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Overview of the NNSS Radiography and Advanced Imaging Development (RAID) Project

Dan Clayton, Project Manager

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The RAID project supports radiography and advanced diagnostic research and development across the NNSA complex

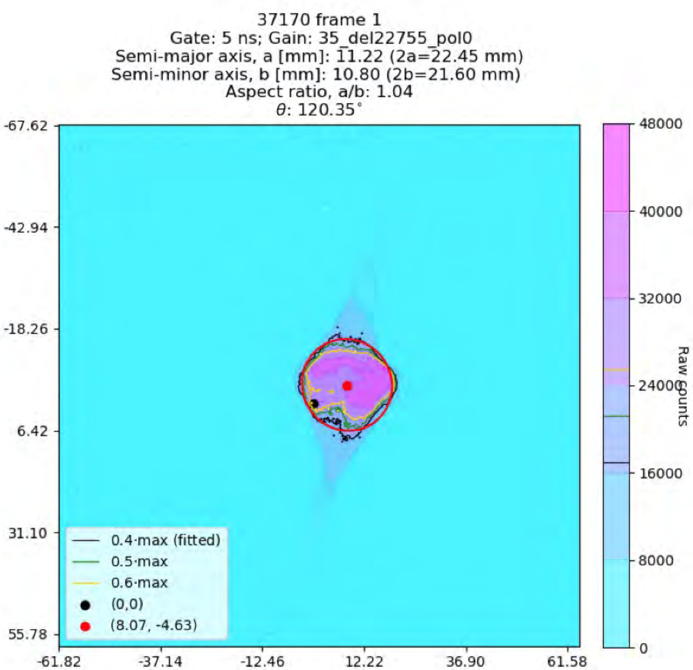
- Today's presentation is an overview of all work within the Radiography and Advanced Imaging Development RAID Project
- Our current work at pRad includes transverse x-ray radiography and automated beam tuning on Lines X/C (with AOT)
  - We are deemphasizing work on motion control systems but will continue to support legacy systems
- My goal for today's meeting is to begin answering two questions:
  - Are there other areas where we can contribute to the pRad mission?
  - Are there topics within RAID for which you would like a follow-up presentation from an SME?

The RAID project supports radiography and advanced diagnostic research and development across the NNSA complex

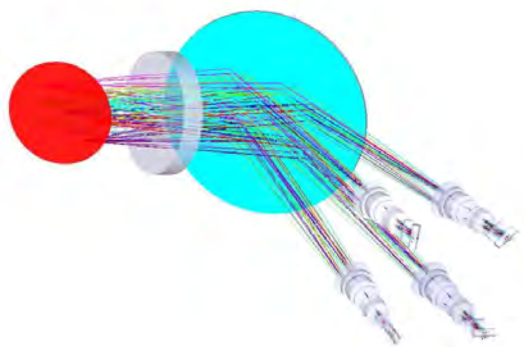
- Advanced Diagnostic Development
  - Beam Diagnostics and Automated Tuning
  - Beam-Target Interaction Studies
  - Continuous Imager
  - Multi-pulse Cold Cathode Studies
  - Source Spectra Monitors
  - Time-Resolved Detector R&D
- Experimental Applications
  - Camera System Development
  - Ejecta Diagnostics and Radiography
  - FXR Imaging
  - Multi-probe Radiography
  - Neutron Imaging
  - Radiographic System Design

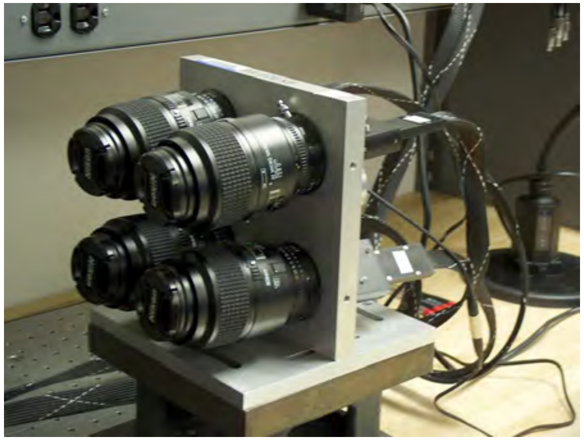
Beam Diagnostics and Automated Tuning: OTR is used to measure the beam spot in DARHT Axis 2 downstream transport

- Optical transition radiation from a thin foil is imaged with a CCD camera, or with anamorphic multi-view tomography



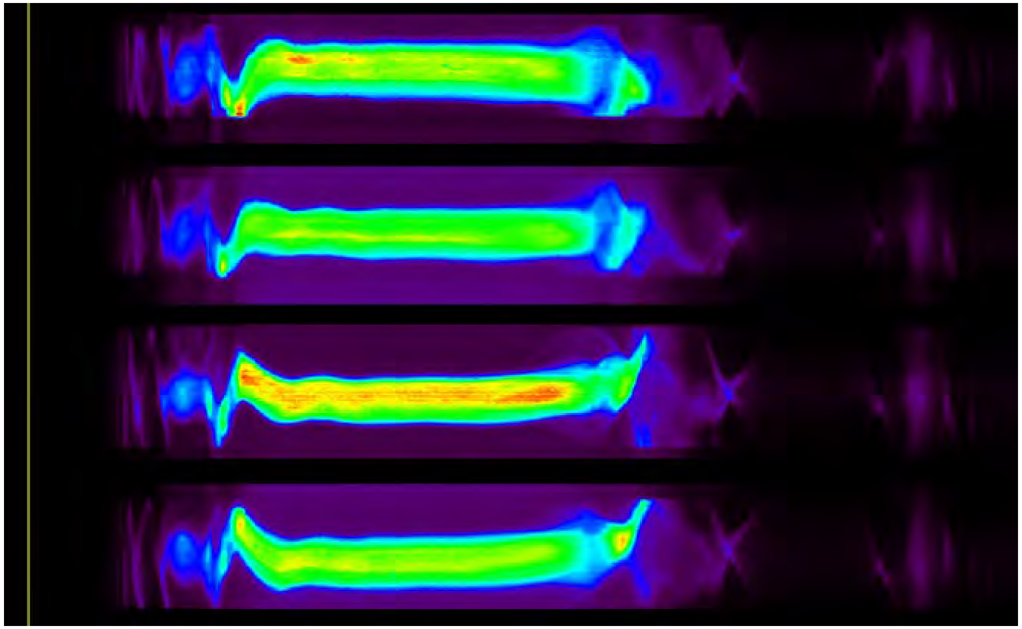
Beam spot image taken with PI-MAX4 ICCD camera, fit with ellipse to measure beam size, taken during DARHT Axis 2 recommissioning in 2021.



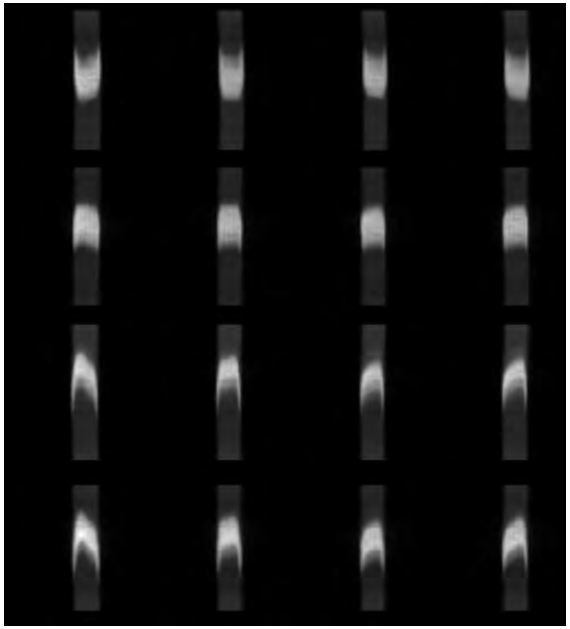


Anamorphic 4-view tomography lens system

Beam Diagnostics and Automated Tuning: Old streak cameras are being replaced with new digital system in anamorphic diagnostic

