This paper describes objective technical results and analysis. Any subjective views or opinions that might be expressed in the paper do not necessarily represent the views of the U.S. Department of Energy or the United States Government.

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Understanding electrode plasma formation on wires and thin foils via vacuum ultraviolet spectroscopy of desorbed surface contaminants

Trevor Johannes Smith [1,2], Mark Johnston[2], Nicholas Jordan[1], Michael Cuneo[2], George Laity[2], and Ryan D. McBride [1]

1: Plasmas, Pulsed Power, & Microwave Laboratory, University of Michigan

2: Sandia National Laboratories

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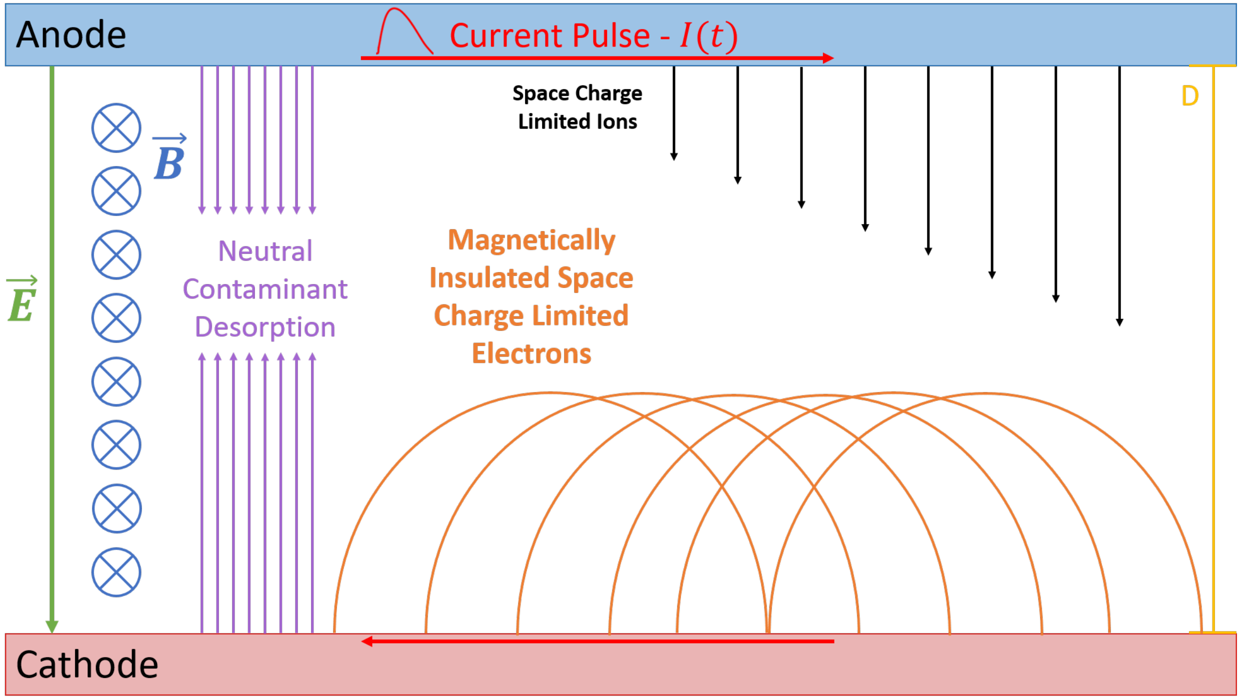
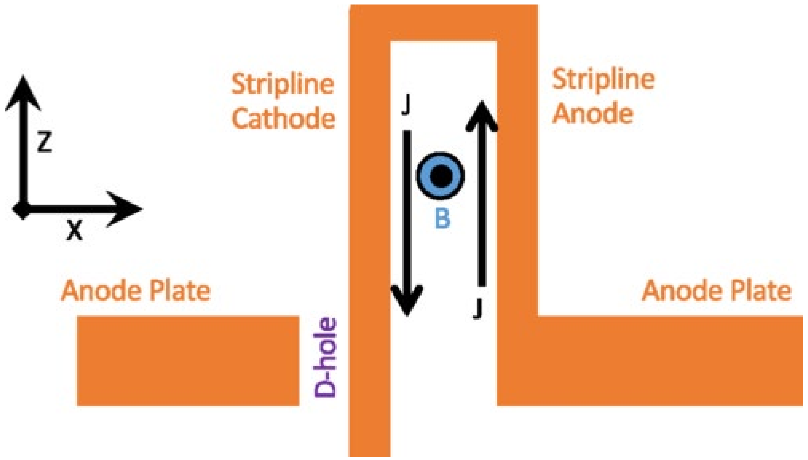
What is Power Flow for Current Delivery?

