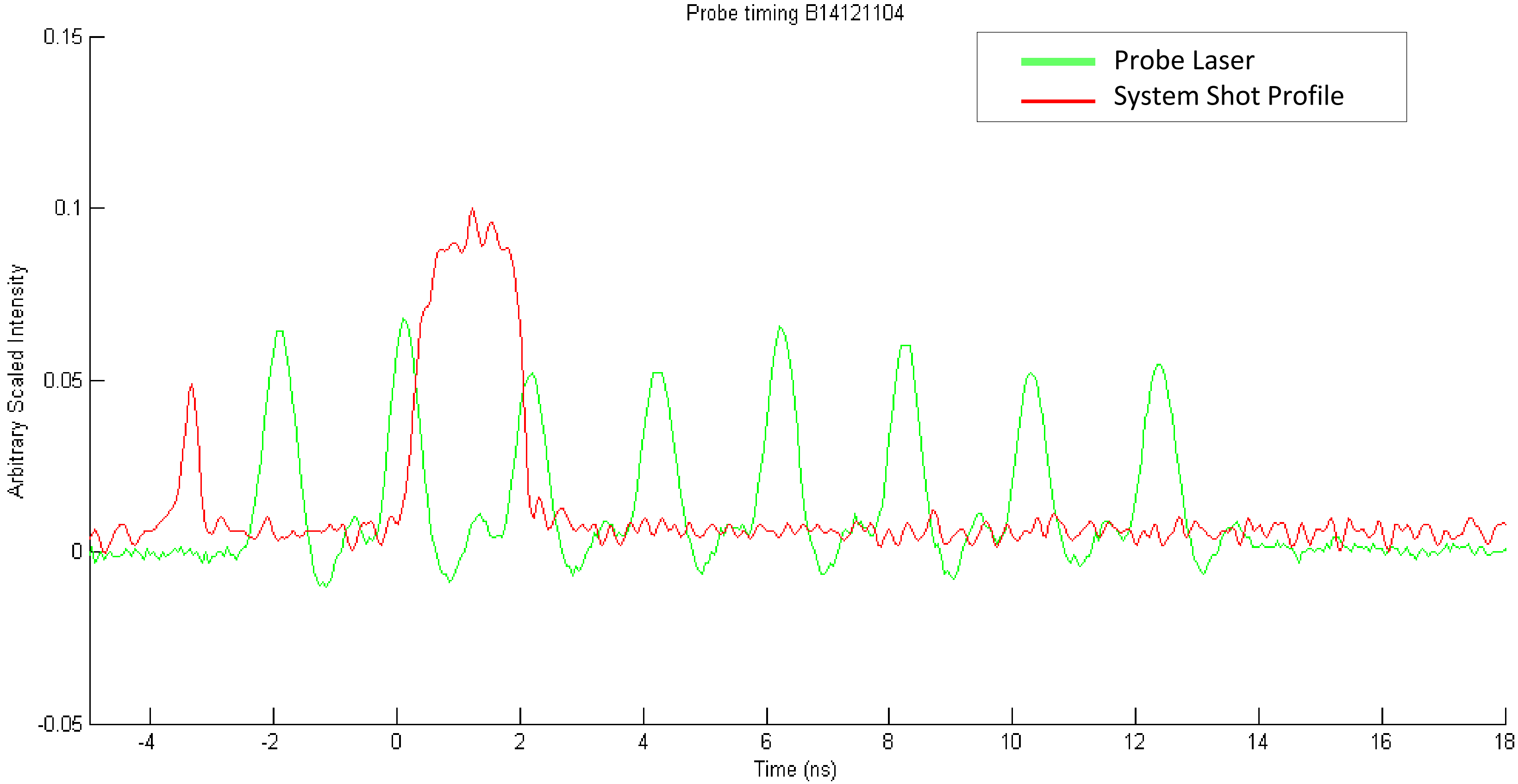
12-11-2014, 250 Torr neon

1.15 mm spot on 1 μm LEH



Courtesy: John Porter, Mark Kimmel, Sean Lewis

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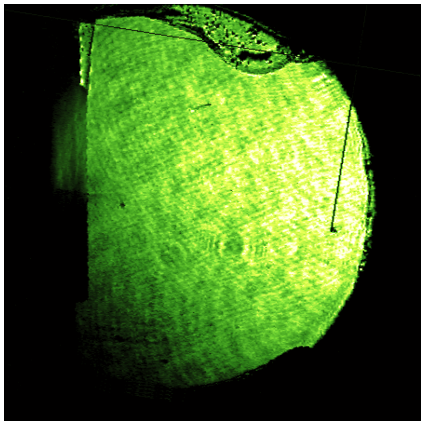
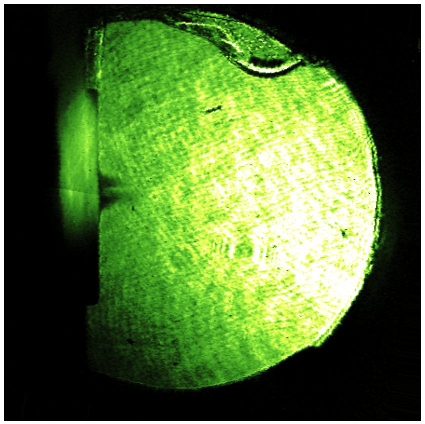
8-frame probe beam B14121104

1µm LEH, ~2kJ


-2 ns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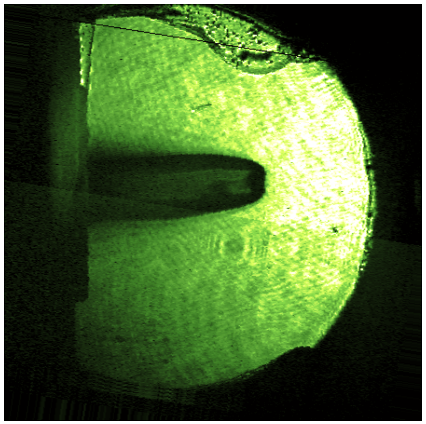
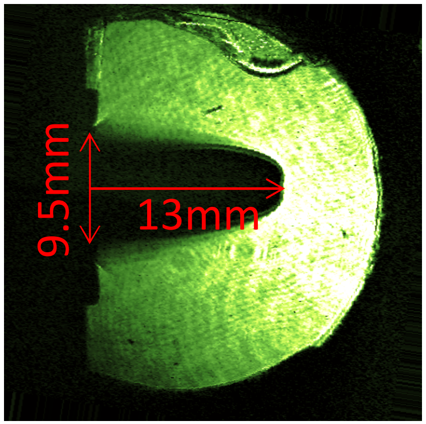
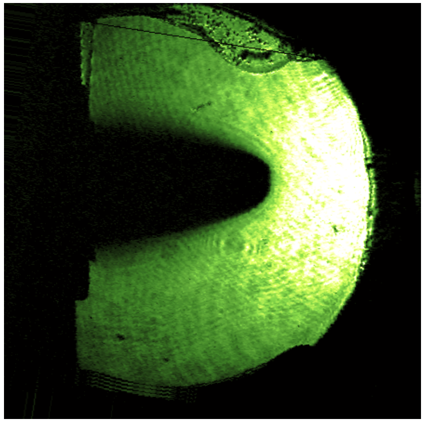
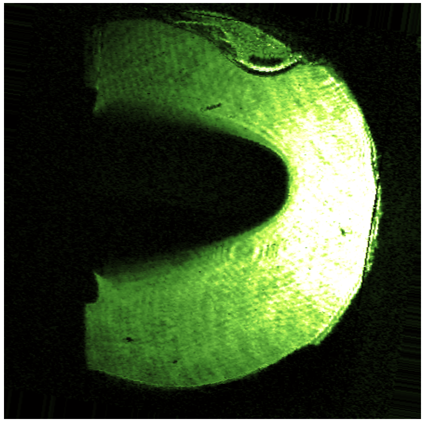
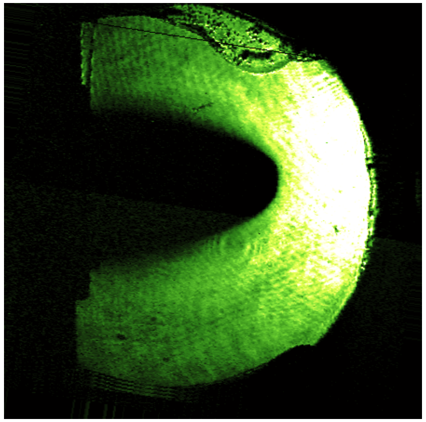