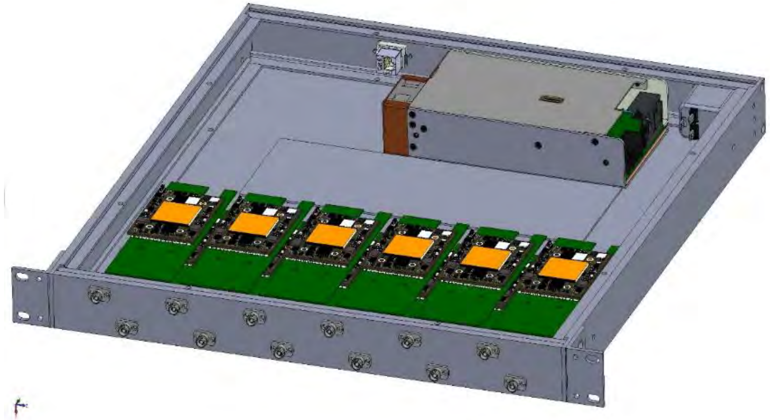


Streaked images of a single DARHT Axis 2 pulse



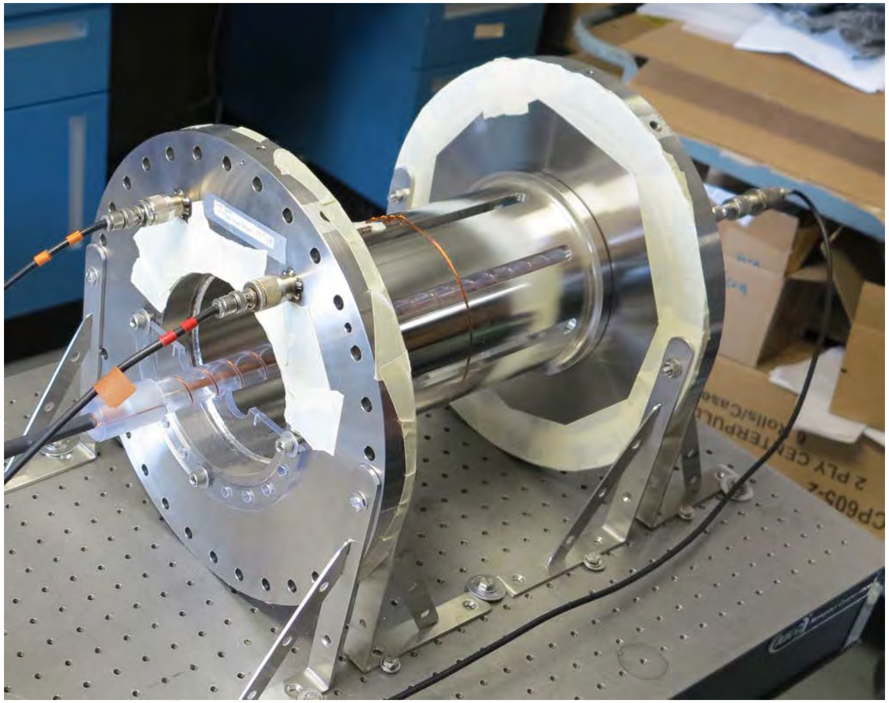
Streaked images of four DARHT Axis 2 pulse

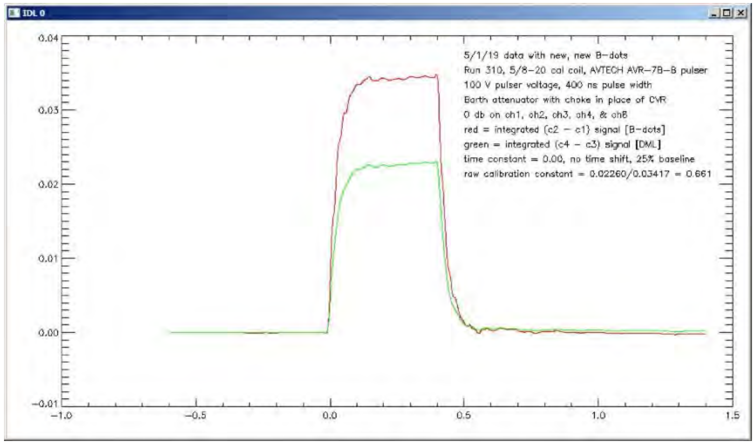
Custom digitizers with onboard APDs are being tested as a replacement for streak cameras

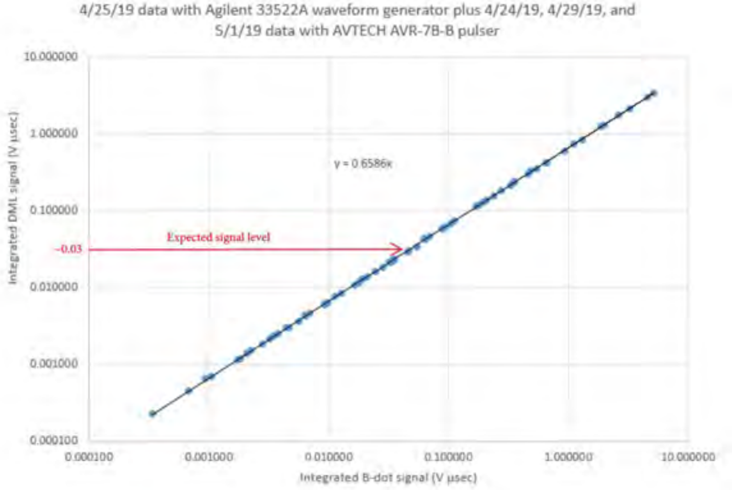


Beam Diagnostics and Automated Tuning: Diamagnetic loops are noninvasive diagnostics that can measure beam radius

- A coil inside a solenoid measures the diamagnetic field flux generated by a passing beam; directly related to beam radius



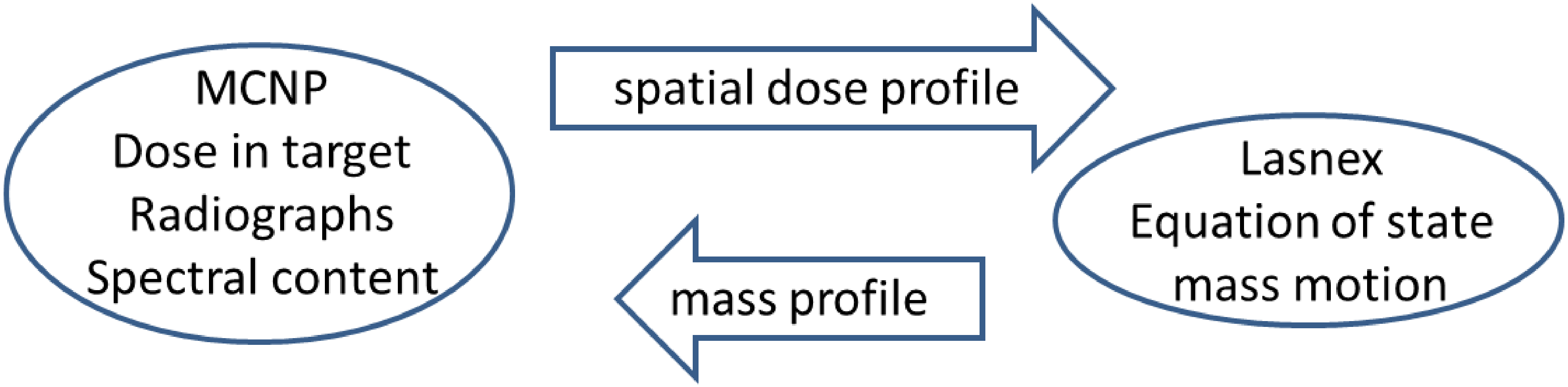




Bench tests successful, will now be tested on DARHT Axis 1 downstream transport

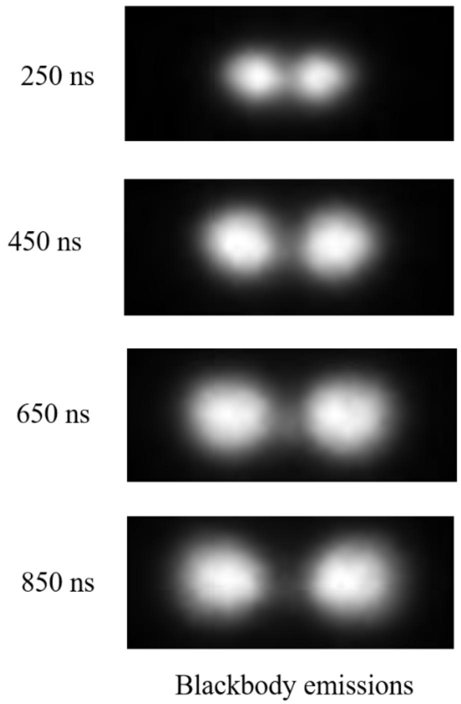
Beam-Target Interaction Studies: A suite of simulation codes are used to model the beam target evolution and resulting radiation transport

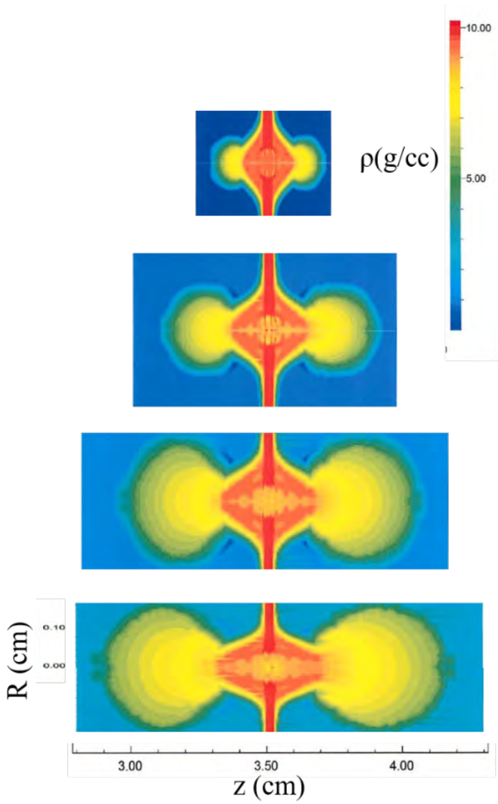
- The beam-target physics is modeled using a suite of three codes
  - LSP particle-in-cell code to model the beam and beam-plasma effects
  - MCNP code to model beam energy deposition into the target and radiation transport
  - LASNEX hydrodynamic code to model target mass evolution between each beam pulse