- The study of how power is delivered from the capacitor banks to the load region
  - Specifically, the magnetically insulated transmission lines in the vacuum section of a pulsed power driver
- Electrodes heat due to ohmic heating, charged particle bombardment, etc.
- This heating liberates contaminants from surface/bulk and ionize
- A strong magnetic field insulates the plasma from crossing the gap
- Plasma drifts along electrodes
- Current loss occurs when a weak or no magnetic field is present to insulate the plasma

M.R. Gomez *et al.* **PRAB** (2017)
10.1103/PhysRevAccelBeams.20.010401



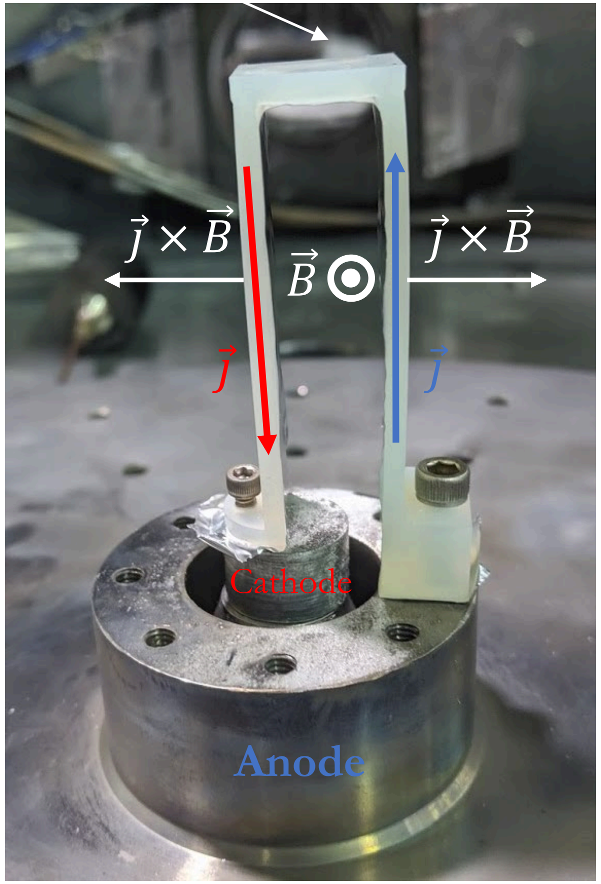
New Power Flow Platform at the University of Michigan



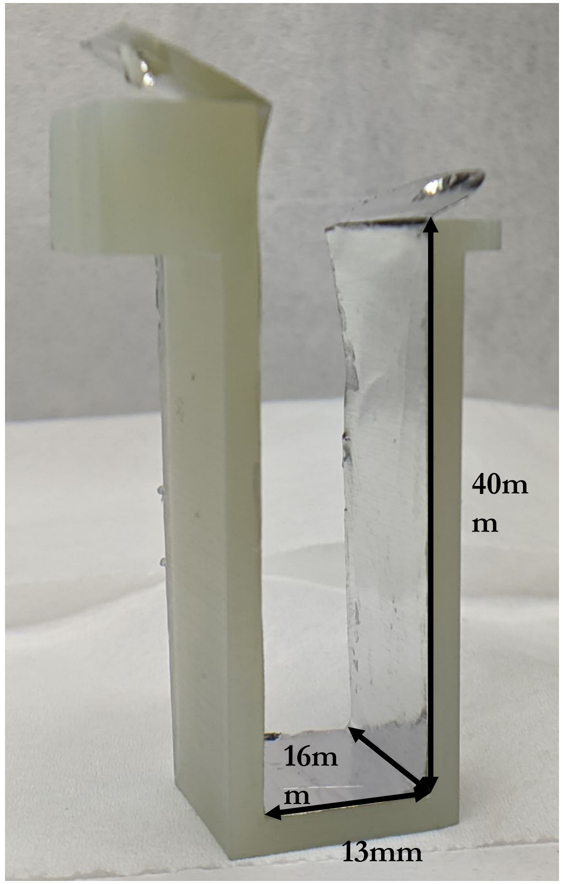
Strip-line flyer plate geometry used on the Z-machine for dynamic material property experiments

A. Porwitzky *et al.* **PRAB** (2019)

laser entrance window



Target in situ inside MAIZE vacuum chamber
50 μm Aluminum Planar Foil
R = 3.6 mΩ
L = 20-50 nH