2 ns

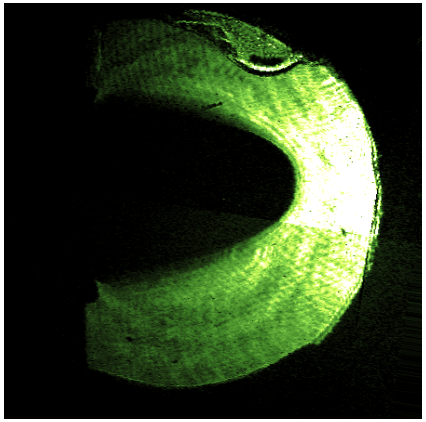


4 ns


6 ns

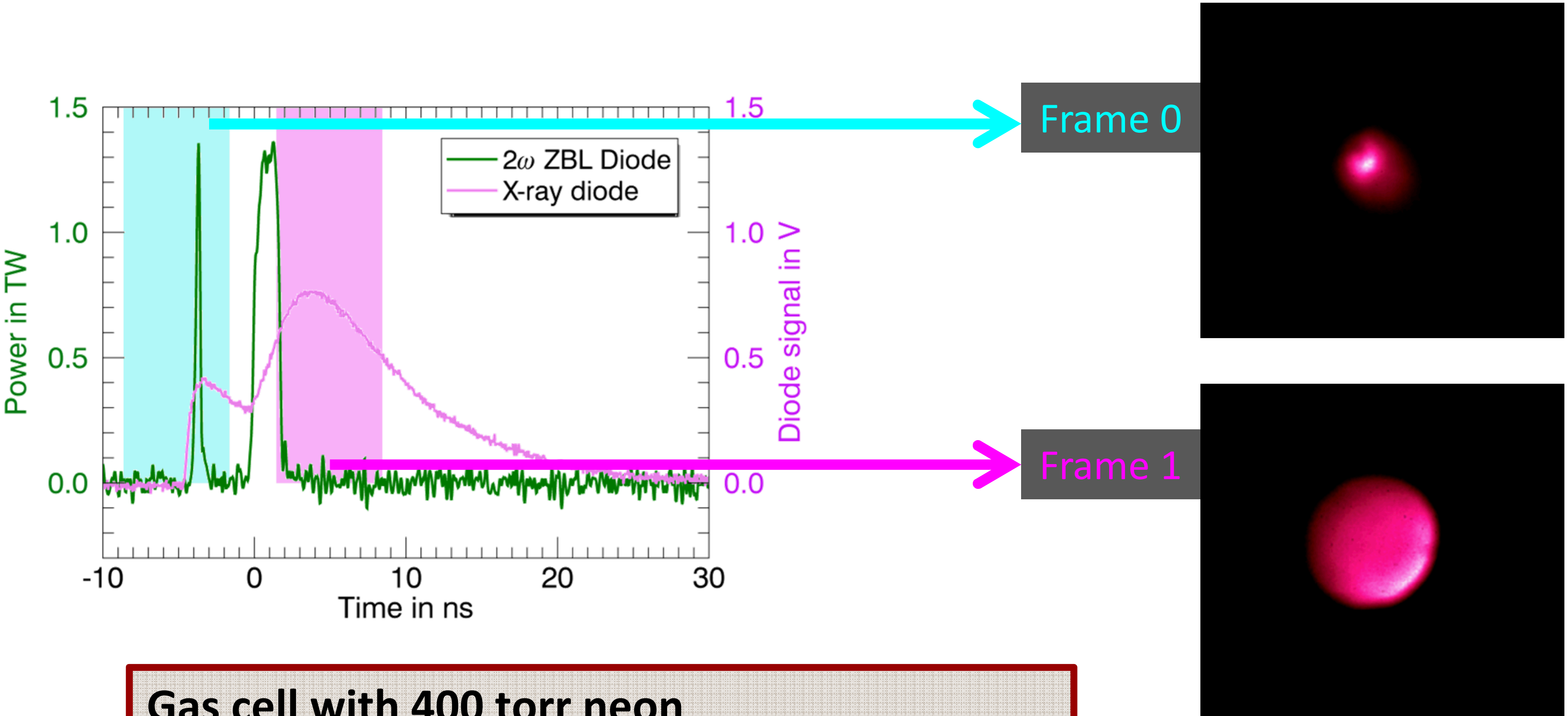

8 ns


10 ns


12 ns

Axial Imager

First Time Resolved Data in Pecos



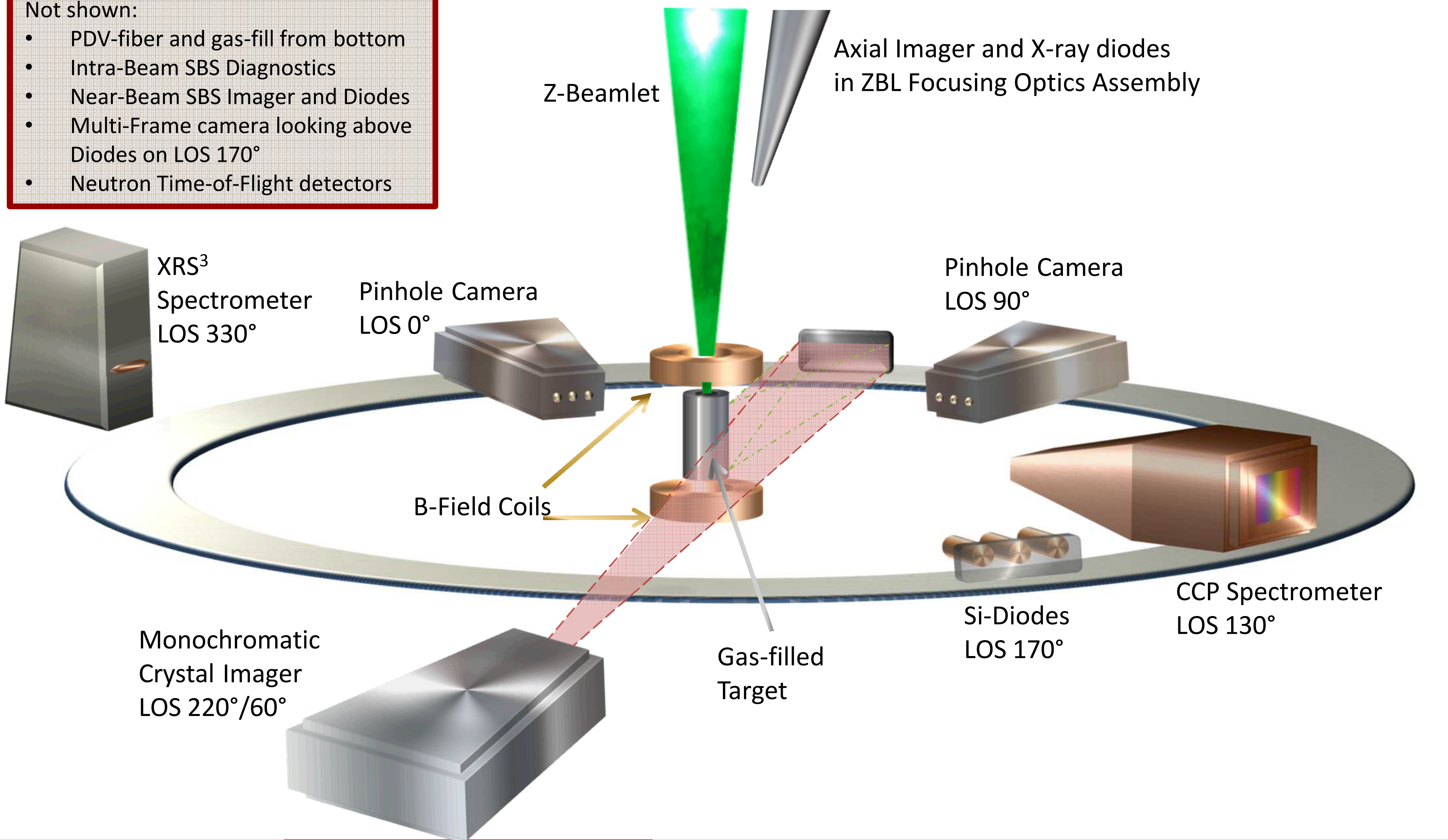
Gas cell with 400 torr neon
1 µm mylar LEH, 1 mm laser spot (defocused)
Frame 0: pre-pulse/LEH response (200 J)
Frame 1: main pulse/gas response (1.8 kJ)

