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VISIBLE SPECTROSCOPY AND MAGNETIC FIELD PROFILE MEASUREMENTS OF PULSED POWER DIODES

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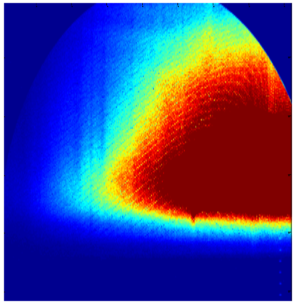

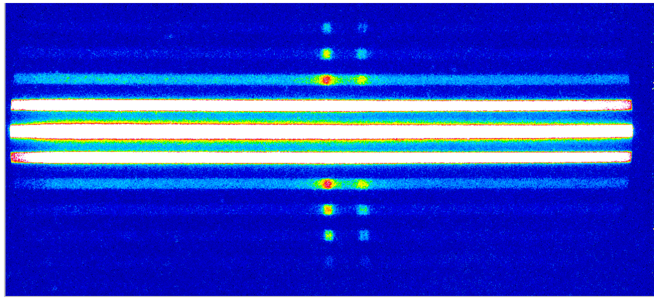

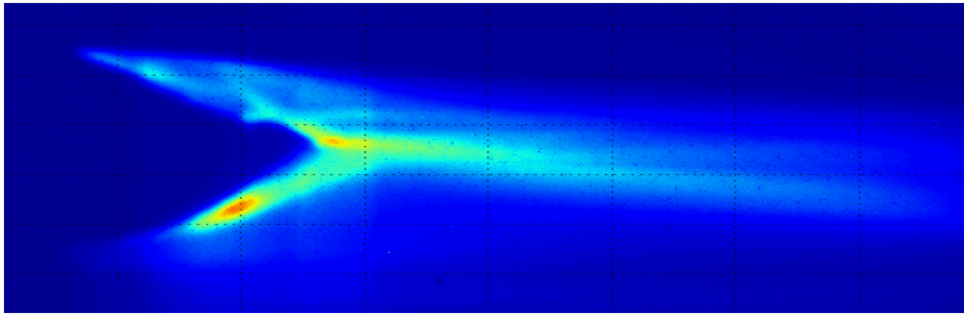

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Outline

- Motivation
- Optical spectroscopy measurements on the Rits-6 SMP diode using multi fiber arrays
  - Temperature/Density profiles
  - Magnetic field profiles
- Planned optical spectroscopy measurements on Z
- Summary/Future work

Motivation

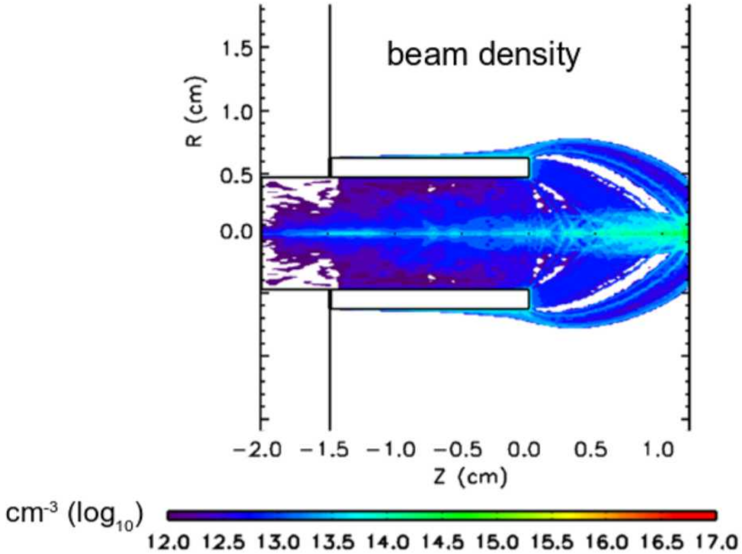
- Determine plasma parameters and the current distribution in the Self Magnetic Pinch (SMP) Diode.
- Use SMP diode measurements to help inform Z convolute measurements of plasma parameters.
- Understand plasma formation and consequentially, current loss along power flow surfaces on Z.