Beam-Target Interaction Studies: Experiments are planned to constrain simulations of multi-pulse beam target evolution

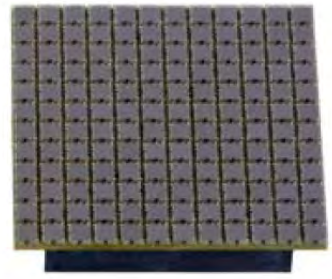
- Beam-target physics will be measured with a suite of diagnostics
  - X-ray radiography to measure mass density
  - Optical spectroscopy to measure electron temperature
  - Optical imaging to measure particle velocity

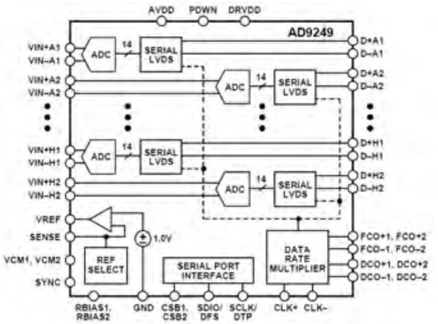




Continuous Imager: A new imaging system will use a 36x36 pixel array of SiPMs, with each individual pixel digitized

- The continuous imager prototype will use Omsemi 12x12 SiPM arrays. Each pixel has a peak wavelength response at 420nm and is comprised of 4,774 microcells.
- Pixels will be digitized using Analog Devices AD9249 IC. This 10 mm x 10 mm package houses 16 individual digitizers. These ADCs can provide imaging as fast as 16 ns.
- Data will be processed and stored in Intel Cyclone FPGAs. Each will store over 100 µs of data from 16 pixels, eliminating the need for external RAM.





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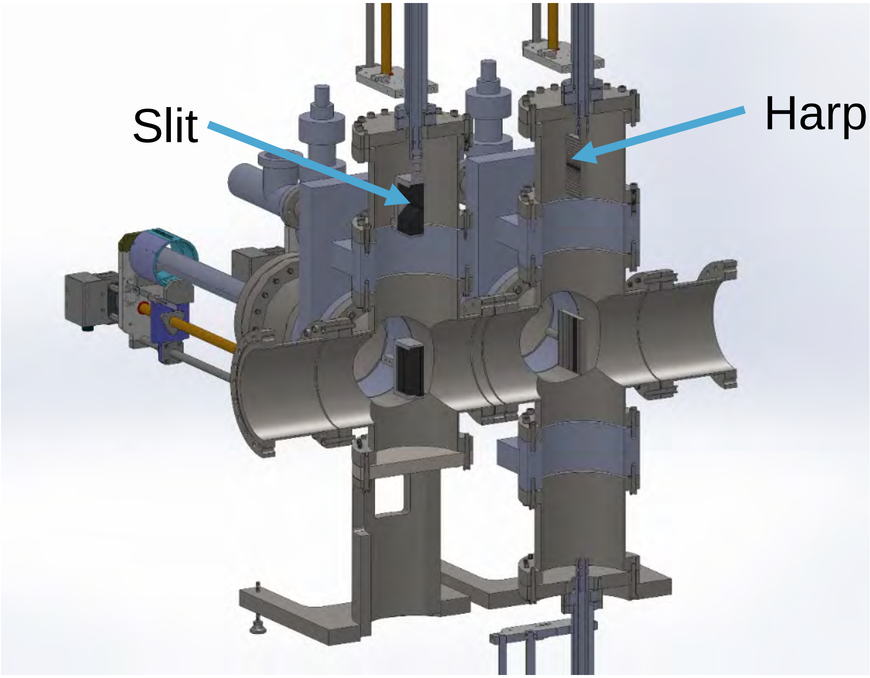
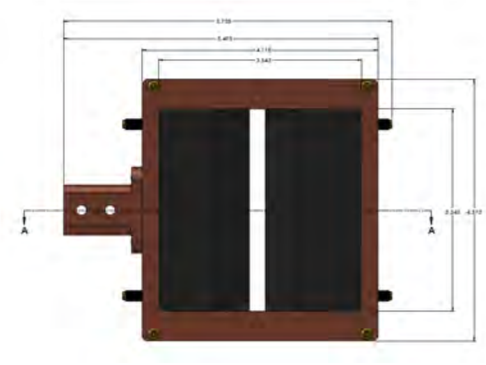
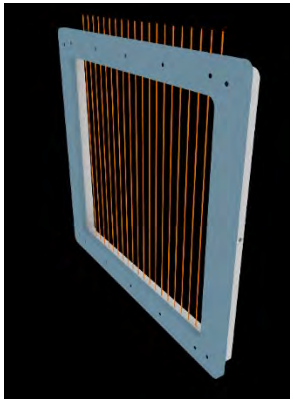
Multi-pulse Cold Cathode Studies: New “slit-harp” diagnostic will measure beam emittance from the injector

- Beam emittance limits radiographic spot size
- LIAs currently have no way to measure emittance at injector
- The slit is scanned across beam diameter while the harp measures the beam divergence





Adjustable graphite slit



Tungsten wire harp

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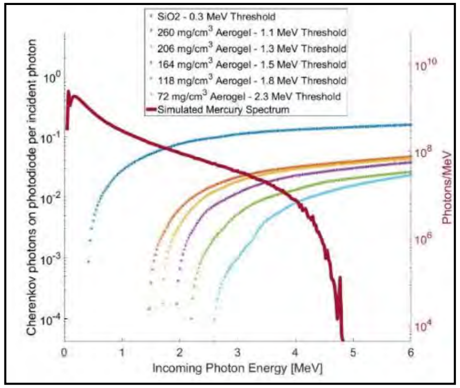
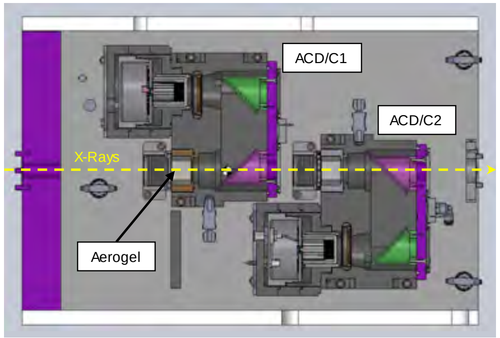
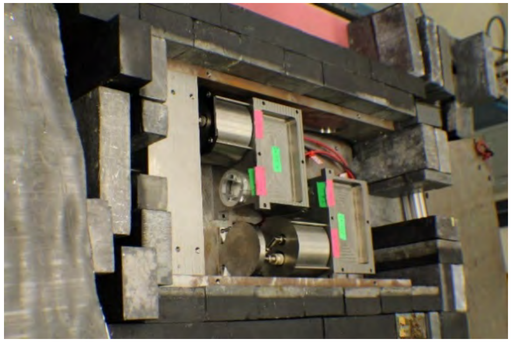
Source Spectra Monitors: Ross filter diode arrays and Cherenkov detectors are being tested as x-ray source spectra monitors

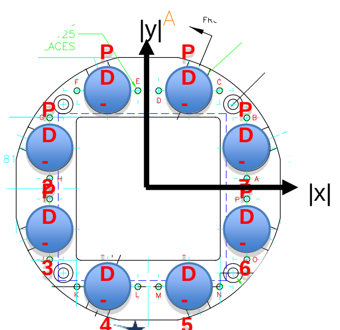
- Aerogel Cherenkov detectors use aerogels with different energy thresholds to measure spectra

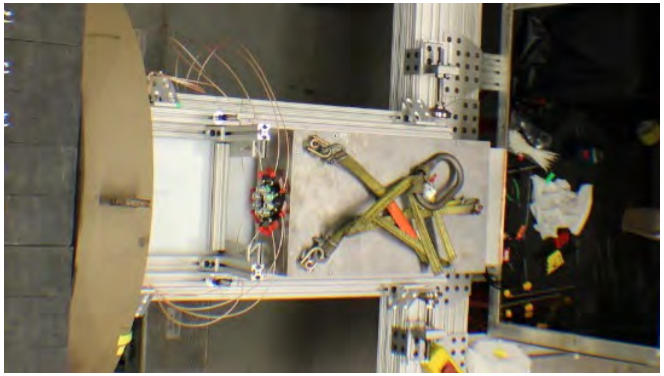


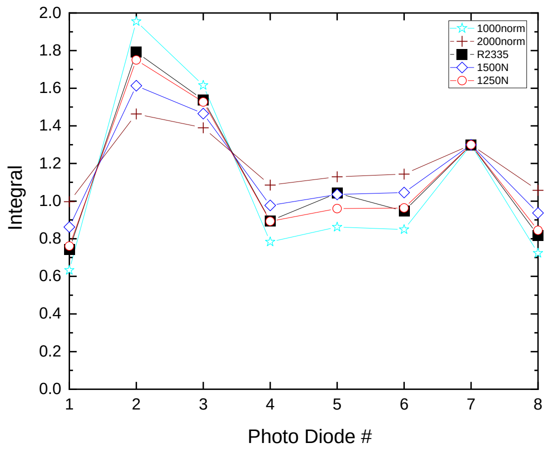




- Ross filter diode arrays use filters with different x-ray attenuation to measure spectra