Experiments in Z Center Section

Diagnostic Configuration (not to scale)

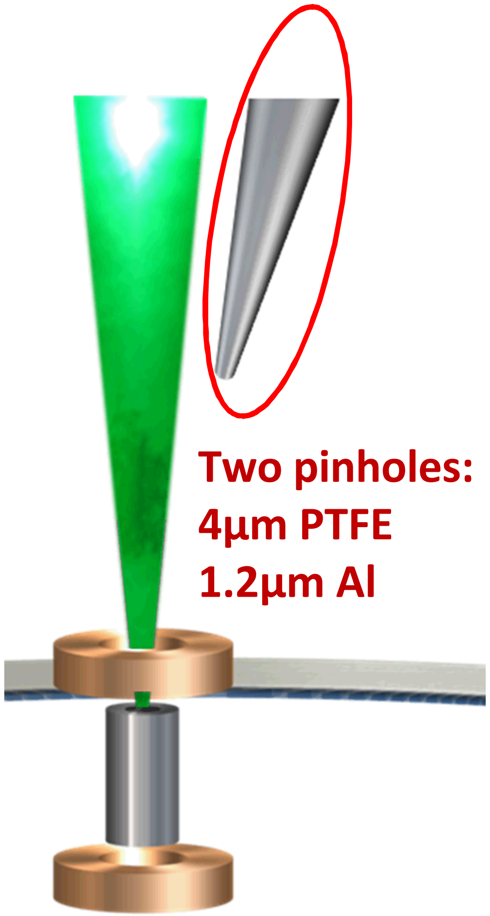
Not shown:

- PDV-fiber and gas-fill from bottom
- Intra-Beam SBS Diagnostics
- Near-Beam SBS Imager and Diodes
- Multi-Frame camera looking above Diodes on LOS 170°
- Neutron Time-of-Flight detectors

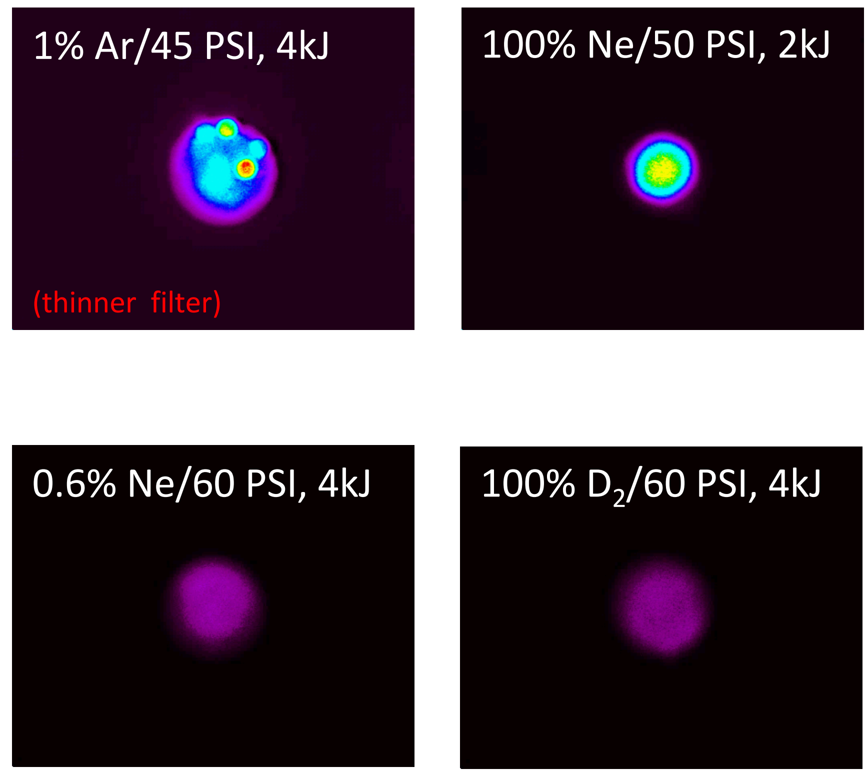


Thermometry for MagLIF

Axial Imager (through LEH)



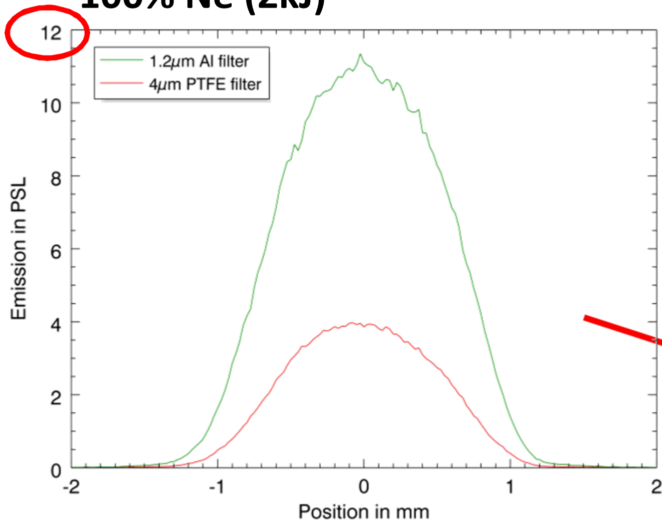
(Ross filtered images, 2nd scan, all on same scale rotational orientation shot-to-shot not verified)



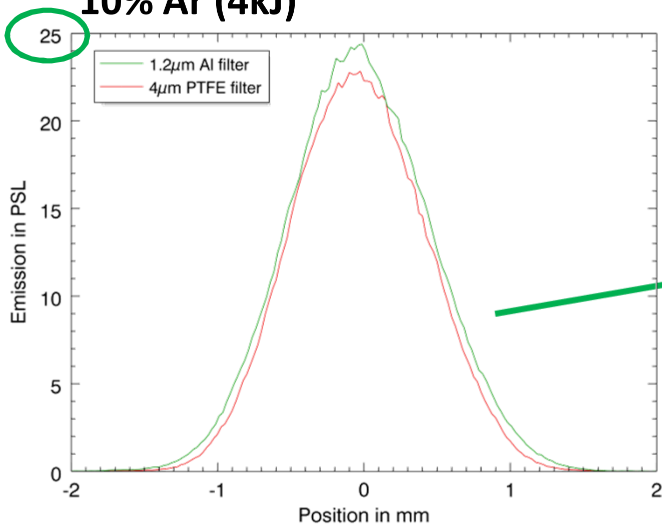
Thermometry for MagLIF

Effectiveness of Ross-Filters

100% Ne (2kJ)

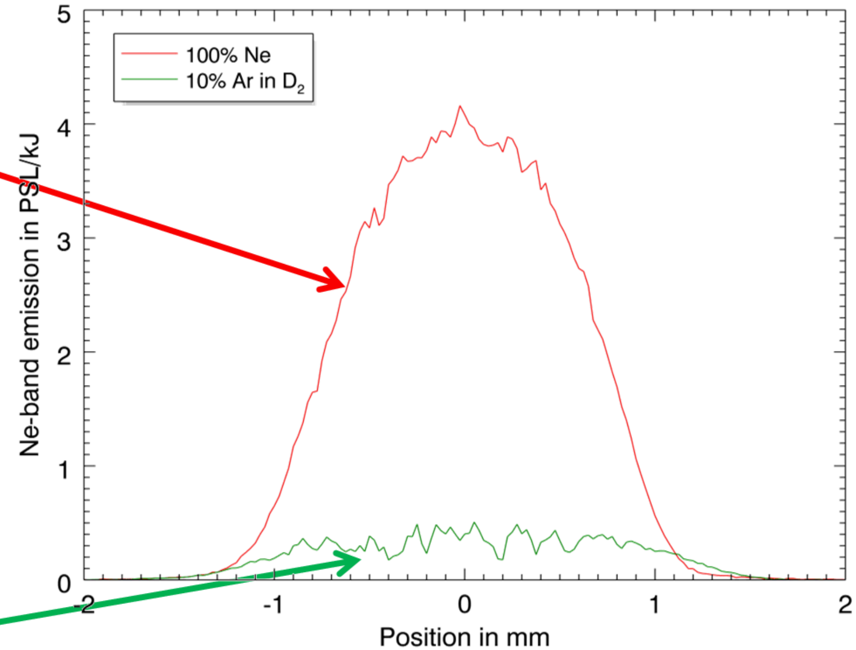


10% Ar (4kJ)