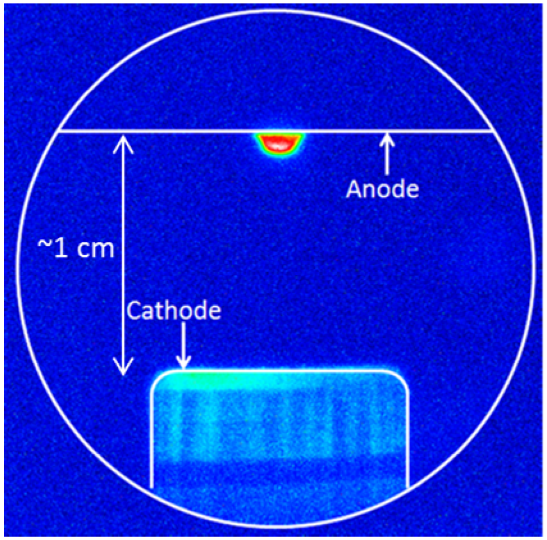
1. LSP Suite: Particle-in-Cell (PIC) code, http://www.mrcwdc.com/LSP/index.html

SMP Diode

- RITS-6 has been used to evaluate the SMP diode as an x-ray flash radiography source.
- The beam pinches from its self B-field as it crosses the A-K gap
- Plasmas form on the electrode surfaces and expand into the AK gap, decreasing the diode impedance over time

SMP diode simulation[1]

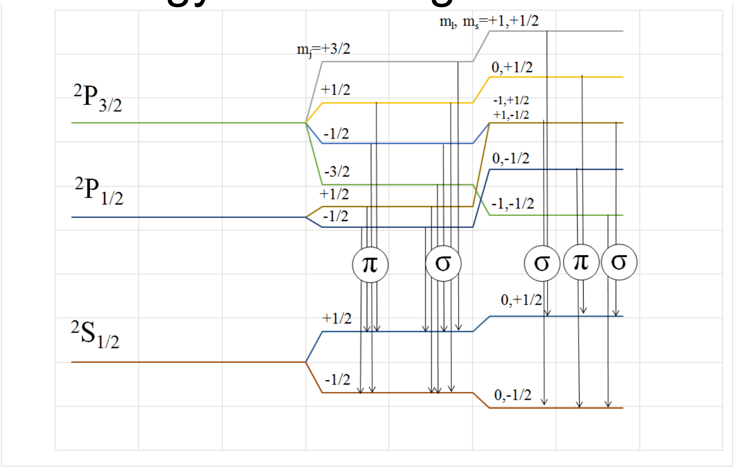




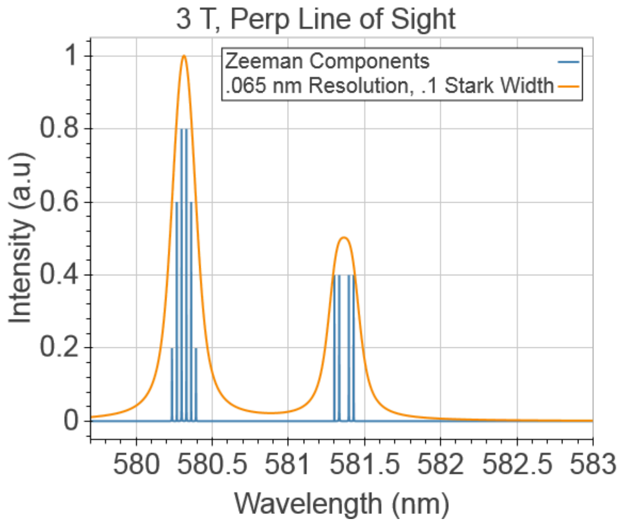
1. N. Bennett, M. Crain, D. Droemer, et al. Phys. Rev. ST Accel. Beams 17, (2014)