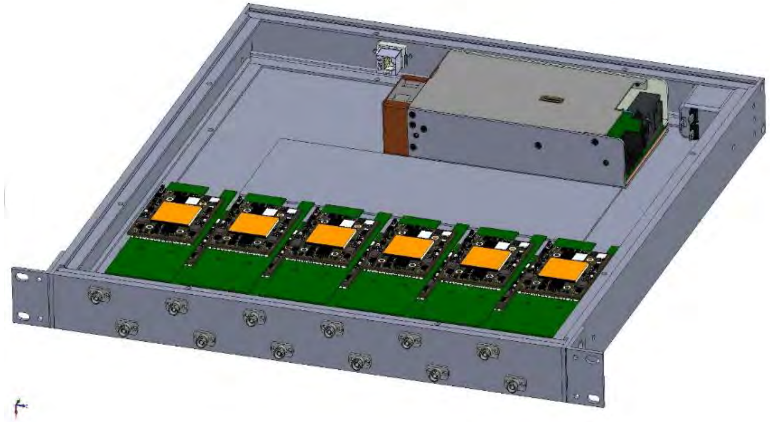






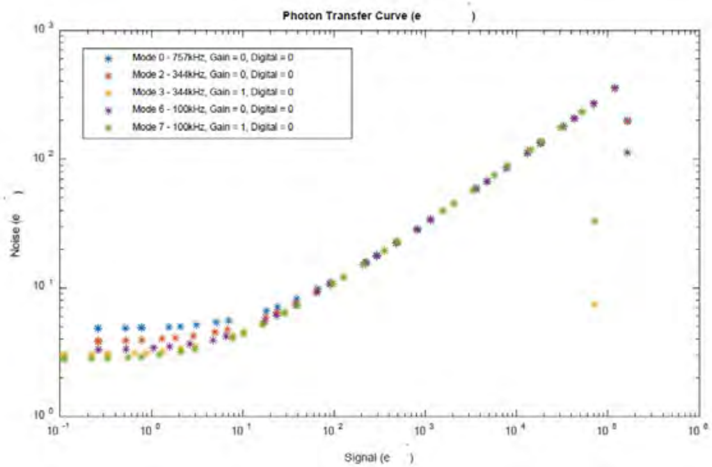
Time-Resolved Detector R&D: New digital radiance diagnostic will be combined with filtered surface imaging for Excalibur

- Multiple imagers with different filters will provide radiance imaging
  - Standard surface imaging probe has already been designed
  - Beam splitters will relay images to four 8-frame filtered Kraken cameras
- A small set of points will be calibrated with time-resolved radiance
  - Single-point probes will use fiber-coupled filter boxes to measure spectrum
  - Redesigned APD/digitizer boards, with diodes more sensitive to IR, will provide GHz time resolution

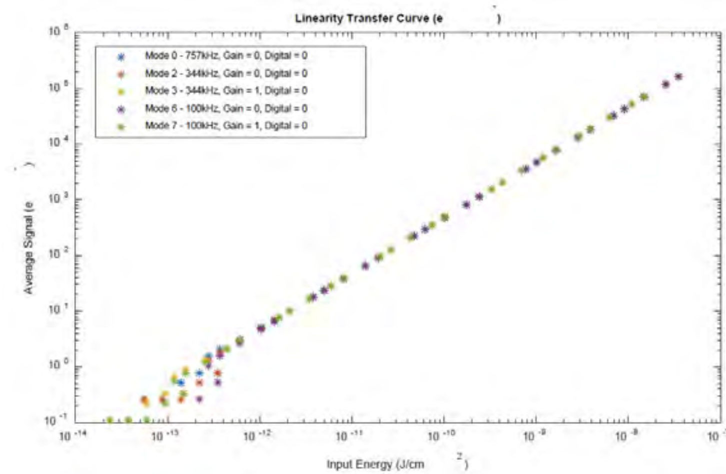


Camera System Development: Camera dark boxes are used to characterize all new cameras before they are fielded

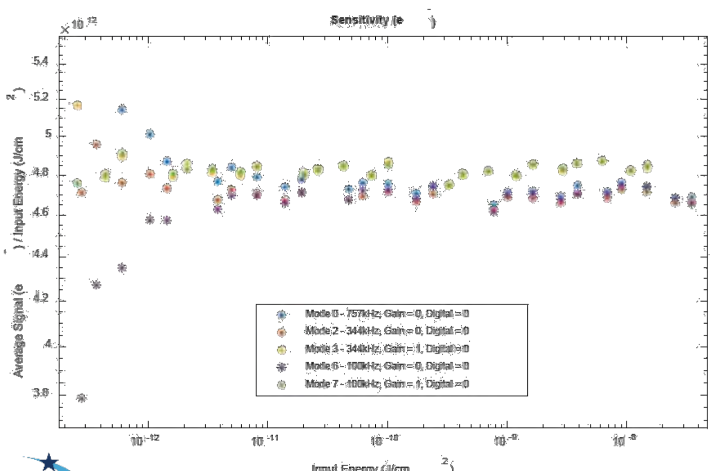
Transfer Curve



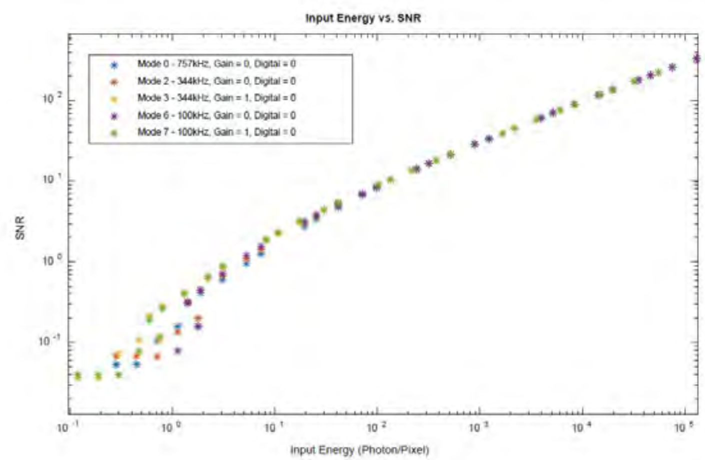
Linearity



Sensitivity



Signal to Noise



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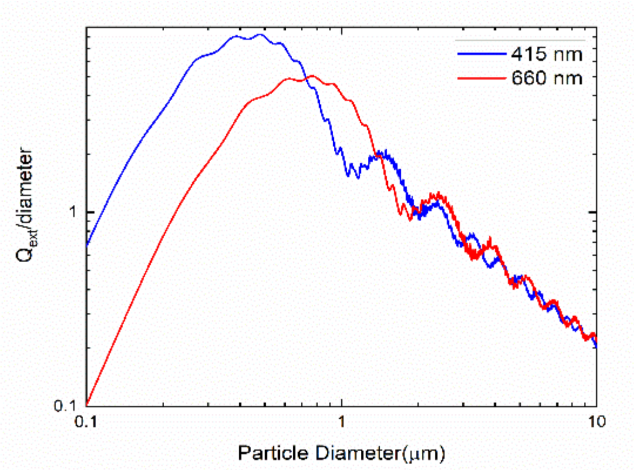
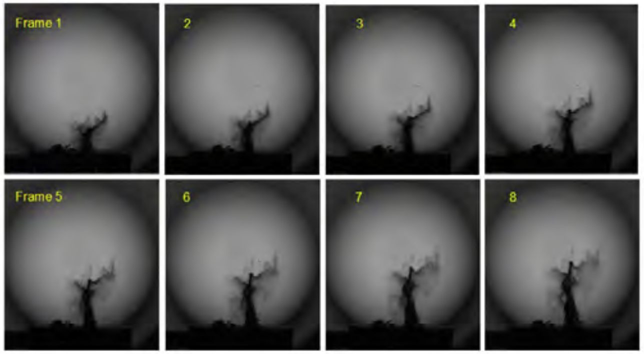
Ejecta Diagnostics and Radiography: Two-wavelength shadowgraphy is being developed to measure ejecta particle size

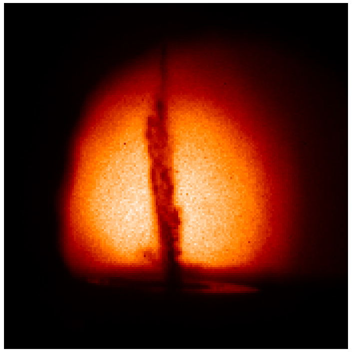
- Ratio of blue light to red light transmission through ejecta cloud can be used to determine particle size
  - Cross section of light scattering off ejecta particles depends on particle size and wavelength of light
  - Ejecta cloud is illuminated with red and blue light
  - Dichroic mirror is used to image shadowgraph at each wavelength