Ross-Pair Difference (Al – PTFE)

(weighed by ZBL main pulse energy)

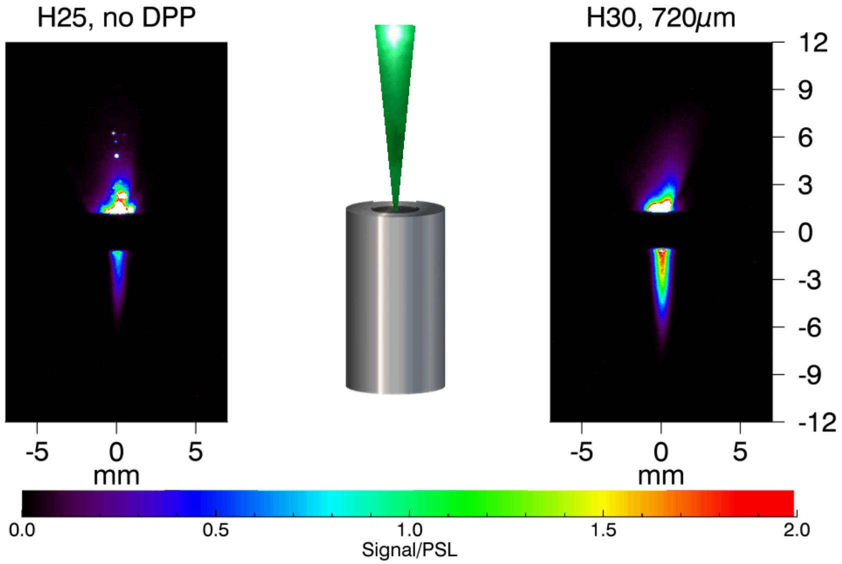


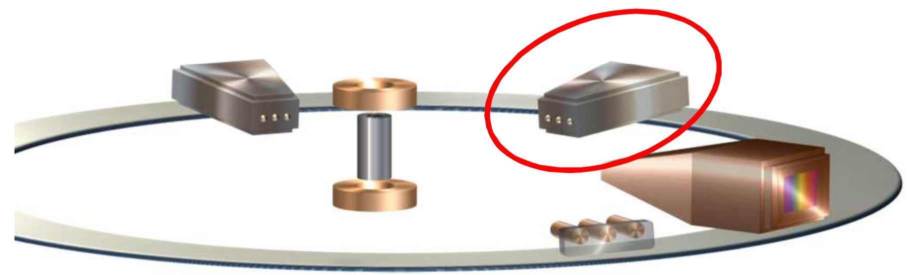
Why we like phase plates:

ZBacklighter

Aperture Ring Camera LOS90

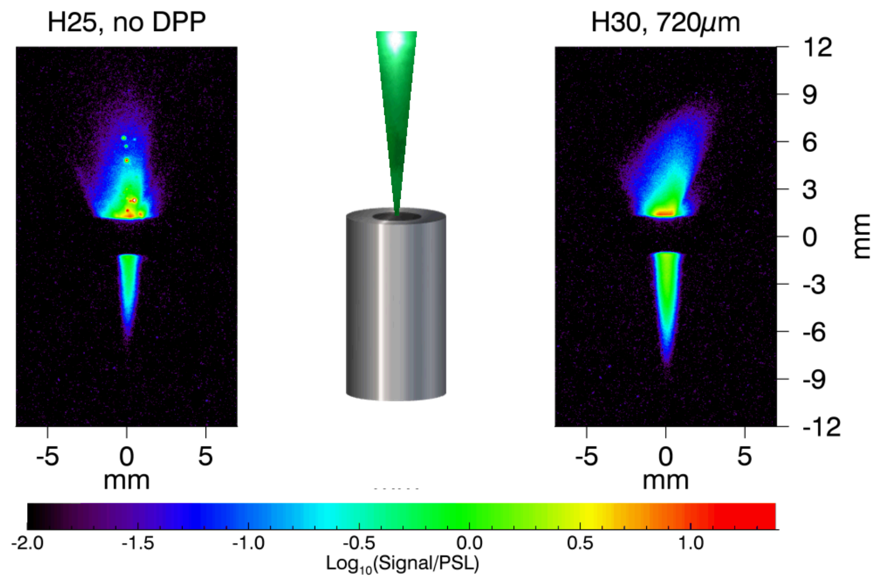
60 psi D_2 with 0.1% Ar-dopant





Linear scale

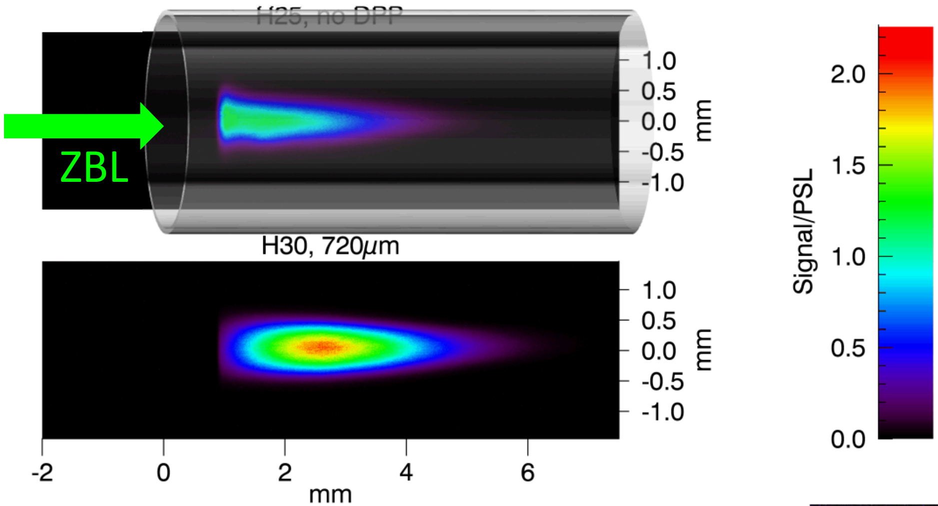
Dust particles hit by laser above LEH in H25.



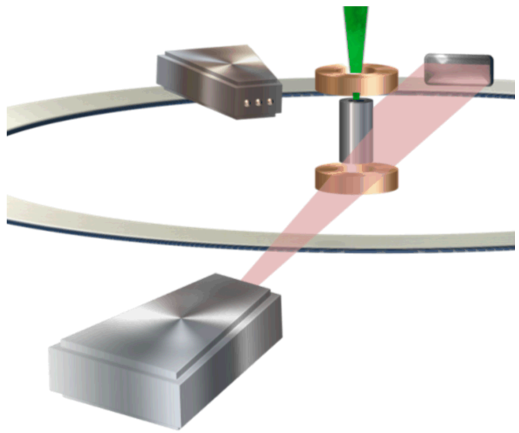
Logarithmic scale: ~ 1.6mm depth increase