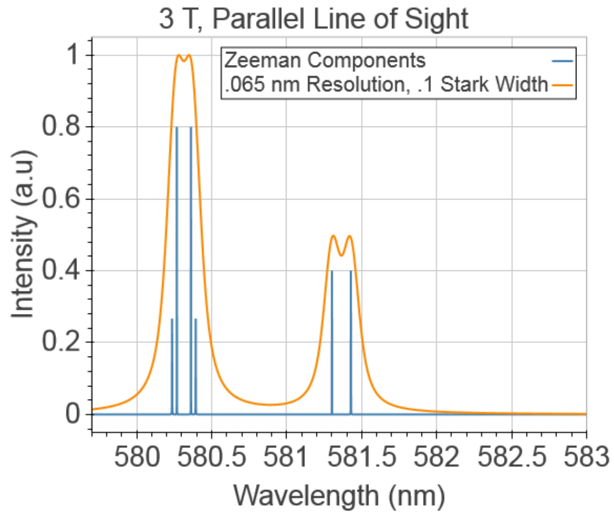
Zeeman Splitting

Energy Level Diagram



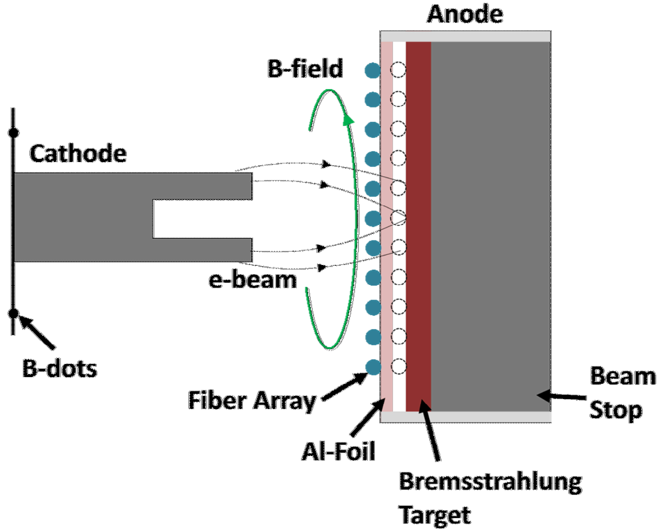
- Weak field:
  - $\Delta E = g m_j \mu_B B$
- Strong Field:
  - $\Delta E = (m_l + 2m_s)\mu_B B$



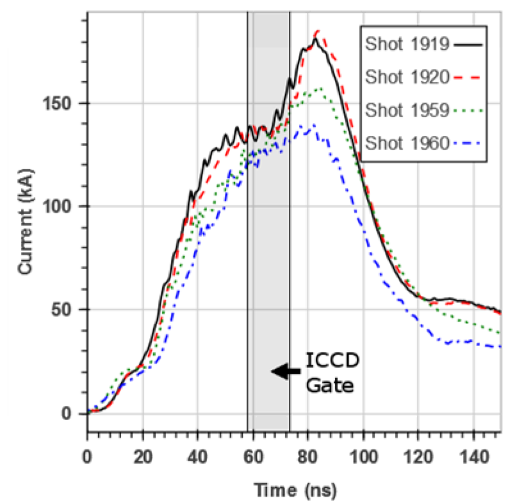


Experimental Setup

- Fibers are focused to a 1mm spot across the surface of the foil or converter where the B-fields are the largest.
- A 0.35m lens coupled spectrometer is used with a 2400 g/mm grating. (~0.6 A resolution)
- Spectra are collected toward the middle-end of the radiation pulse, just before impedance collapse to maximize light.