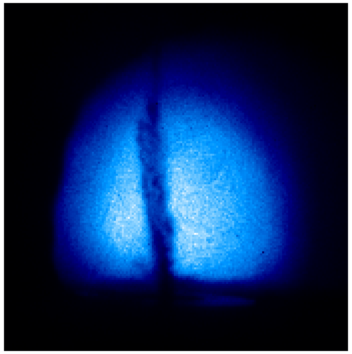


Cross section of scattered light



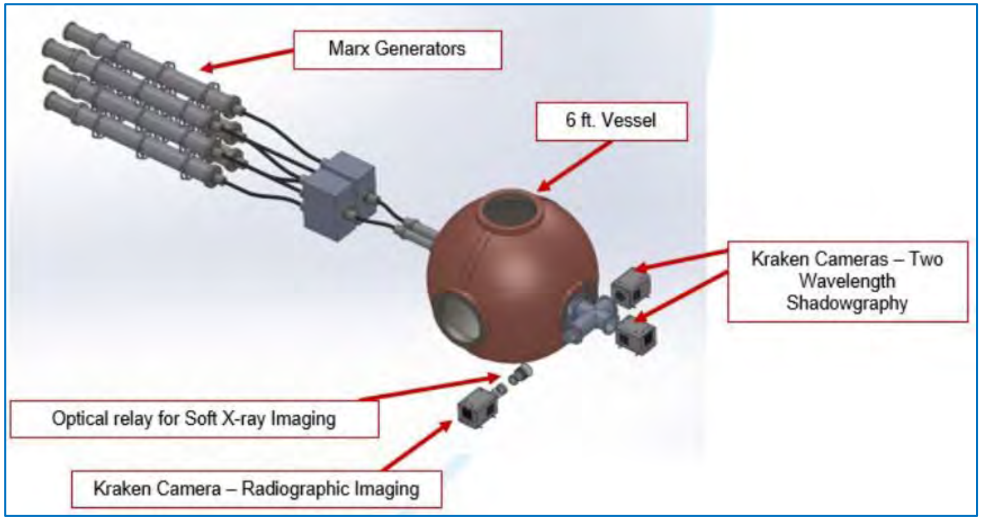
Images of laser-ablated ejecta taken with 8-frame Kraken Camera

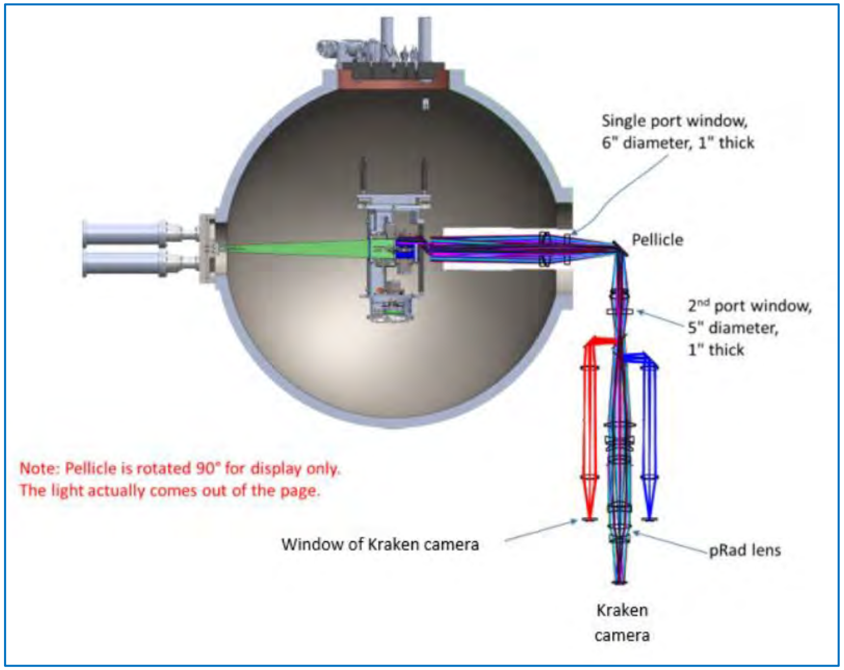




Ejecta Diagnostics and Radiography: Shadowgraphy will be combined with multi-pulse soft x-ray radiography for Wolfsbane

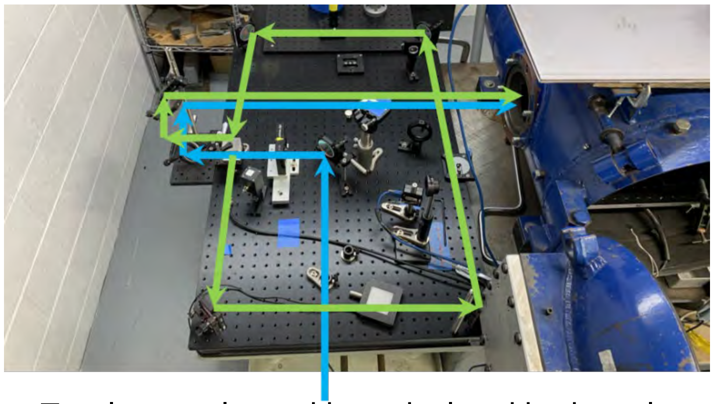
- A single anode, two-pulse flash x-ray system (Marx banks and pulse adder from APELC) is now being tested
- Optical relays have been designed for 6-foot vessel



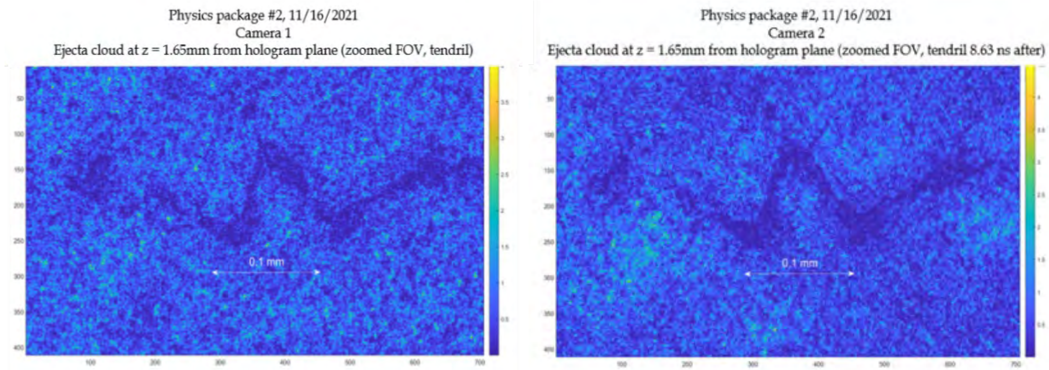


Ejecta Diagnostics and Radiography: Digital holography can capture images at two points in time to measure ejecta position and velocity

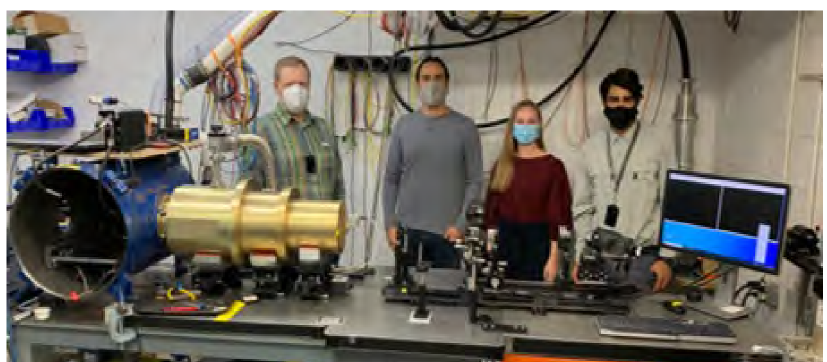
- In collaboration with LANL and Sandia, first digital holograms were recorded on a dynamic ejecta experiment at the STL boom box



Two laser pulses with vertical and horizonal polarizations are used to collect holographic images at two times, one on each camera