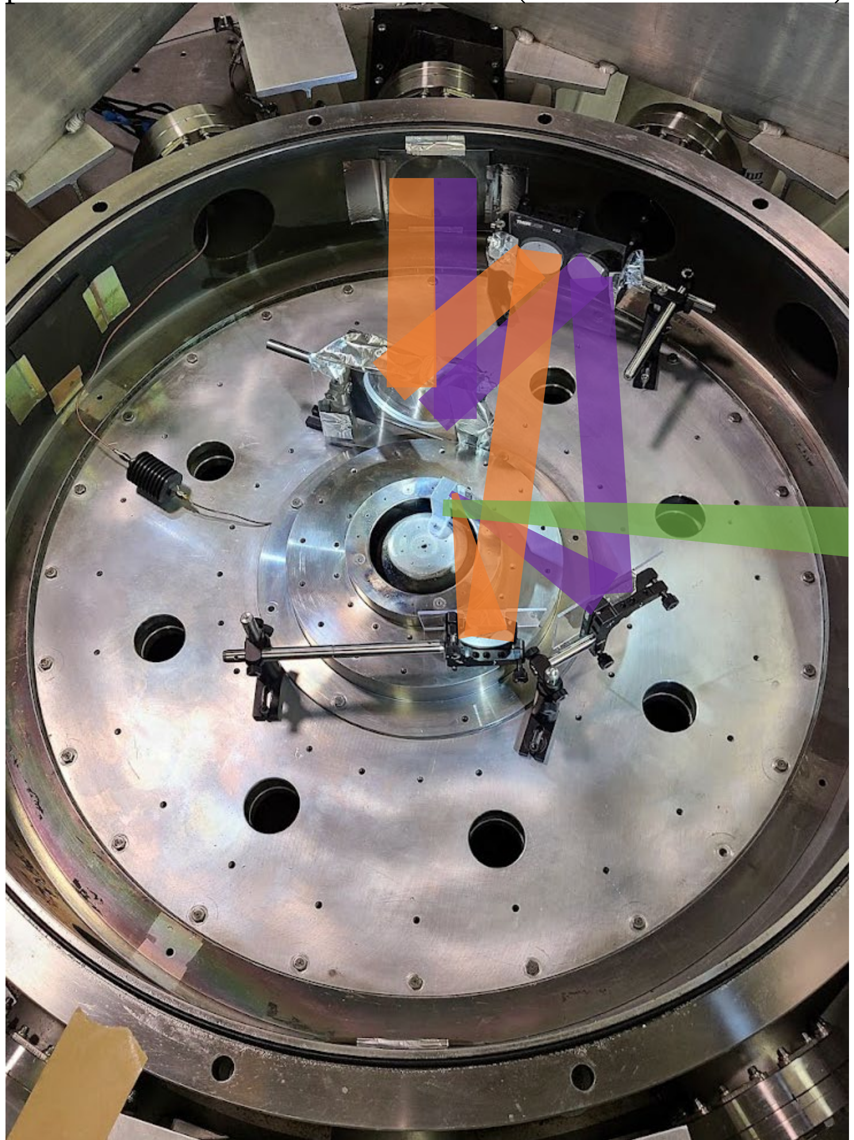


- 3D Printed Support Structure
- Uses Form 2 SLA printer Durable Resin
- 31.8 MPa tensile strength

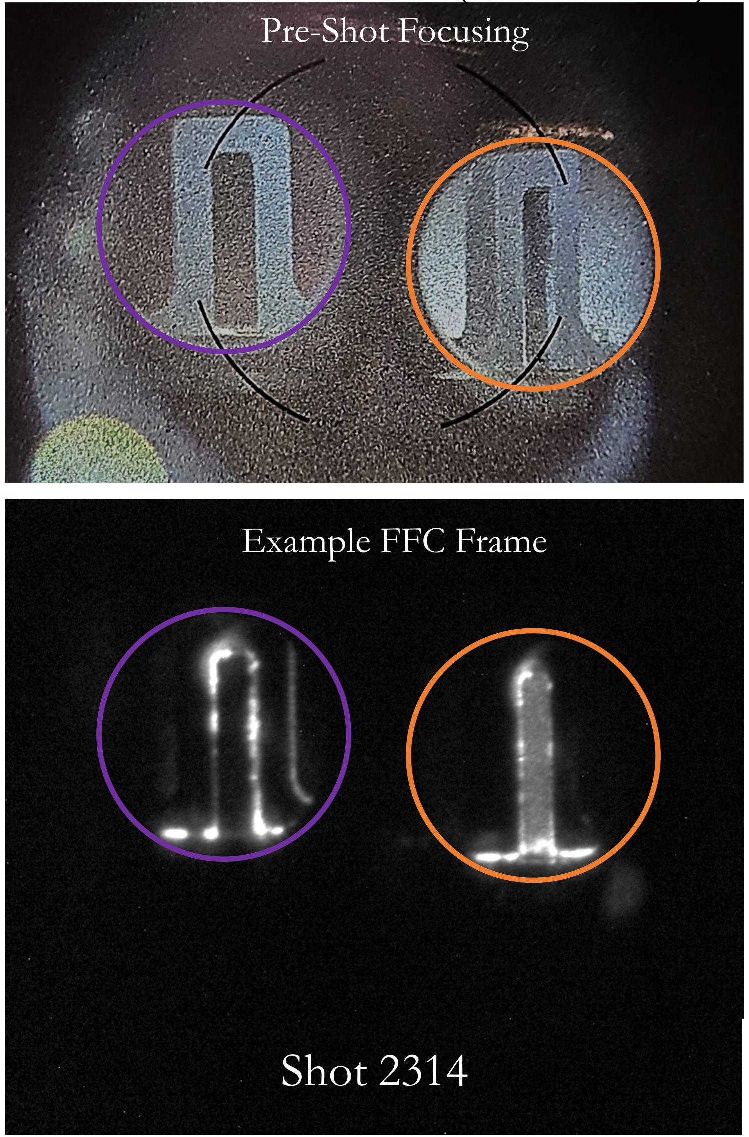
T.J. Smith *et al.* **RSI** (2021) 10.1063/5.0043856