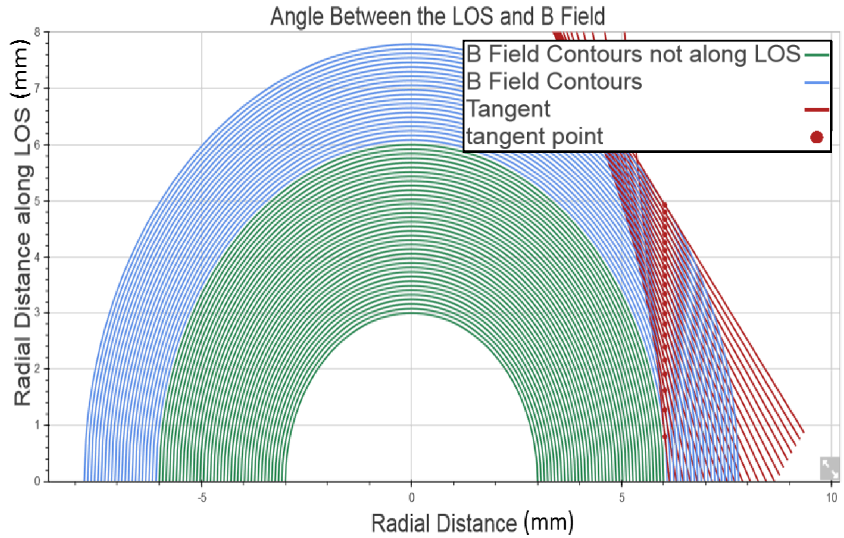


SMP Diode



Magnetic Fields

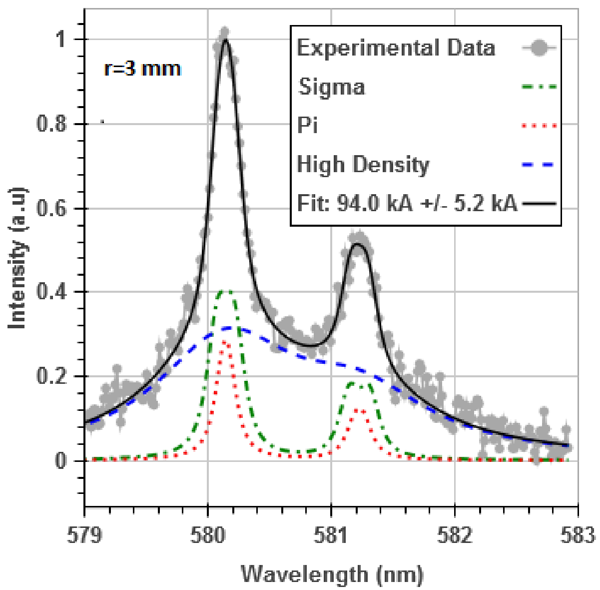
- Each component of the Zeeman lines are broadened by density, the instrument, and Doppler effects
- Zeeman splitting is fit assuming:
  - Fiber is well focused for a ~2 cm chord
    - Sigma and pi line components are factored into the fit
  - Cylindrical symmetry of e-beam
  - Optically thin plasma, $^2P_{3/2}$->$^2S_{1/2}$ to the $^2P_{1/2}$->$^2S_{1/2}$ ratio is 2
  - Weight each point by the Abel inverted intensity



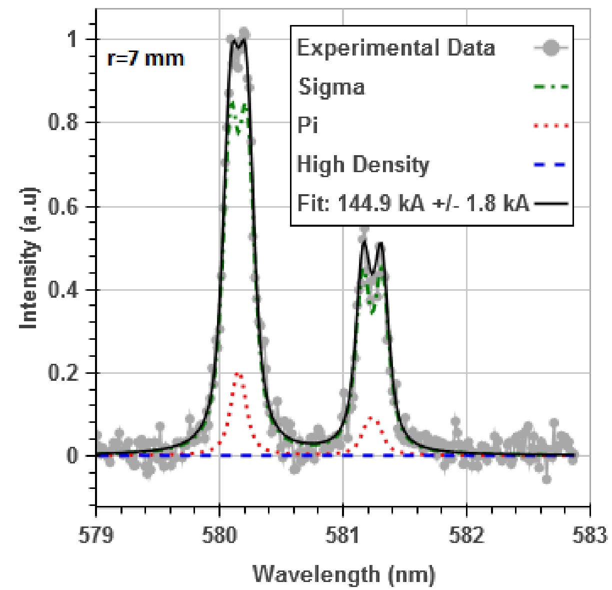
Parallel and perpendicular components change the line profiles. Line of sights closer to the center contain more pi components than lines further from the axis.

Comparison between fits

r=3 mm



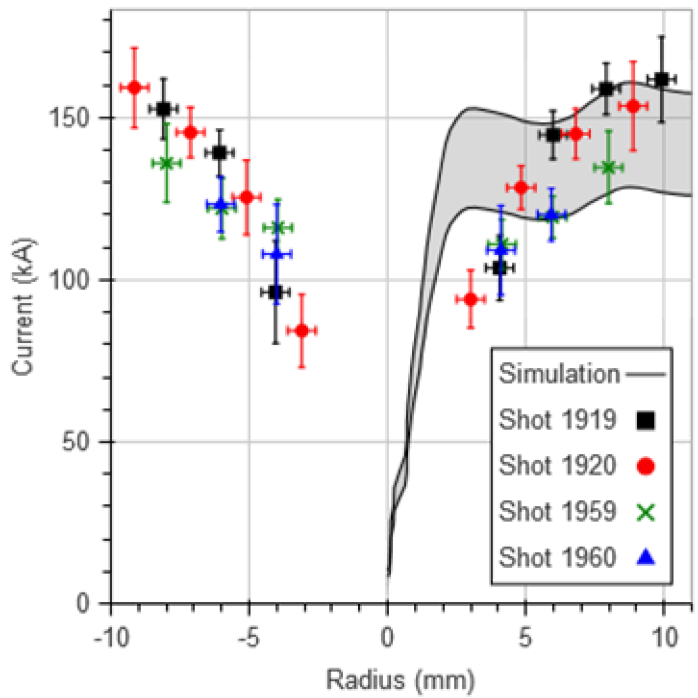
r=7 mm



The FWHM ratio for the $^2P_{1/2} \rightarrow {}^2S_{1/2}$ to the $^2P_{3/2} \rightarrow {}^2S_{1/2}$ is ~1.15 and it is fit by including a magnetic field.