3.1 keV Crystal Imager

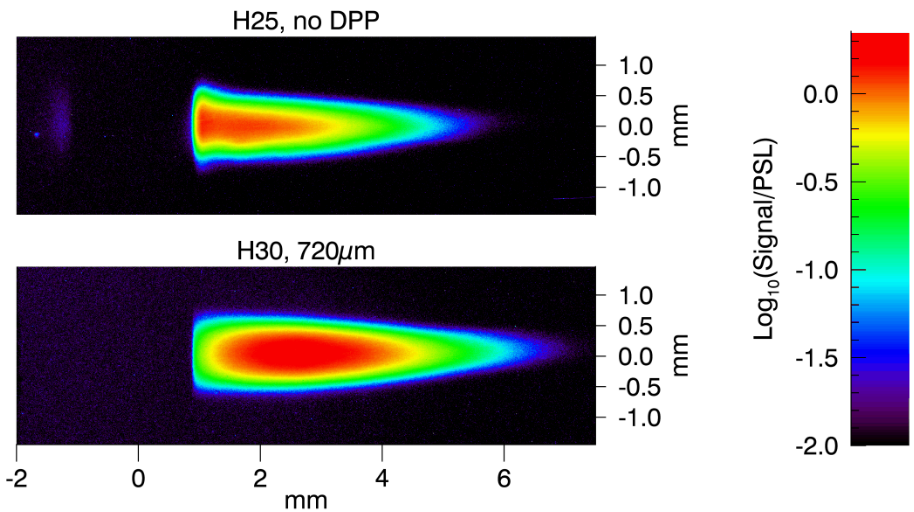
60 psi D_2 with 0.1% Ar-dopant



Linear scale



Scientist in Charge: Erik Harding



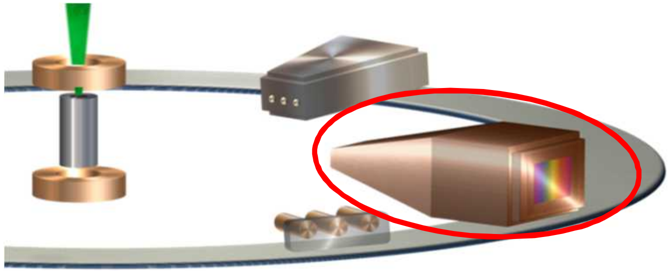
Logarithmic scale

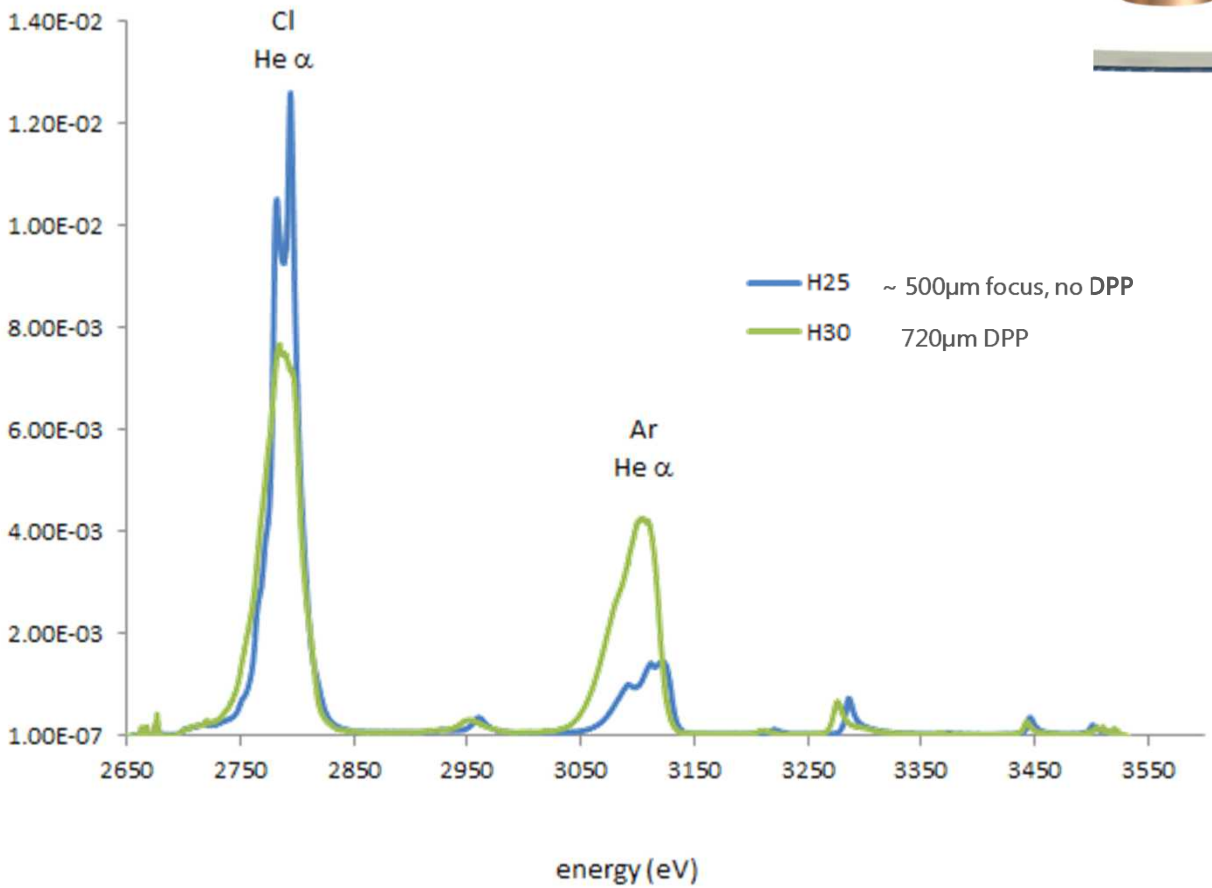
Integral emission H25: **86**k PSL
Integral emission H30: **175**k PSL

~ 1.25mm depth increase (log.)

CCP Spectrometer

60 psi D_2 with 0.1% Ar-dopant





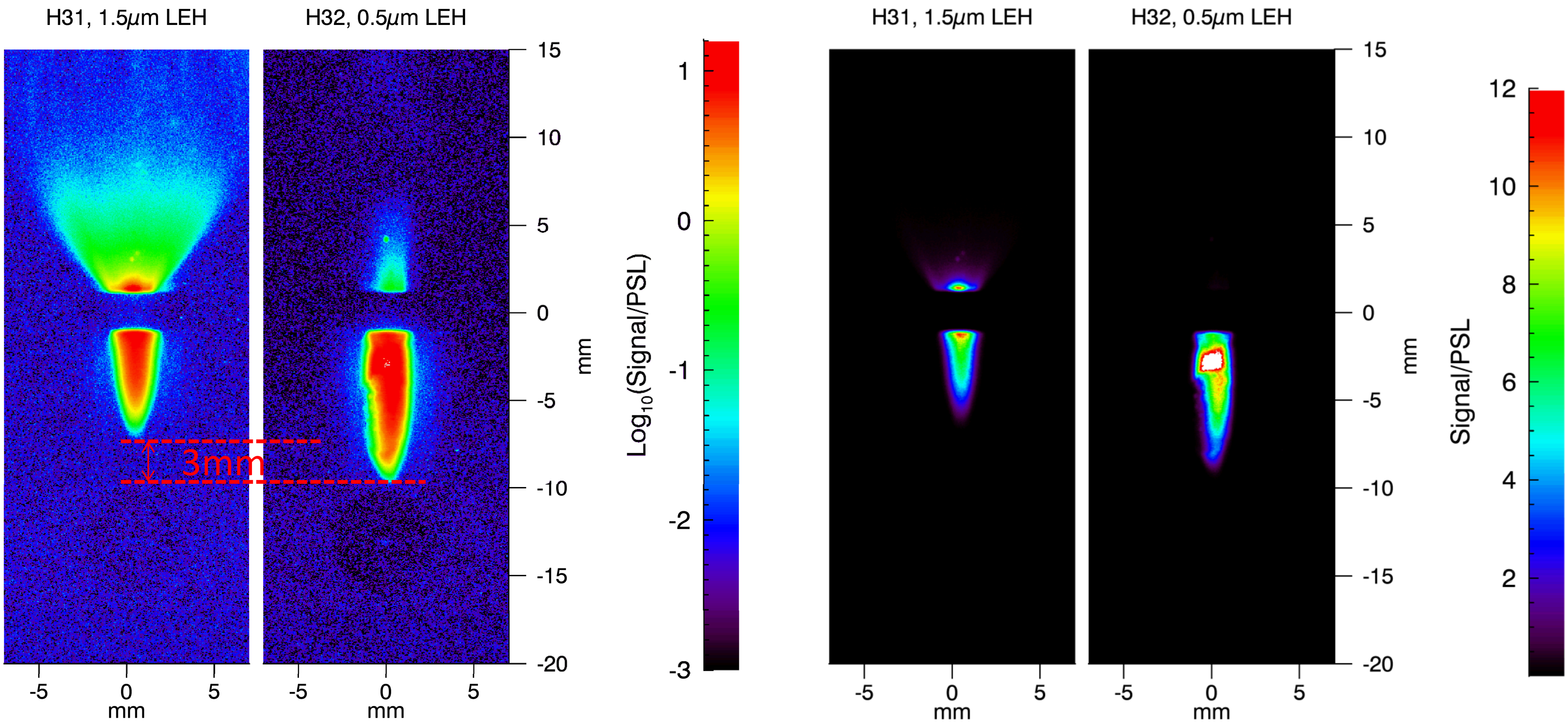
Data analysis: Stephanie Hansen

Why we like thin windows:

ZBacklighter

Aperture Ring Camera

15 psi neon, LOS 90



Logarithmic scale

Linear scale

EXTRAS

ZBacklighter

AXIAT 2 Pre-heat Experiments

Sandia National Laboratories

May 20/21, 2015, with ~720µm diameter LLE phase plate ("DPP")

Shot-#	Old name	Drawing	LEH thickness	LEH purity	Body purity	Gas fill	ZBL Pre	ZBL Main
H30	AXIAT 3	J34326-002	1.5µm	Doped ($CaCl_2$)	Undoped	60 psi D_2 (0.1% Ar)	445 J	2167 J
H31	AXIAT 4	J34326-002	1.5µm	Doped ($CaCl_2$)	Undoped	15 psi Ne	468 J	2263 J
H32	AXIAT 1	J34326-000	0.5µm	Undoped	Doped (HNa_2OP)	15 psi Ne	525 J	2338 J

ZBL Pre-pulse lead time: 3.7ns (pre-peak to half-height of main).
Main pulse time: (TZn)-3043.3 ± 0.1 ns. 3044 requested.