Imagining Lines of Sight - Examples

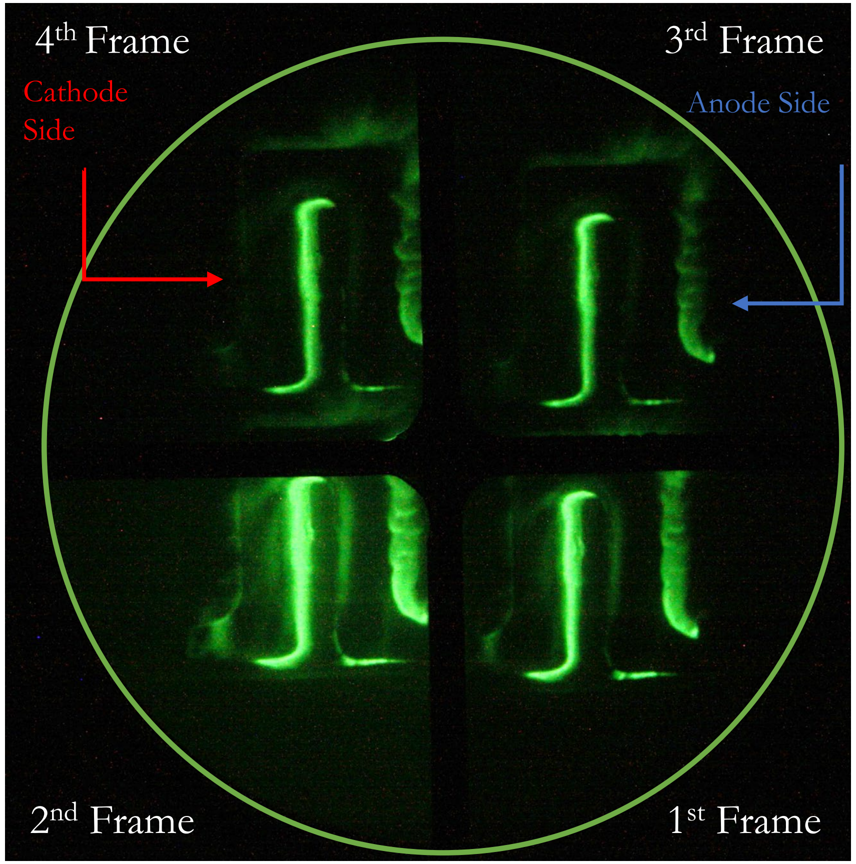
Optical Paths for Mirrors/XUV (Color Coordinated)



Visible Self Emission (12 – Frames)

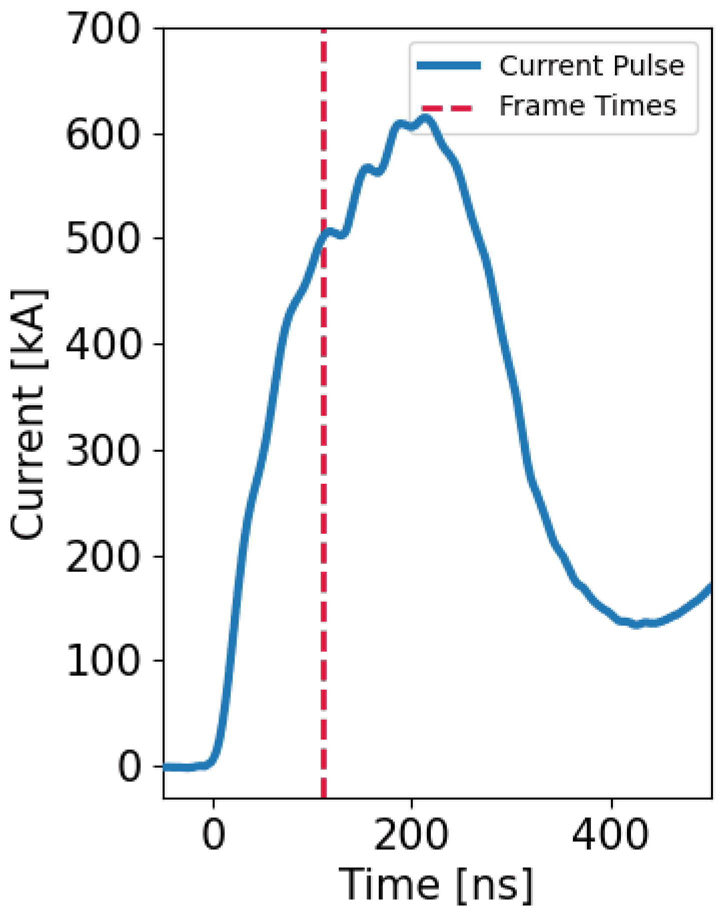


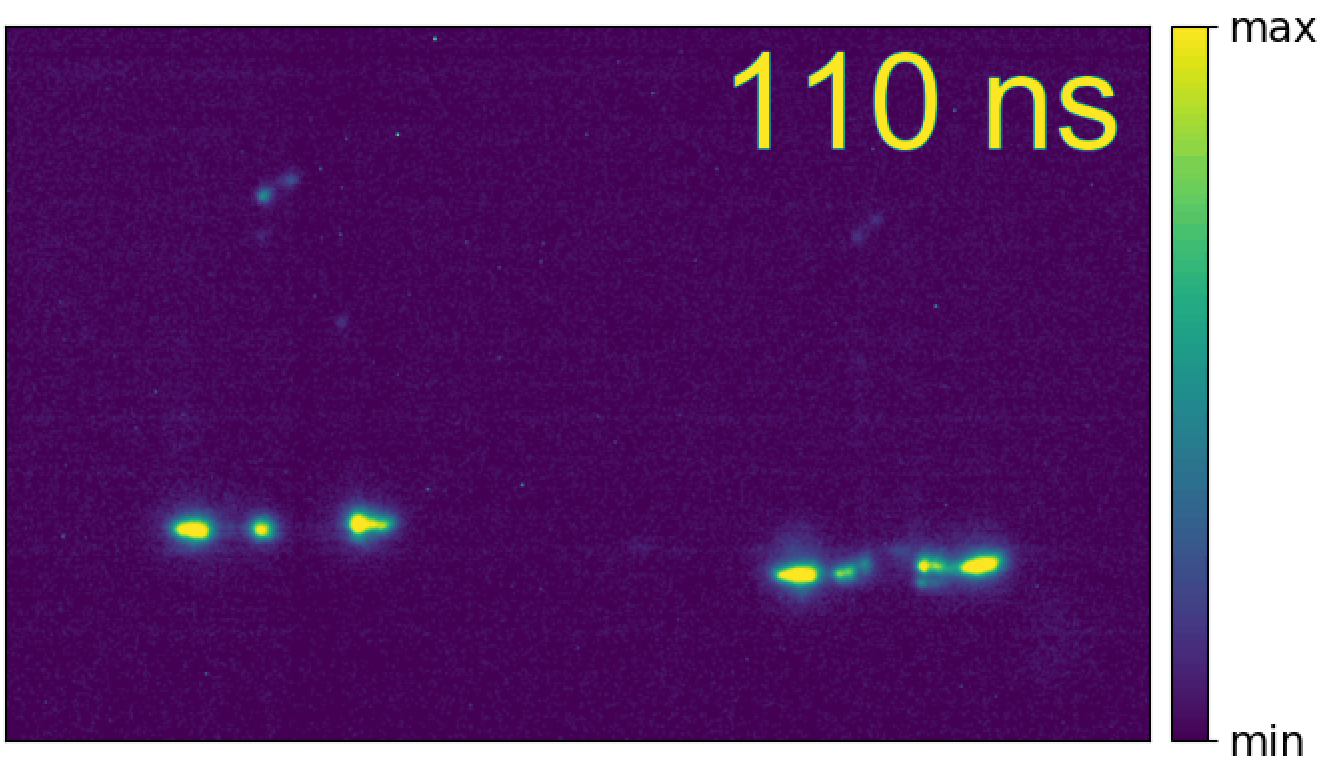
XUV MCP Pinhole Self Emission (4 – Frames)