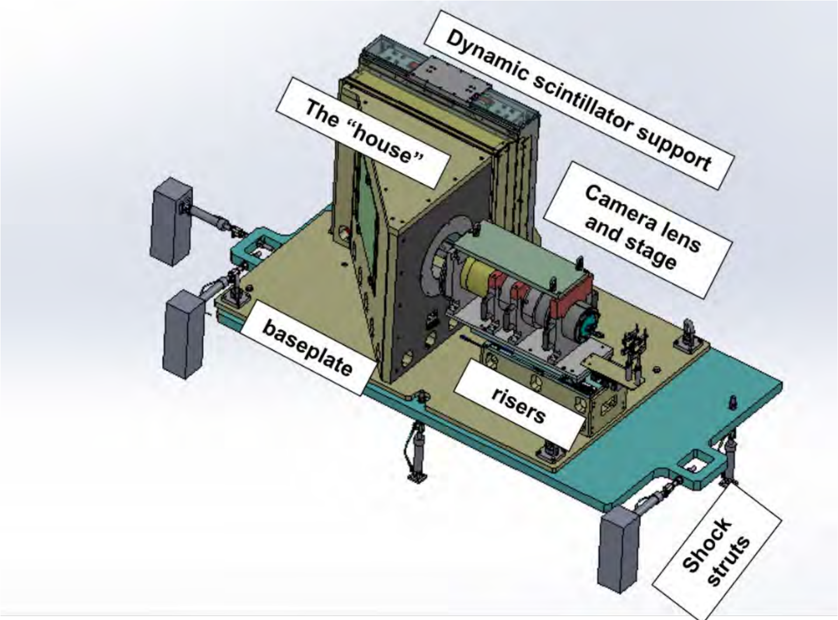
Two processed holographic images from a specific focal plane within a dynamic shock experiment, 9 ns apart, showing motion of the ejecta particles

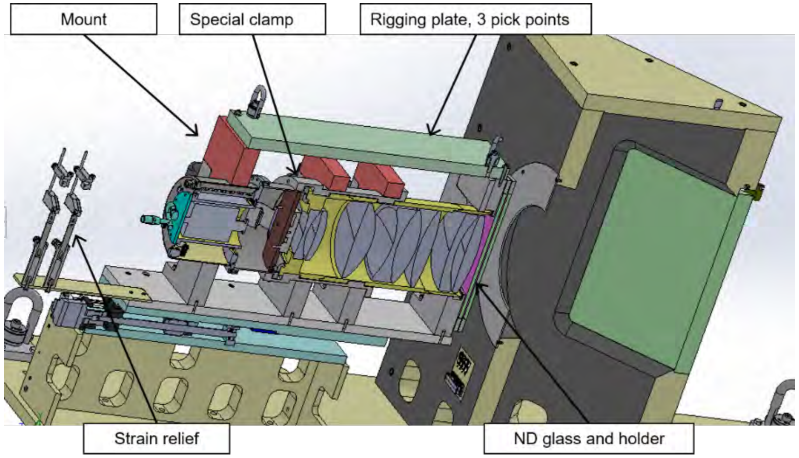


Jeremy Danielson (LANL), Andrew Corredor (NNSS), Emma Rudziensky (LANL), Anthony McMaster (SNL)

FXR Imaging: New gamma-ray camera enclosure has been designed to protect multi-frame imaging system in the CFF

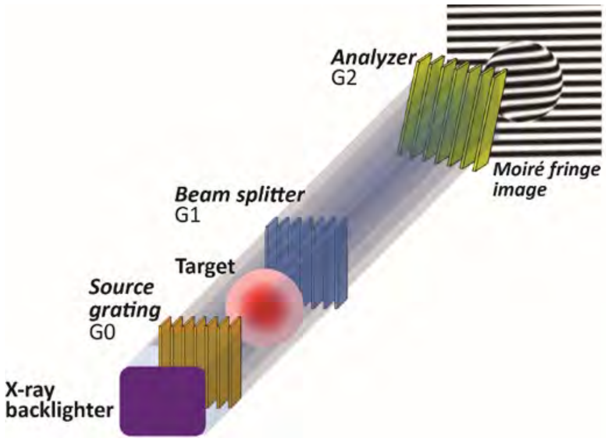
- Previously fielded multi-frame camera and lens system for initial multi-pulse FXR experiments and analyzed data (664 series)
  - Previously FXR relied on film for single-pulse radiography
- Currently developing permanent fixture that will protect new scintillator, lens, and camera

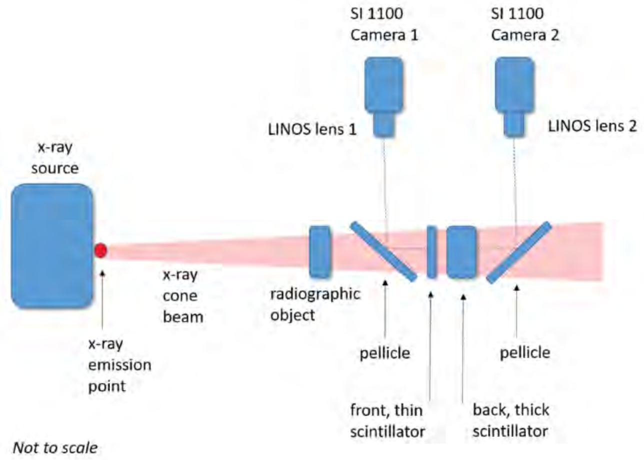




Multi-probe Radiography: Can be used to increase dynamic range of density measurement, identify a mix of materials

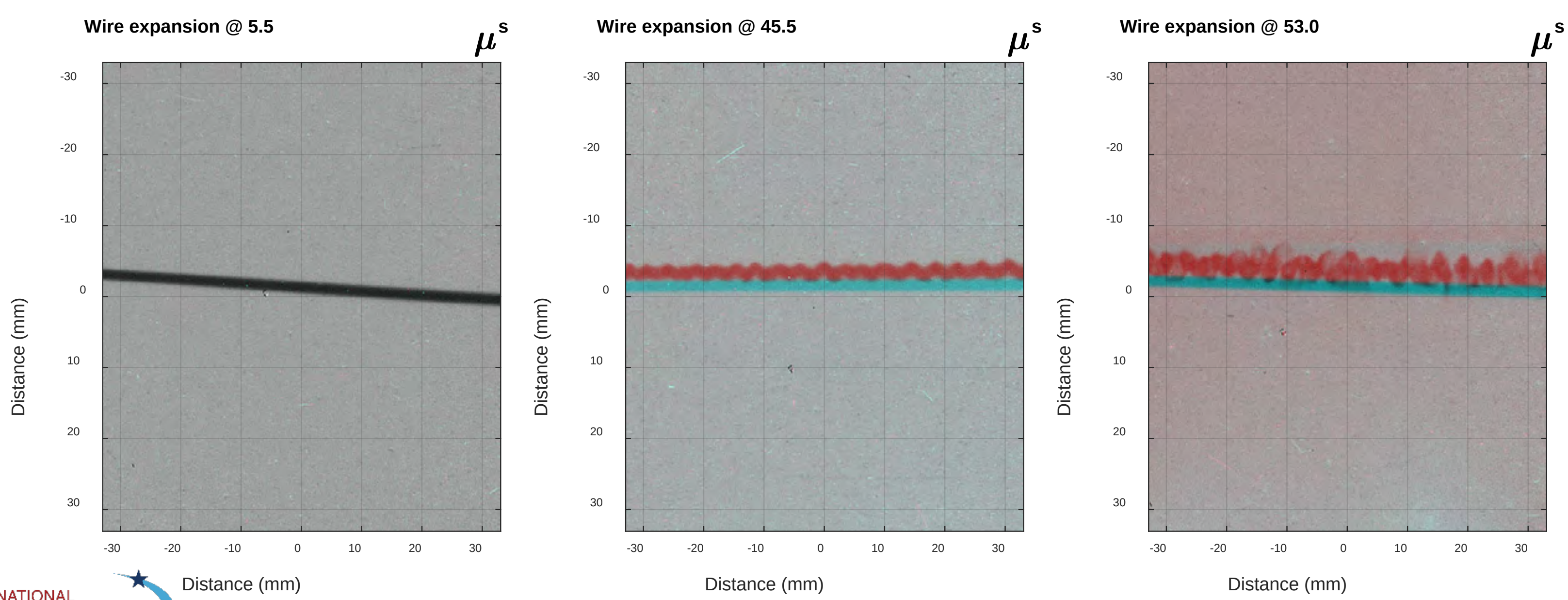
- Multi-color radiography
  - Imaging systems with spectral discrimination (dual scintillators)
  - Multiple sources (soft + hard x-ray measurements at NRL)
- Multi-species radiography
  - Combinations of photons, protons, electrons, and neutrons (transverse x-ray radiography at pRad)
- Multi-mode radiography
  - Phase contrast imaging (Talbot-Lau x-ray deflectometry [TXD])
- Results are summarized in recent 7109 milestone report, in collaboration with LANL





Multi-Probe Radiography: In collaboration with pRad and ARL, we fielded transverse x-ray radiography on exploding wire experiments