E. Stambulchik, K. Tsigutkin, and Y. Maron, PRL 98, (2007)
2. S. Tessarin, D. Mikitchuk, R. Doron, et al. Phys of Plasmas 18, (2011)

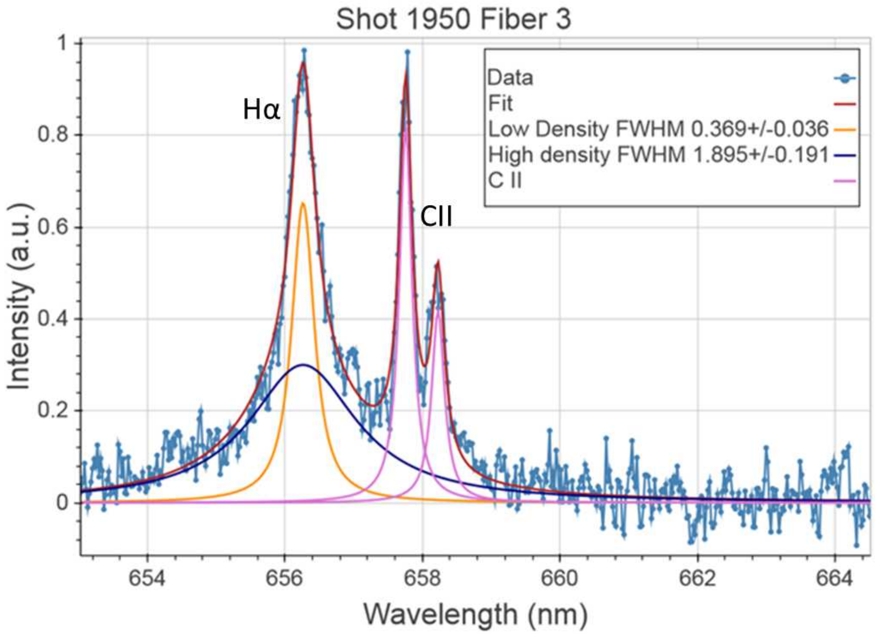
Enclosed Current

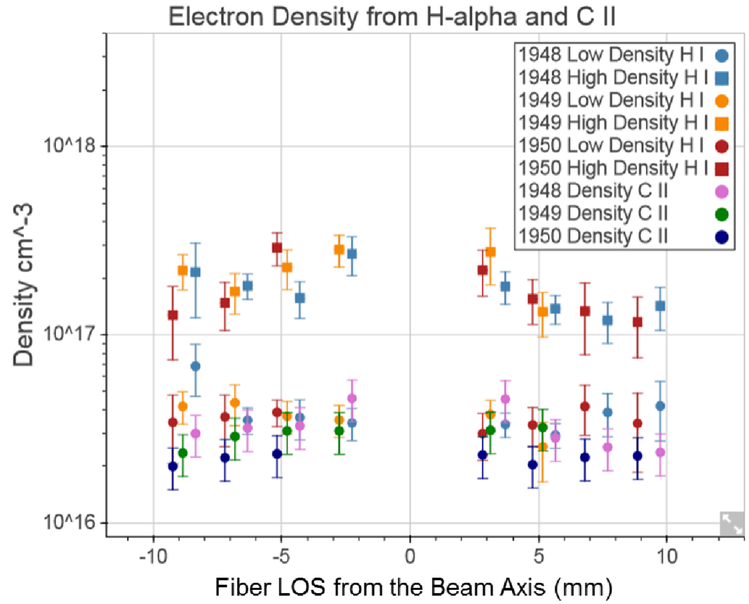


Simulation From N. Bennett

- Enclosed current increases roughly linearly with radius
- Symmetric measurements.
- LSP simulation for a standard foil SMP diode (scaled to match shot current of 120-150 kA)
  - Suggests more of the current is enclosed within a few mm region than the splitting measurements would suggest.