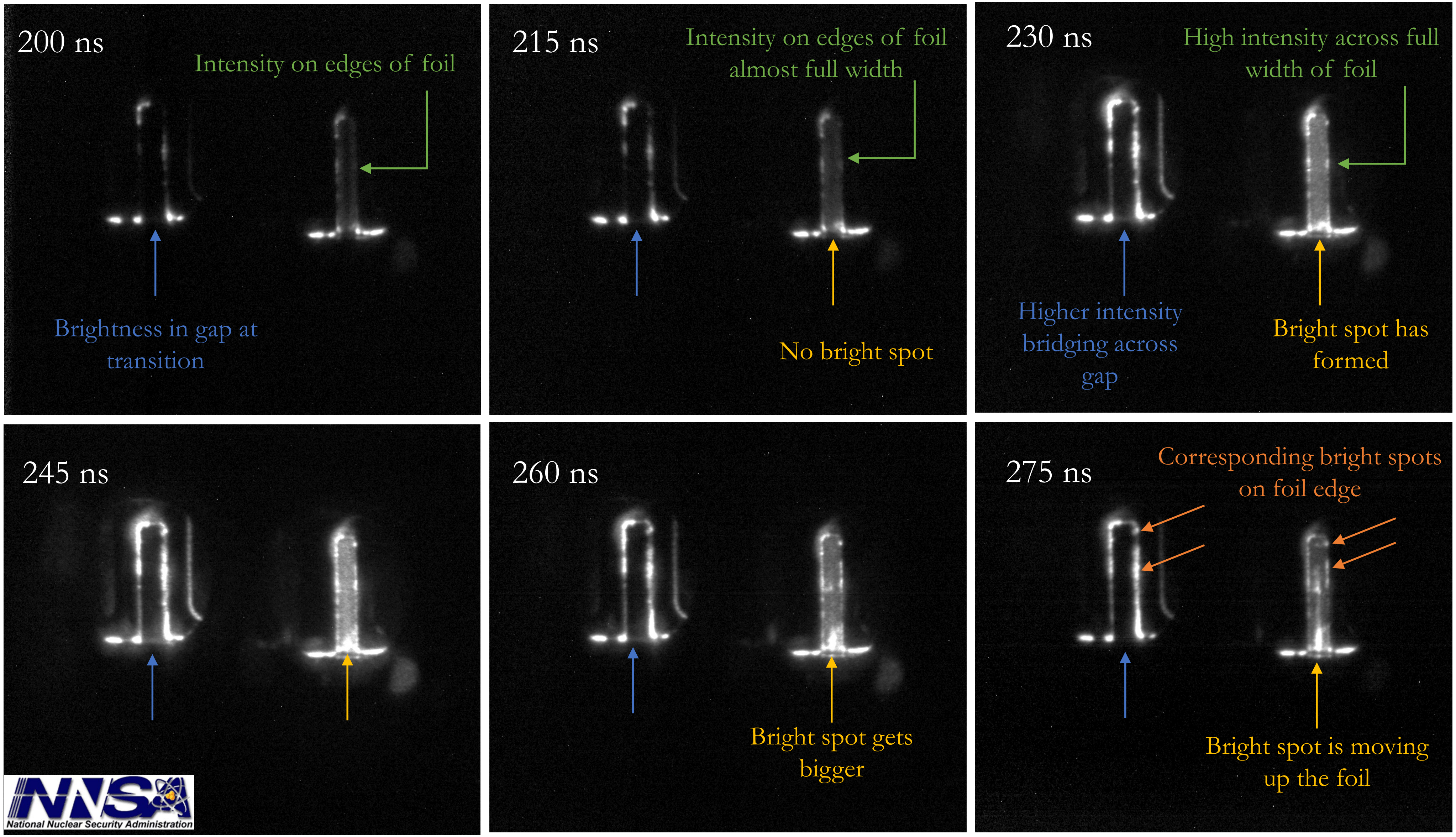
Shot 2317

Visible Self Emission Imaging - Shot 2314 – 25-μm Al





Visible Self Emission Imaging - Shot 2314 – 25-μm Al



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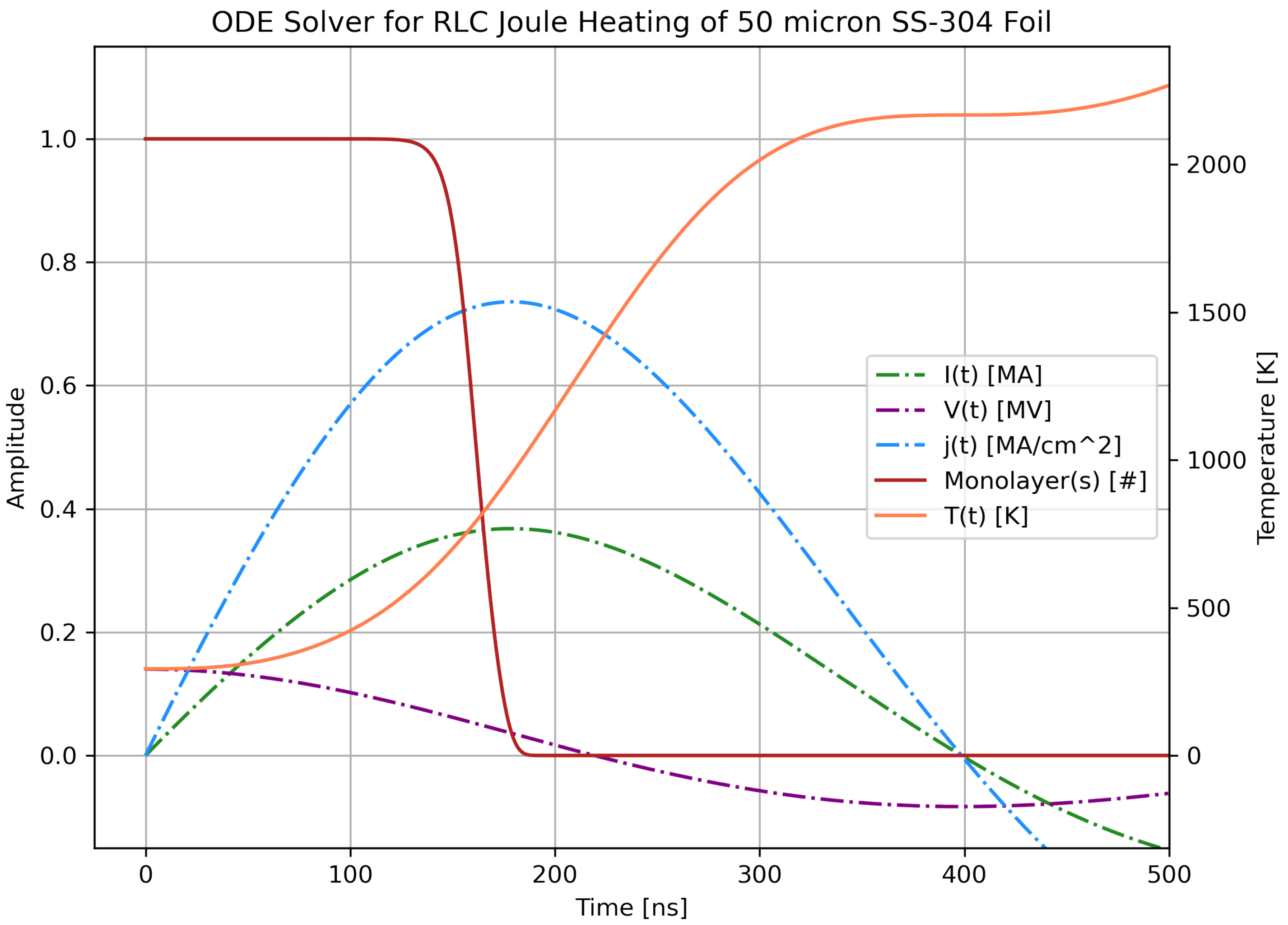
Semi-Analytic Model for Foil Heating & Contaminant Desorption

- Python ODE solver solves RLC voltage driven/user defined current trace to determine solid foil temperature and rate of neutral contaminant desorption
- Knoepfel model defines rate of heat entering through resistive Joule heating
  - $\frac{\partial Q}{\partial t} = \frac{j^2}{\sigma} + k\Delta T$
- Modified Temkin Isotherm, E', determines rate of desorption of contaminant surface layers
  - $\frac{dn}{dt} = k_0 n_m \theta e^{-E'/k_B T}$
- Solver gives semi-analytic solution in a matter of seconds
- Currently working to add
  - heat transfer from skin depth to foil bulk
  - bulk hydrogen desorption
  - metal vaporization
  - ionization