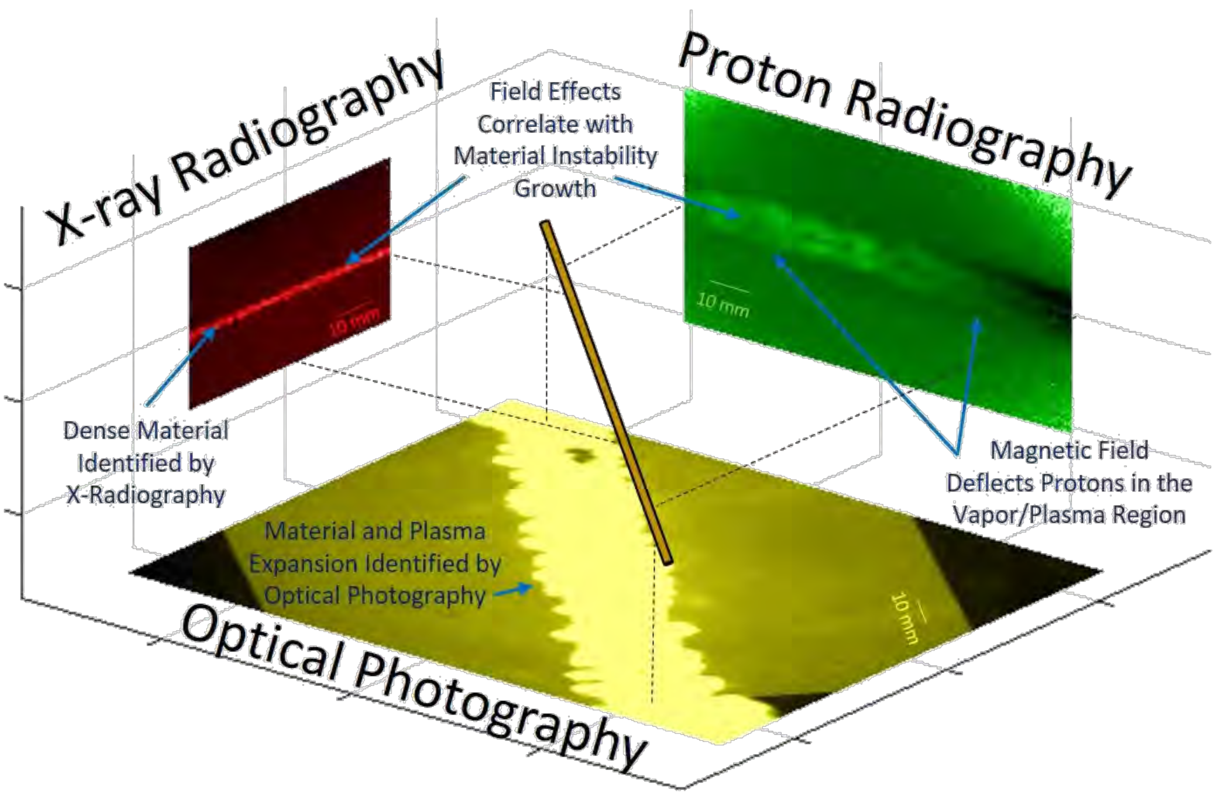
- Independently triggered x-ray radiographs from a single experiment show evolution of expanding wire
- Current system uses four anodes a few cm apart, creating some parallax
  - A single, in-vessel, multi-pulse diode is now being developed for Wolfsbane, and it would be a good fit for pRad as well



Multi-probe Radiography: In pRad ARL experiments, each diagnostic probed a different physical property of the exploding wire

- Proton radiography measured magnetic field
- X-ray radiography measured wire density
- Optical photography measured expanding plasma

Multi-Probe pRad-EMV Exploding Wire Experiment



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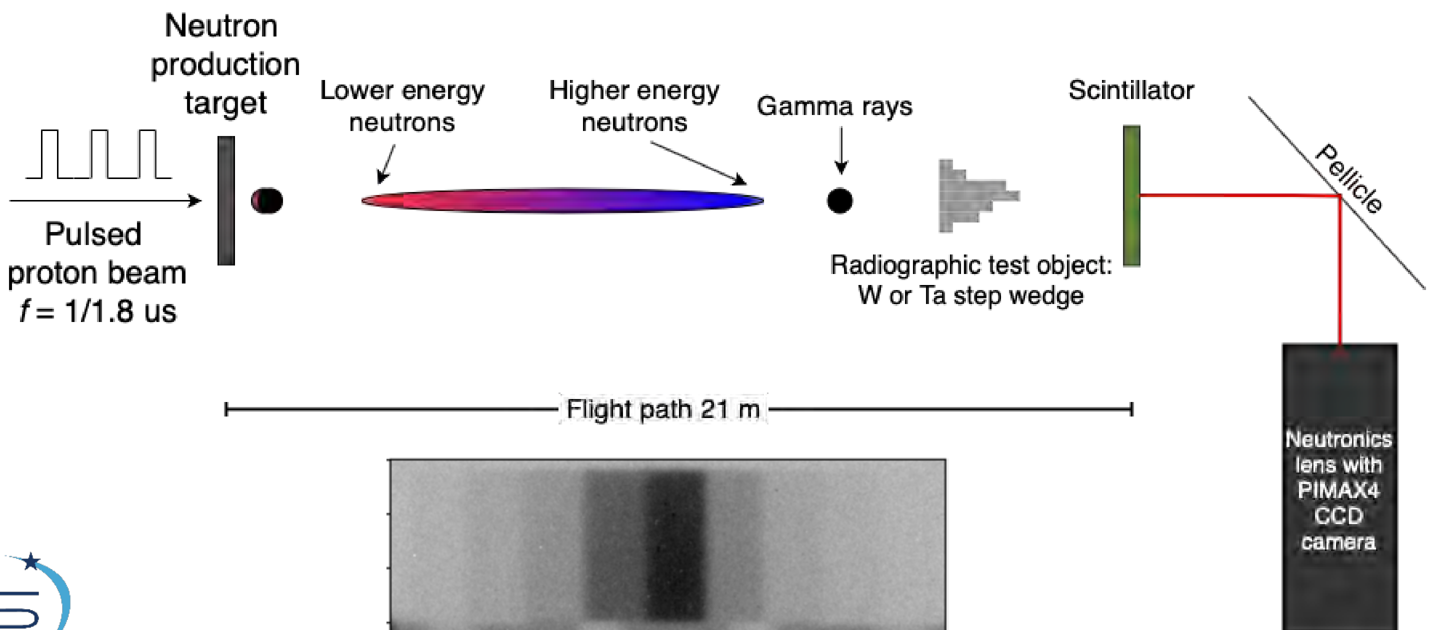
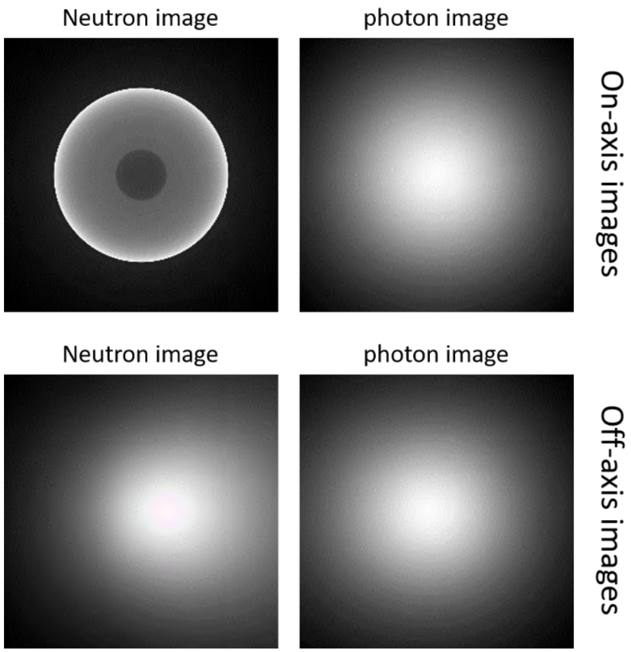
Neutron Imaging: New scintillators were characterized for neutron radiography at 14 MeV at the LANSCE WNR facility

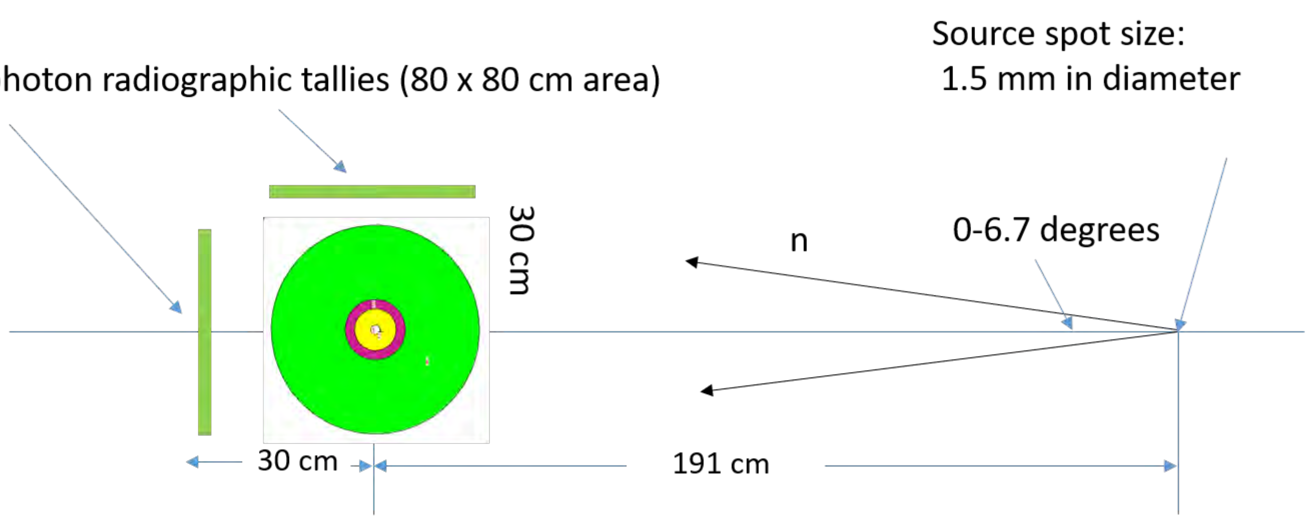
- RAID team awarded four weeks of beam time at LANSCE WNR FP60R neutron source at LANL
- Camera gating was programmed to select 14 ± 2% MeV neutrons
- Imaging qualities (blur, contrast) of 8 scintillators were tested using a dose of 14 MeV neutrons equivalent to a DPF D-T shot (10^7 neutrons/cm^2/image)