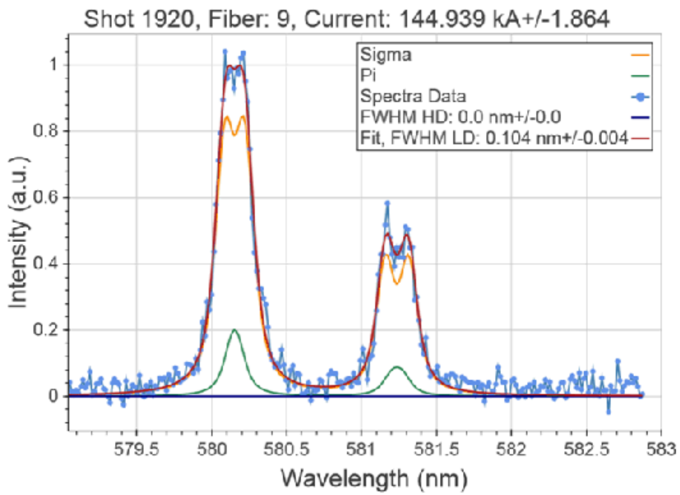
Stark Broadening

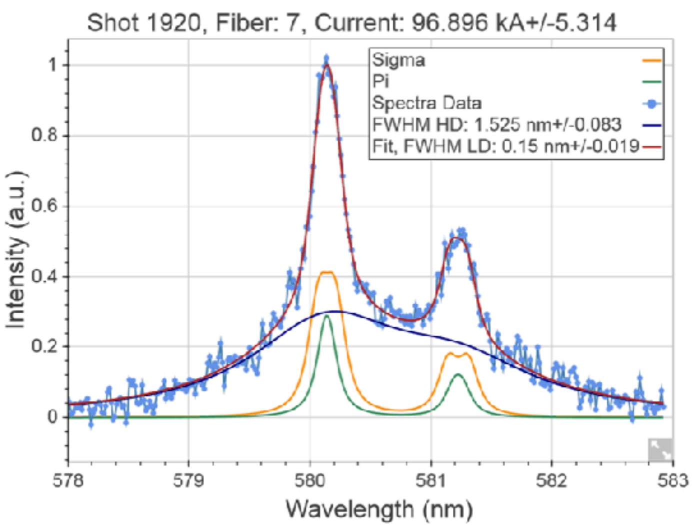


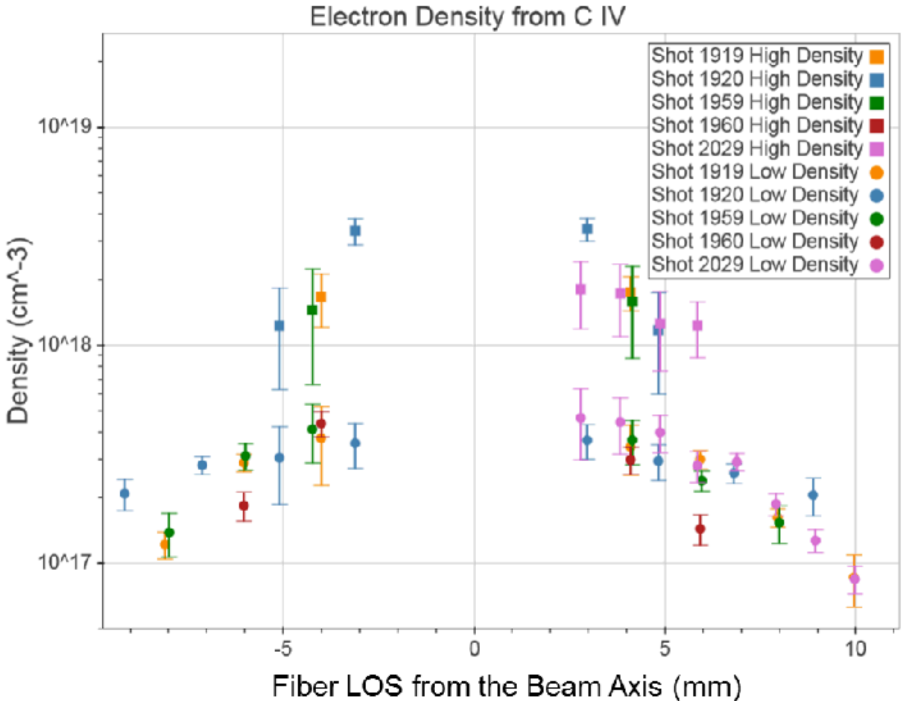


- H-alpha measurements were taken on bare or coated convertors.
- H-alpha and C II lines were fit with Voigt profiles. The Lorentzian components were used to calculate electron densities using Griem's tabulated values[1]
- H-alpha was fit with two densities to account for the broad, lower intensity "wings"