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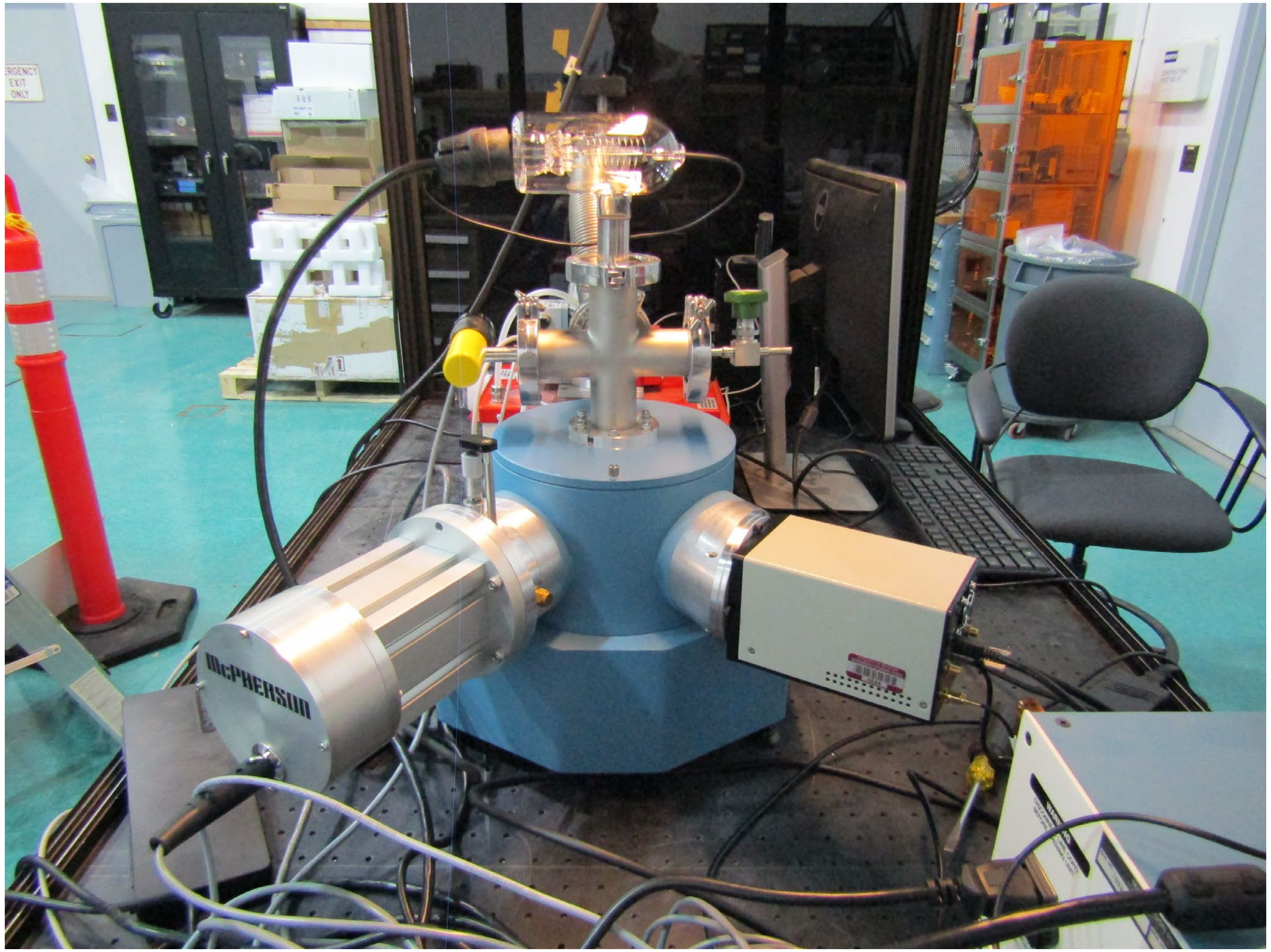
Spectrometer Calibration Setup