H30 compares to H25 and H28 (LASPE 2):

Shot-#	LEH thickness	Gas fill	ZBL Pre	ZBL Main	Phase Plate
H25	1.5µm	60 psi D_2 (0.1% Ar)	496 J	2357 J	(none)
H28	1.5µm	60 psi D_2 (0.1% Ar)	438 J	2087 J	(none)
H30	1.5µm	60 psi D_2 (0.1% Ar)	445 J	2167 J	720 µm

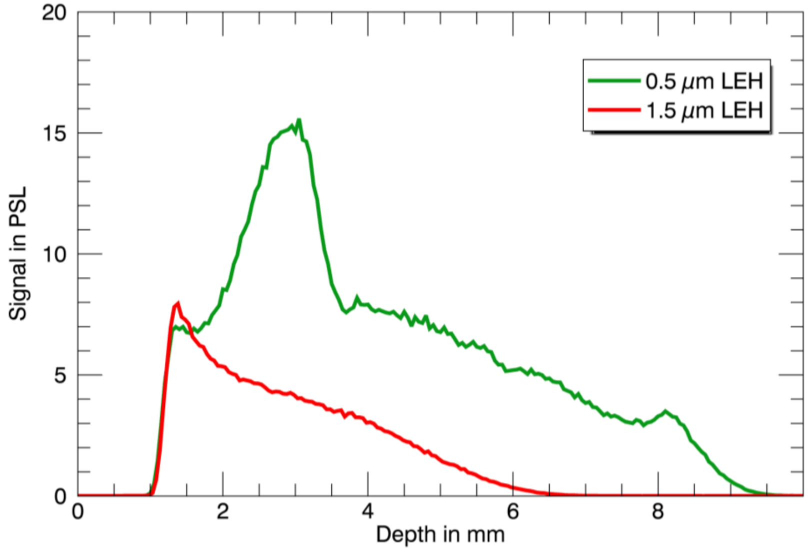
Benefit of LLE's Phase Plate

Comparison of April's LASPE 2 series with AXIAT 2 series:

- **60 psi Deuterium fill**
- **0.1% Argon dopant**
- **1.5 μm polyimid window**
- **460 J ± 7% pre-pulse**
- **2200 J ± 7% main pulse**
- **No phase plate in April, 720 μm diameter phase plate in May.**
- *H28 probably had a partial hit on the LEH washer: dismissed.*

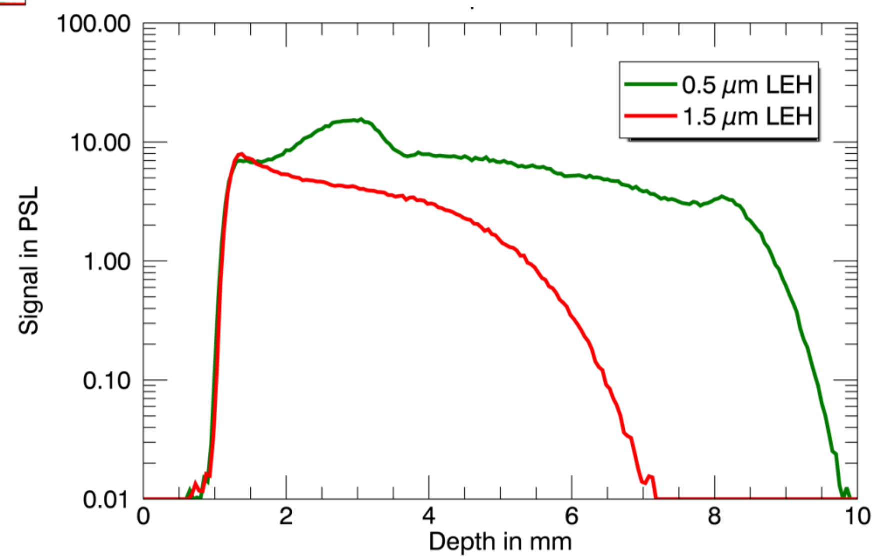
Aperture Ring Camera

15 psi neon, LOS 90



3mm more penetration with 0.5mm LEH.