Stark Broadening





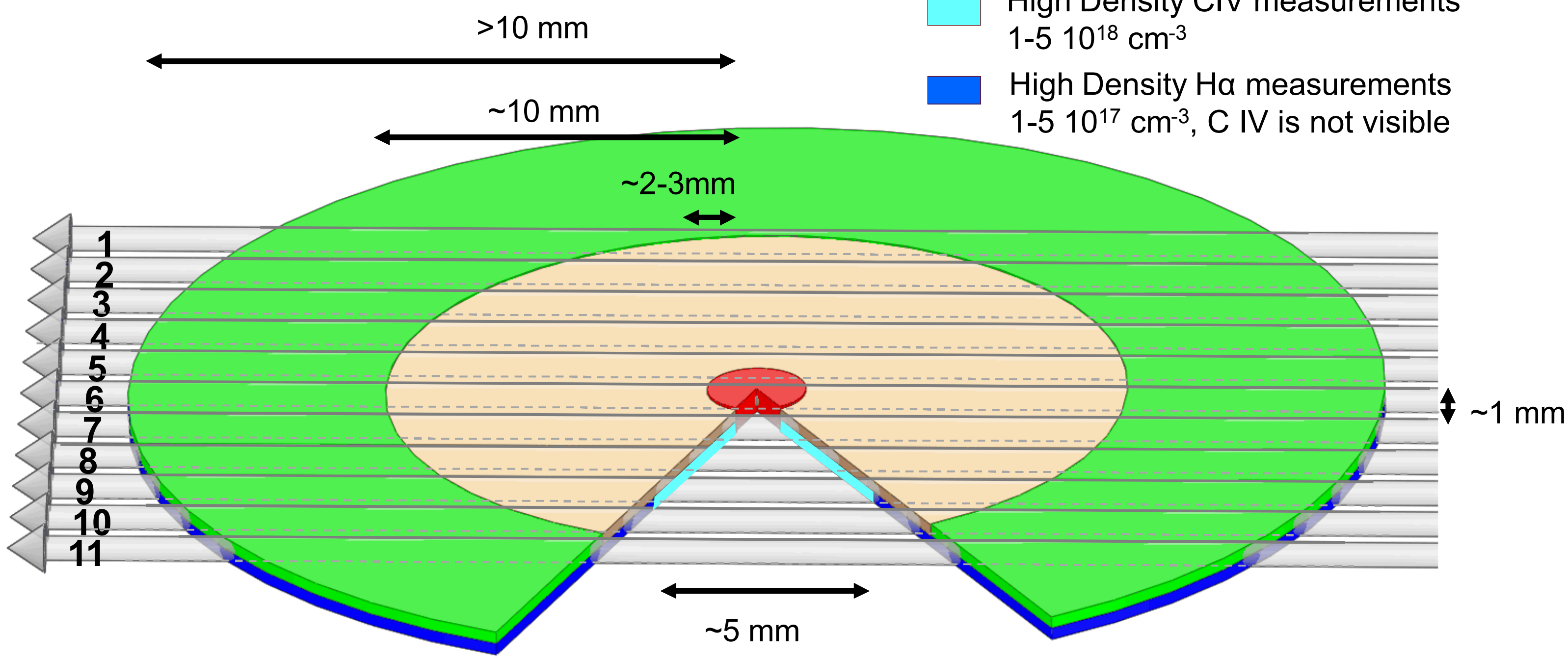


- Electron densities from C IV are determined from Prof. Yitzhak Maron's Stark width calculations[1]
- ~Order of magnitude larger than H-alpha measurements

1. E. Stambulchik and Y. Maron, J. Quant. Spectrosc. Radiat. Transf. 99, 2006

Electron Densities

- Hot dense plasma near axis
  Continuum/very broad lines
- Low Density CIV measurements
  1-5 10^{17} cm^{-3}
- Low Density Hα measurements
  1-4 10^{16} cm^{-3}, C II is visible
- High Density CIV measurements
  1-5 10^{18} cm^{-3}
- High Density Hα measurements
  1-5 10^{17} cm^{-3}, C IV is not visible