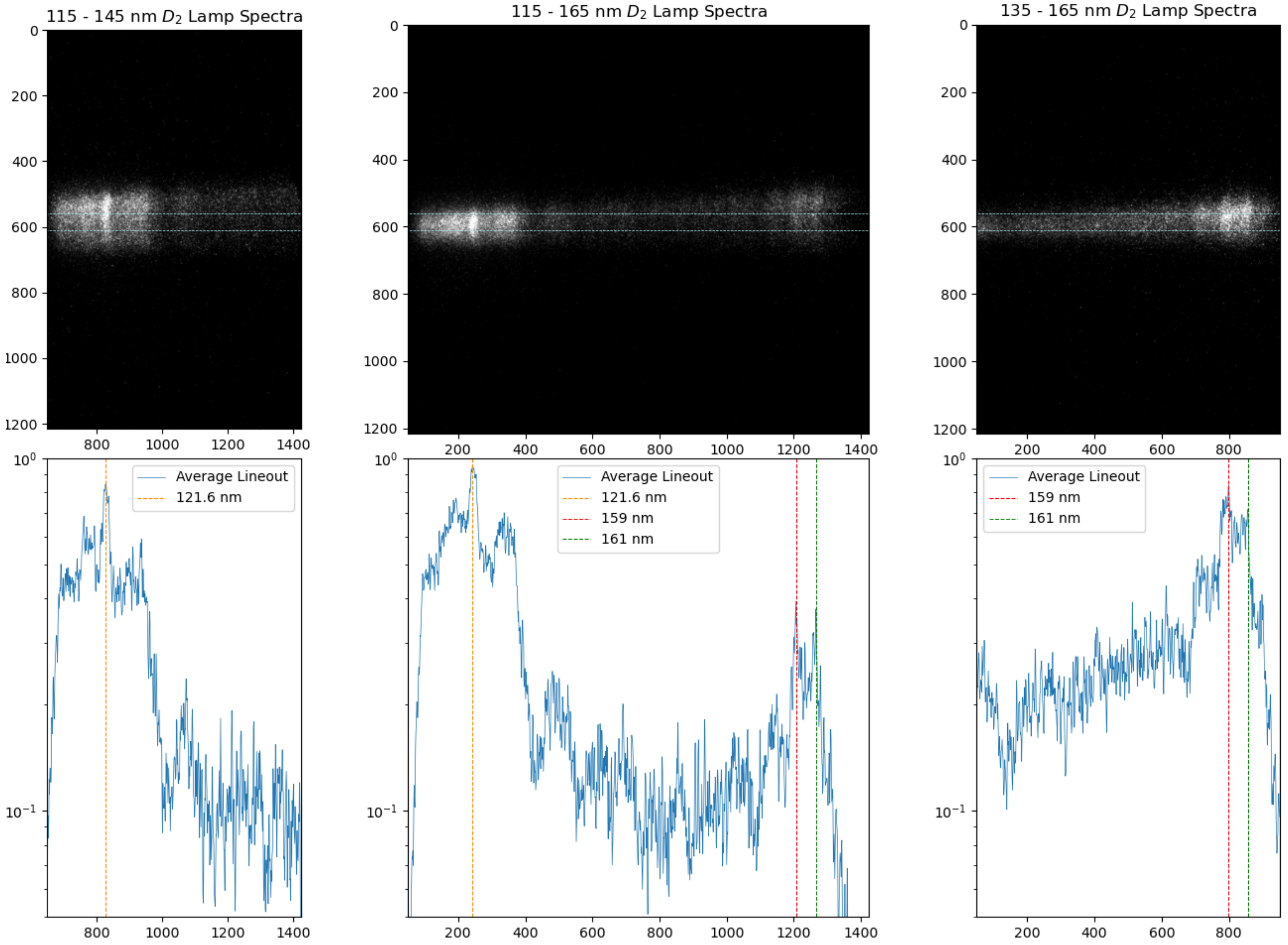
McPherson 234/302 VUV Spectrometer

- **Optical Design:** Abberation Corrected Seya-Namioka
- **f/#:** f/4.5
- **Focal Length:** 0.2 m
- **Gratings:** 600, 1200, 2400 g/mm
- **Grating Coatings:** Al + MgF2
  - Pl for 2400 g/mm
- **Operating Wavelengths:** > 40 nm
- **Required Vacuum:** ~10^{-5} Torr
- **Linear Dispersion:** 4 nm/mm
- **Slit Width:** 0.1-3 mm

Photek iCMOS 160

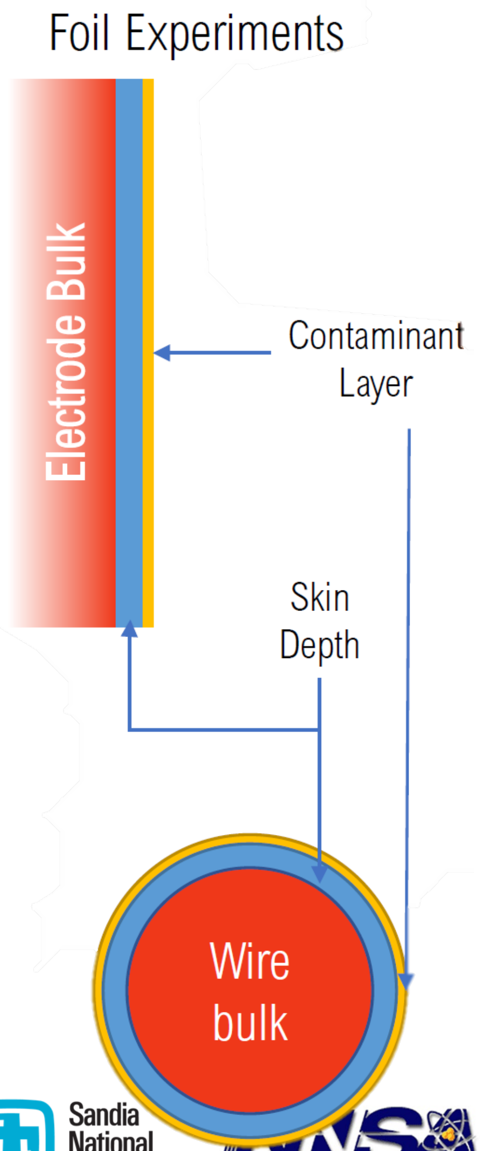
- **Quantum Efficiency:** 20-25% (100-300 nm)
- **Gate Width:** > 3 ns
- **Window Size:** 25mm, 1920x1200 pixels
- **Pixel Size:** 13.3 μm
- **Window Material:** MgF_2

First Collected Spectra Using Deuterium Lamp Source



- 1200 g/mm Grating – 1400 Å Blazed
- 2 μs Gate Width
- 70/100 Gain (Photek Camera)
- 50 μm slit width
- Centered @ 1216 Å (left), 1440 Å (center), & 1600 Å (right)
  - Left and Right images are cropped

Electrode Surface Science – Upcoming Experiments



- Ohmic Heating occurs at skin depth of conductor
  - Heat transfers to foil/wire bulk and surface contaminant monolayers
- As bulk thickness decreases, how does the rate of contaminant layer desorption react?
  - Should be directly proportional to ohmic heating rather than other heating methods like ion/electron deposition
  - Finite energy in a current pulse. Thermal Energy scales from current density at skin depth layer (for planar geometry)
  - Heat transfer should take place from skin depth layer to bulk material and contaminant layer
  - Shot-to-shot, increasing bulk thickness in relation to skin depth of current pulse should increase the thermal energy deposited there rather in the contaminant layers (should act as a heat sink).
  - Conversely, shrinking the bulk material thickness should see more heat transferred to the contaminant layer, increasing the rate of material desorbed from the surface (and possibly electrode material melt)
  - Using spectroscopy, we should be able to measure the plasma density and thus the contaminant inventory from the wire/foil