Linear scale

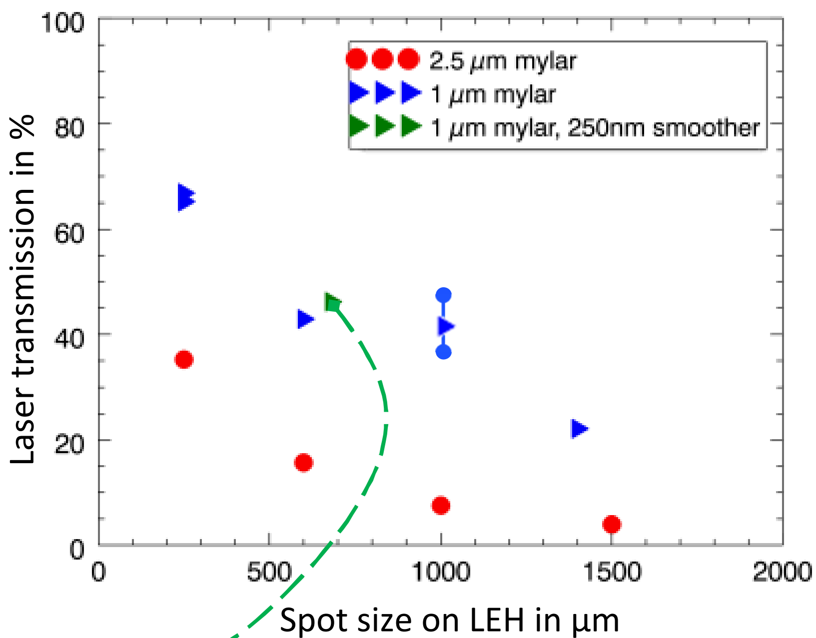


Logarithmic scale

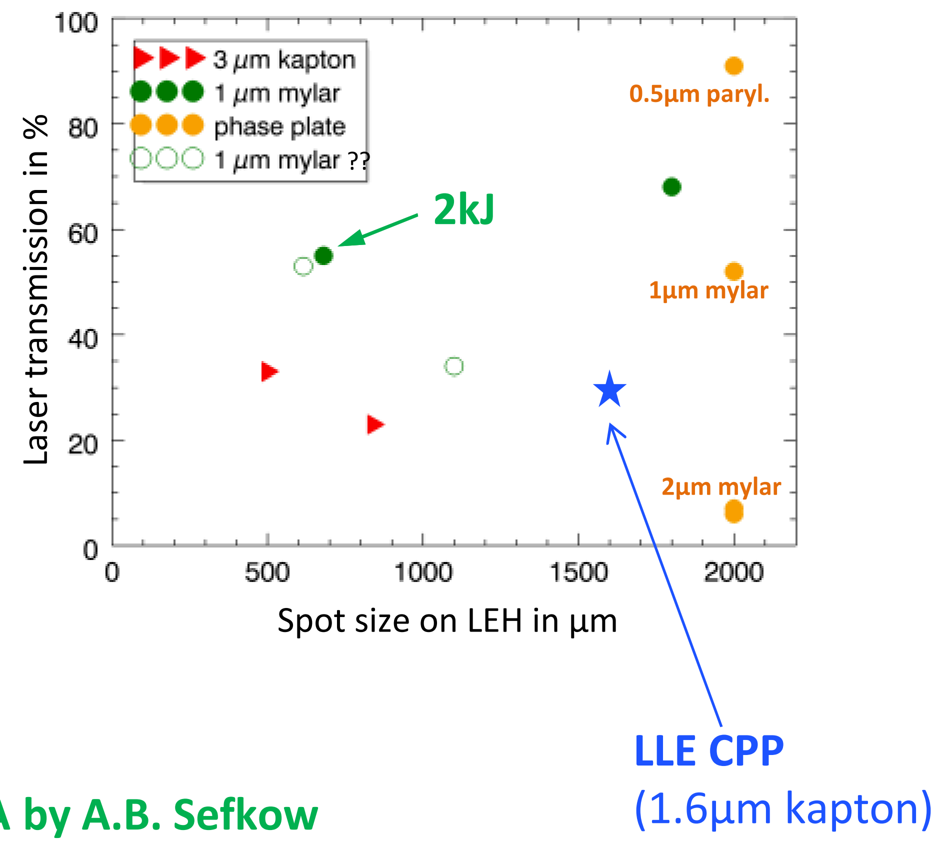
Comparison Graphs

Summary of Results

2 kJ laser pulse, no smoothing



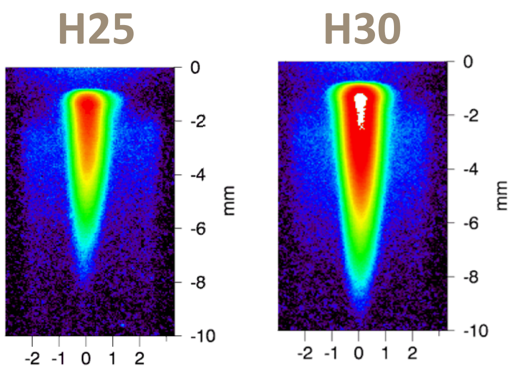
4 kJ laser pulse, smoothing

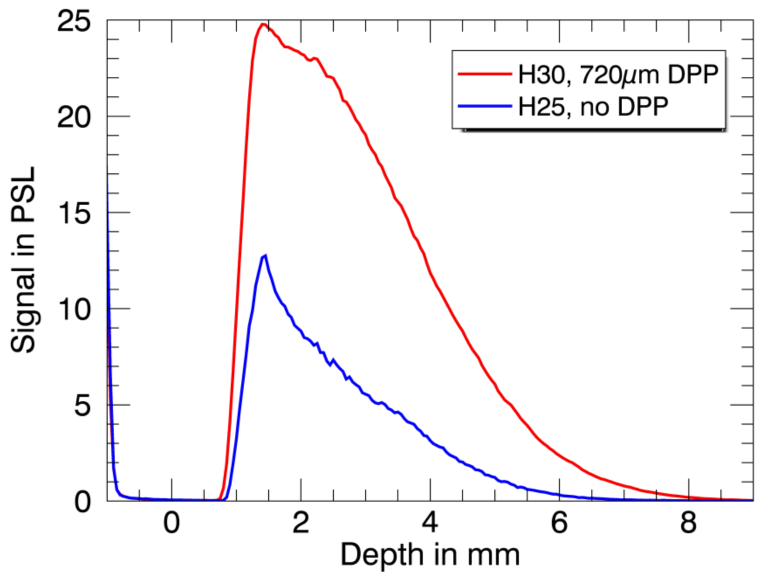


Result was reproduced with HYDRA by A.B. Sefkow using experimental observation of smoothing foil output!!