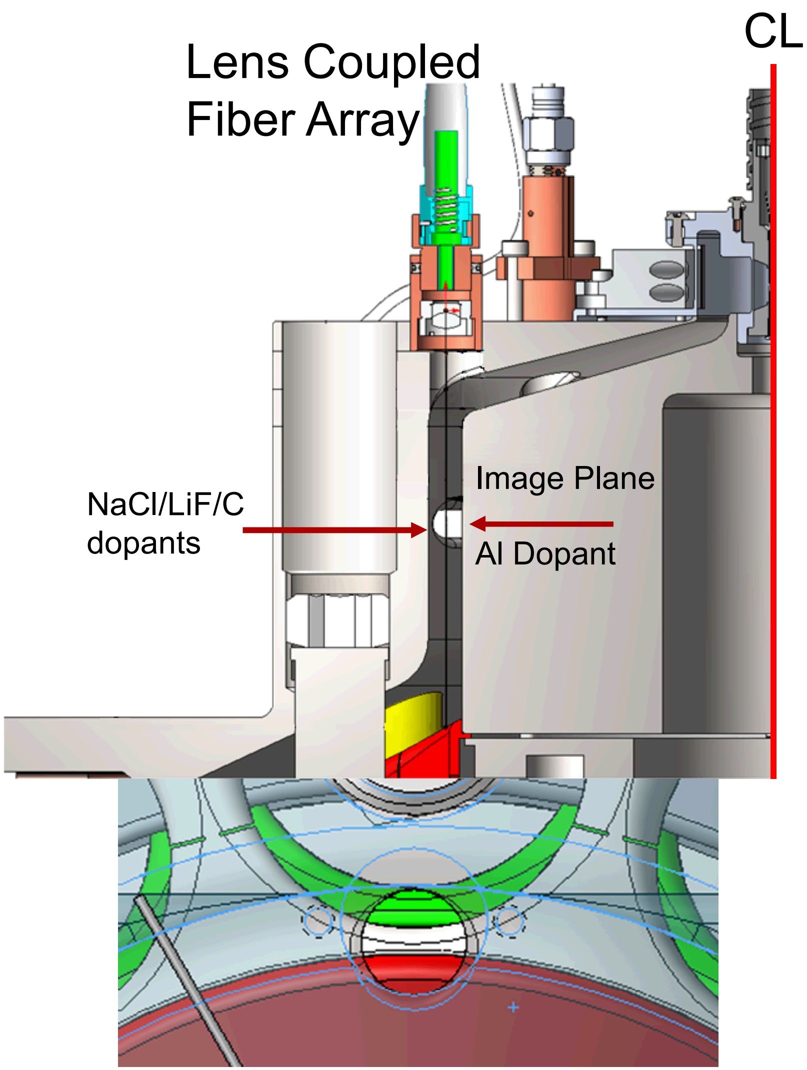


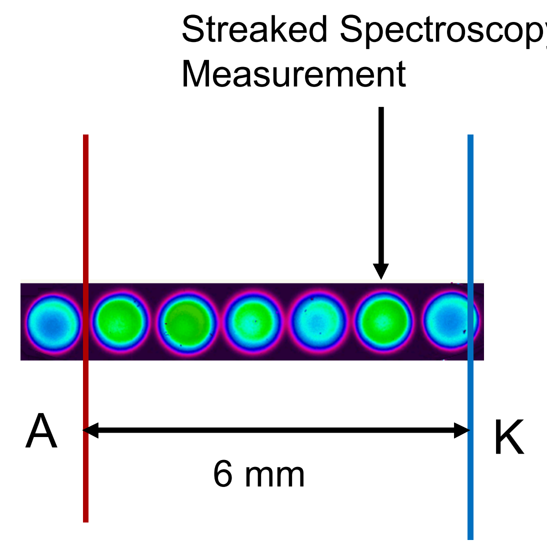
Z Convolute Measurements

- Current loss on Z can range from 1-2 MA up to 7–8 MA, depending on the load[1]
- Experiments using lens coupled fiber arrays are currently in progress on Z
  - Spatially resolve regions of interest.
  - The goal is to understand plasma development and parameters on power flow surfaces.

1. M. R. Gomez *et al.*, “Experimental study of current loss and plasma formation in the Z machine post-hole convolute,” *Phys. Rev. Accel. Beams*, Jan. 2017.

Future Z Convolute Measurements





- Measurement taken parallel to the cathode, ~1 mm from the surface.
- Measurement may still be backlit from the upper cathode.

Conclusions

- B-field profile measurements have been made on RITS-6
  - Yields current distribution on the anode
- Electron density and temperature profiles have been measured across the diode.
- Multi-fiber arrays have been fielded on Z, and experiments and analysis are in progress in order to obtain a more complete picture of plasma formation in these regions.