Neutron Imaging: MCNP model is now being used to study feasibility of neutron and gamma imaging for NDSE

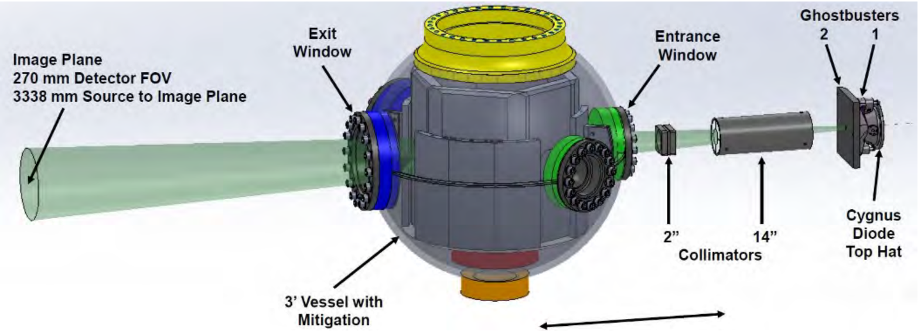
- MCNP is being used to simulate radiographs of the French test object using 14 MeV neutrons from the ZEUS dense plasma focus
- Neutron and gamma radiographs are being considered, both along the axis of the DPF and off-axis
- Results will be presented and reviewed soon



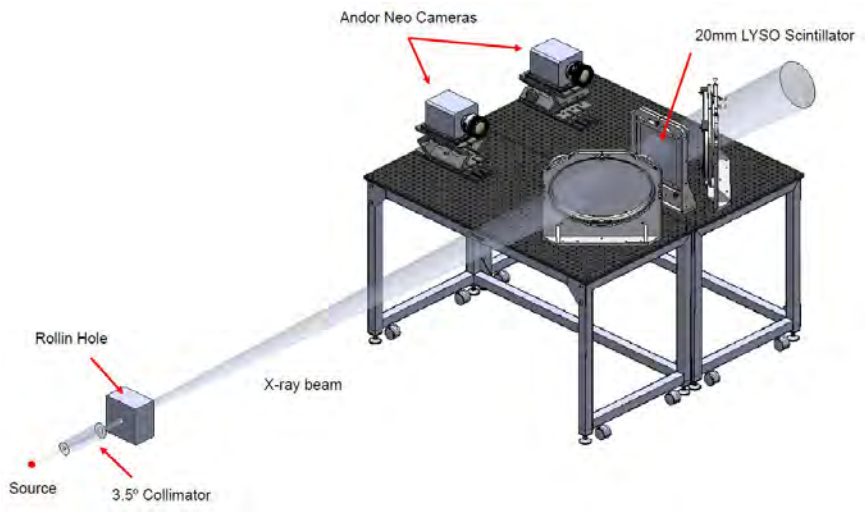


Radiographic System Development: In collaboration with LLNL and LANL, the current focus is on Great Basin radiography development

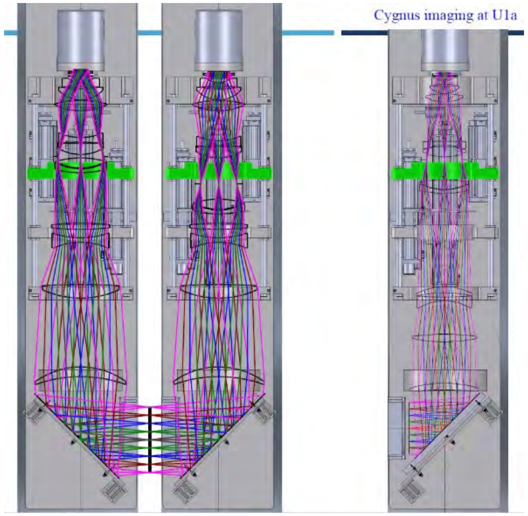
- Great Basin radiography development includes optical design work, experiments, and the development of radiographic analysis tools



“Great Basin Cygnus Radiography Raytrace” (D. Phillips)

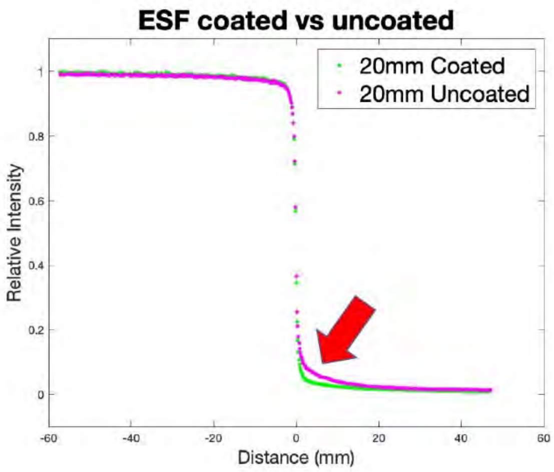


“Dual and Double-Sided Imaging Systems for Great Basin” (A. Corredor)

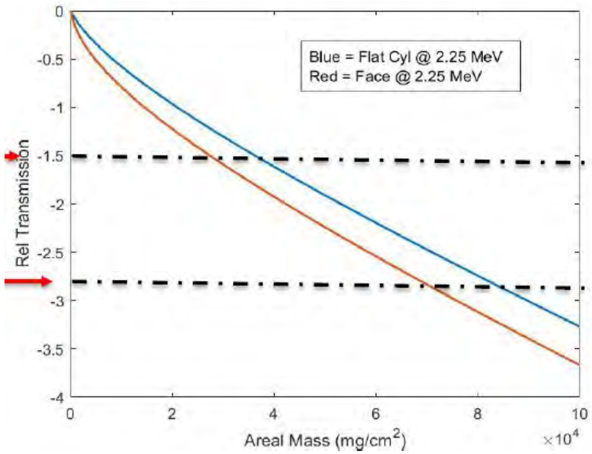


“Lens and Camera Designs for GB” (R. Malone)

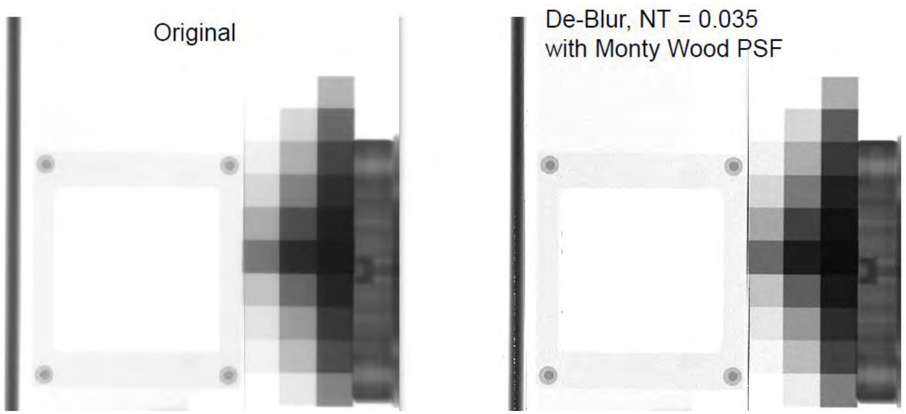
Radiographic System Development: In collaboration with LLNL and LANL, the current focus is on Great Basin radiography development



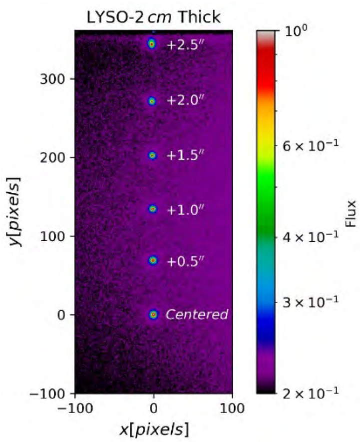
"SEALab Measurements of Tile Glow" (E. Zepeda-Alarcon)



"Acceptable Systematic Error Uncertainty in PSF Measurement/Modeling" (T. Haines)



"Validation of PSF Models for Applying a Radiographic De-blur" (J. Clayton)



"Methodologies for a Spatial Error Budget" (L. Hovey)