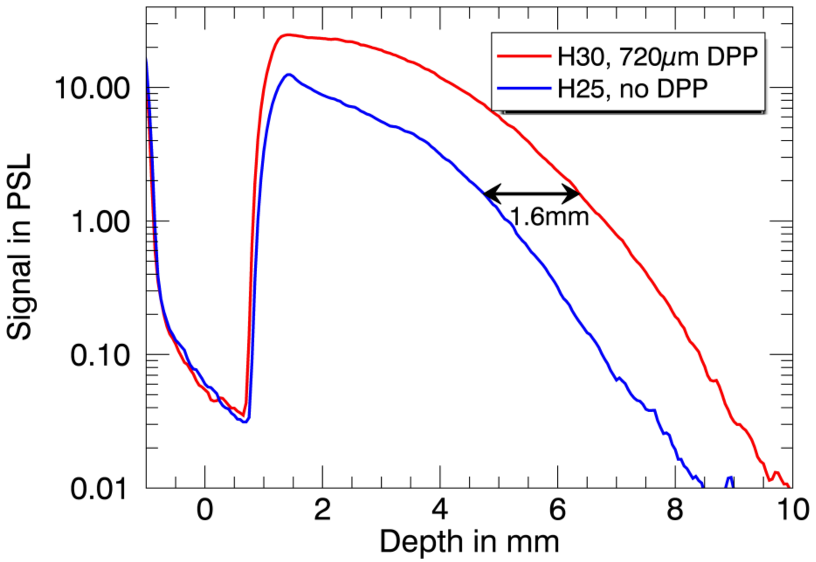
Aperture Ring Camera LOS90

60 psi D_2 with 0.1% Ar-dopant





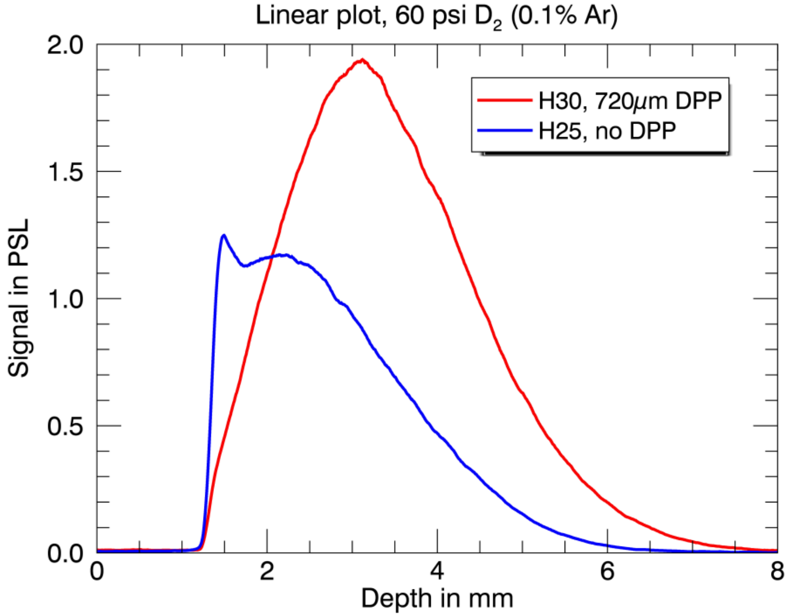
Linear scale



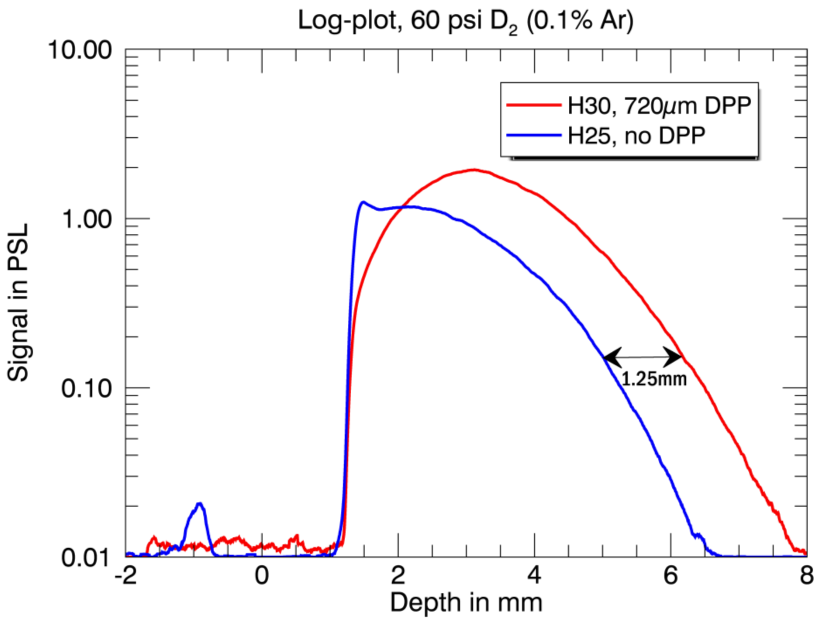
Logarithmic scale

Argon Imager

Lineouts, smoothed over 125 µm box



At least 1.25mm more penetration with DPP



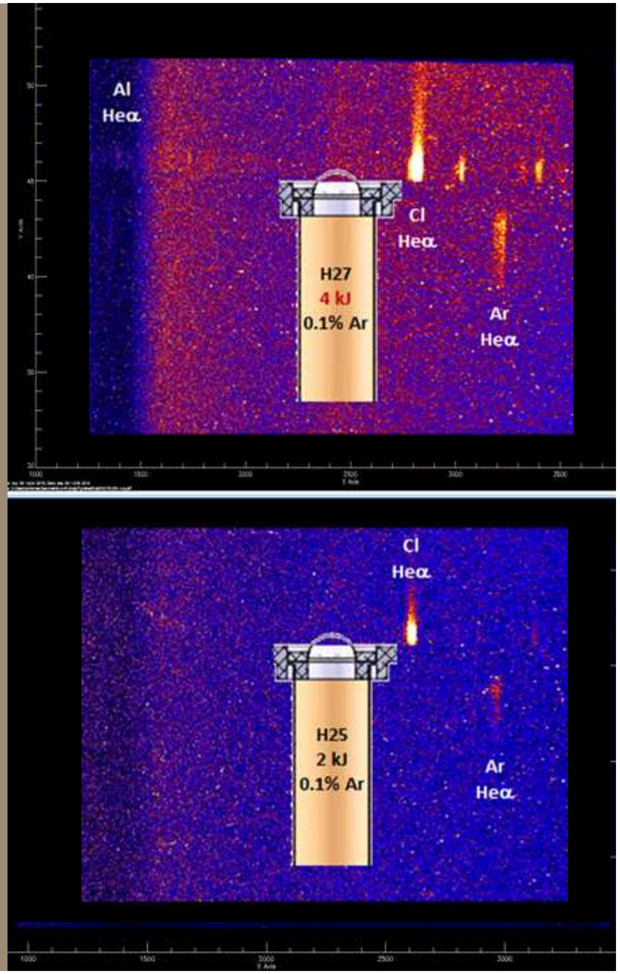
Linear scale

Logarithmic scale

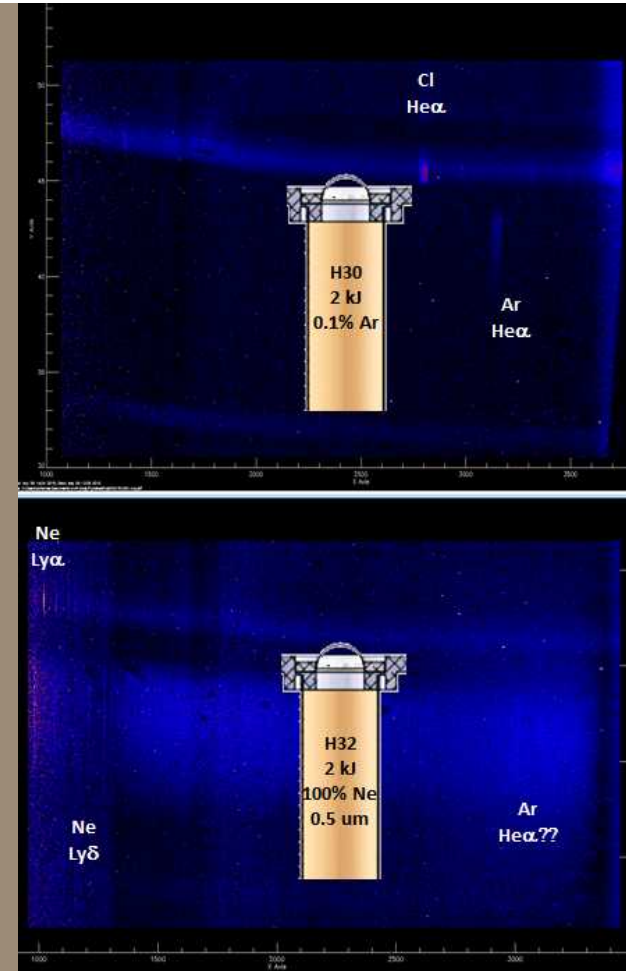
CCP Spectrometer

60 psi D_2 with 0.1% Ar-dopant

LASPE: no DPP, high noise



AXIAT: 720µm DPP, low noise



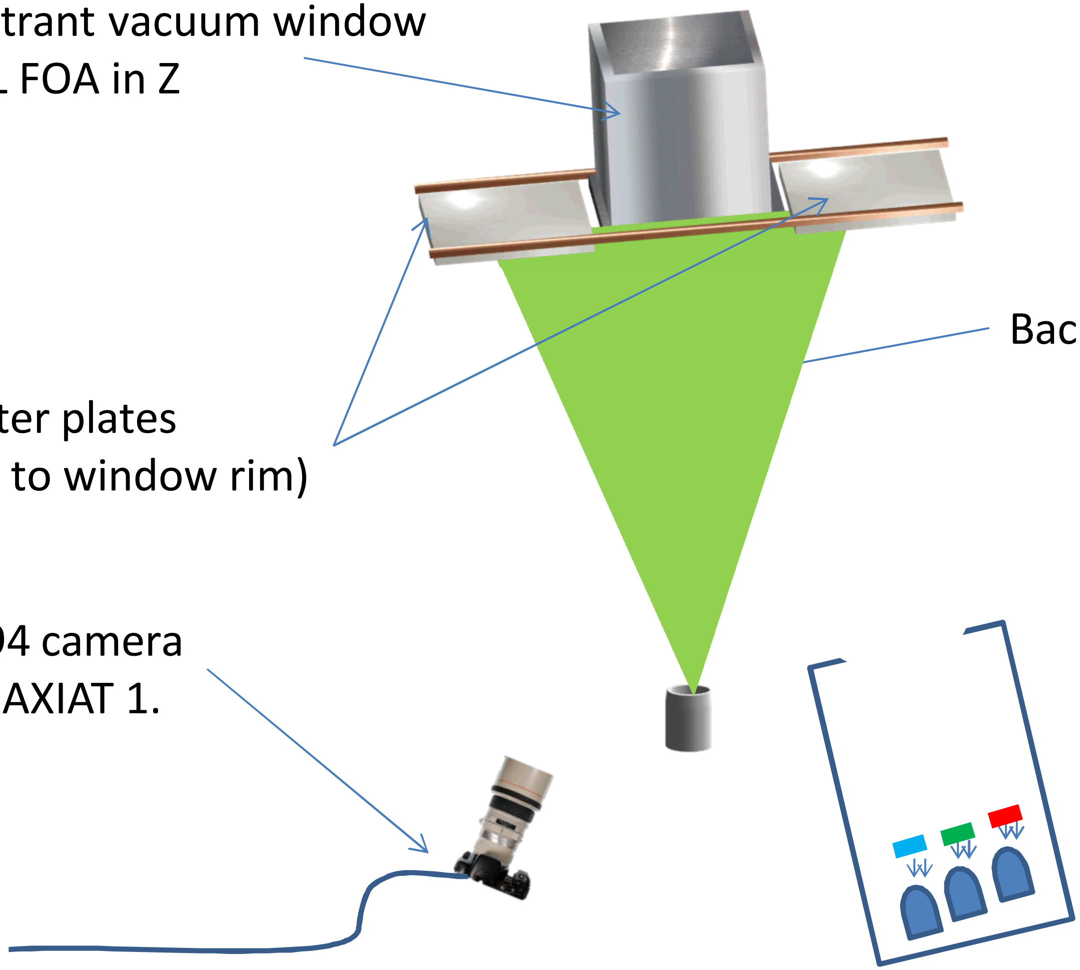
Acknowledgement:
Stephanie Hansen, data analysis

Benefit of reducing LEH to 0.5µm

- 15 psi Neon fill
- 1.5 µm polyimid window on H31, 0.5 µm on H32
- 500 J ± 6% pre-pulse
- 2300 J ± 2% main pulse
- 720 µm diameter phase plate.

SRS/SBS (see also LASPE)

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.

NEW:

Filtered SRS diode array in Collimator-can with vis. filters (600nm – 1µm)