Abstract

Emissive plasma gun current sources are employed as helicity injection devices for non-inductive start up of ST plasmas in PEGASUS. The characterization of plasma impurity content and radiated power loses is of special interest in these non-ohmic discharges. To that end, radiated power losses are measured by two 16-channel AXUV silicon diode arrays that view the plasma tangentially, across the mid-plane from the center column to the outside limiter. These measured intensities are post-processed using an Abel Inversion technique and fitted plasma equilibria to produce radial emissivitty profiles. Bolometery of gun-produced plasmas indicated a rapid increase in radiated power after flux closure. Impurity species content is provided by VUV spectra obtained using a SPRED spectrometer, this instrument is capable of delivering a full spectrum from 10 to 110 nm at 5 kHz rate. Oxygen is typically the dominant impurity, although at highest injection powers, metallic impurities from the gun and/or diverter impact region become evident. Qualitative observations of the O-V/O-IV line ratio suggest $T_e > 50$eV for these larger start-up plasmas.

Work supported by U.S. D.O.E. Grant DE-FG02-96ER54375.

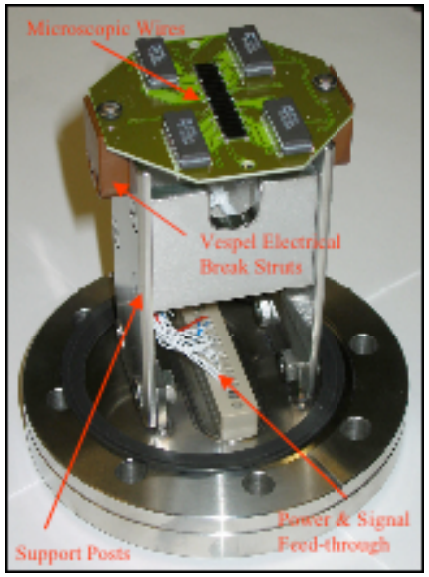
Outline

- Diagnostics
  - Bolometers
    - *Provides Emissivity Profile vs. Major Radius*
  - SPRED
    - *Provides Relative Impurity Measurement vs. Time*
- Helicity Injection using an Electrostatic Plasma Gun
  - Nitrogen impurities are observed and hinder plasma current
- Pre-Ionization of Ohmic Plasmas using an Electrostatic Plasma Gun
  - Emissivity Profiles show high edge emission
  - Spectra indicate nitrogen impurities in plasmas
- Microwave Start-up Ohmic Plasmas
  - Emission spectra show little to no nitrogen impurities
- Non-Inductive Tokamak Start-up using a Mid-Plane Plasma Gun
  - Emissivity profiles suggest a small plasma collapsing into center column

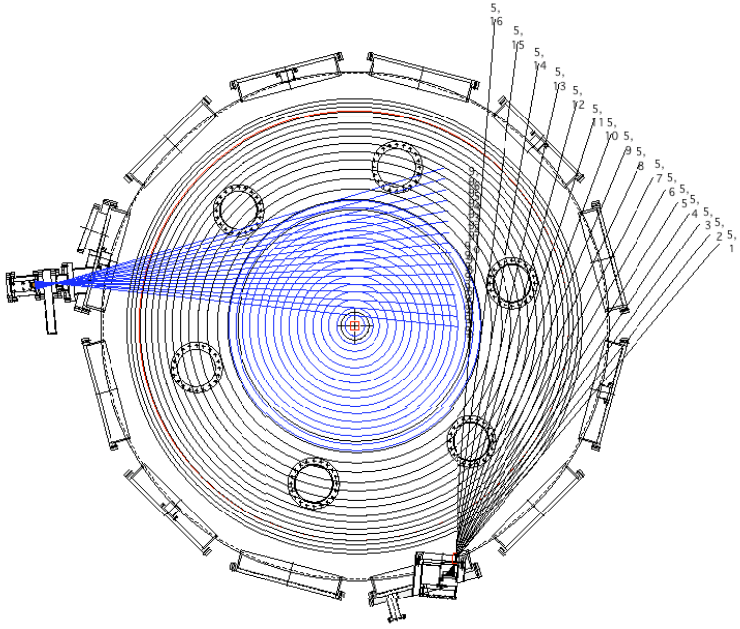
Bolometers on PEGASUS

- Two arrays, each consisting of 16 AXUV silicon photodiodes
  - Views across toroidal mid-plane
    - *Port 9 array views inboard, 4 to 49 cm*
    - *Port 5 array views outboard, 46 to 90 cm*

- Post Processed using an Abel Inversion Technique.
  - Converts Raw signal to Emissivity vs Major Radius
  - Integrate Profile for Total Radiated Power
  - See *Boivin, RSI 1999*



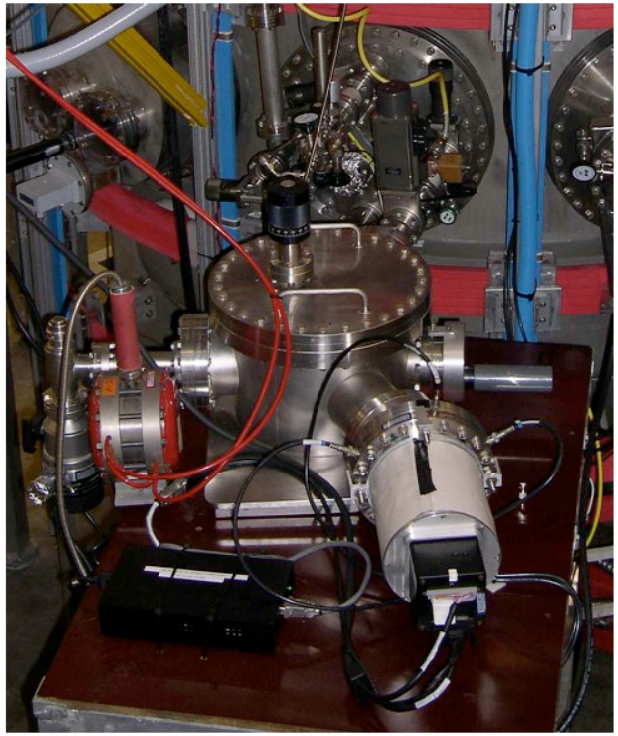
Bolometer on Bench



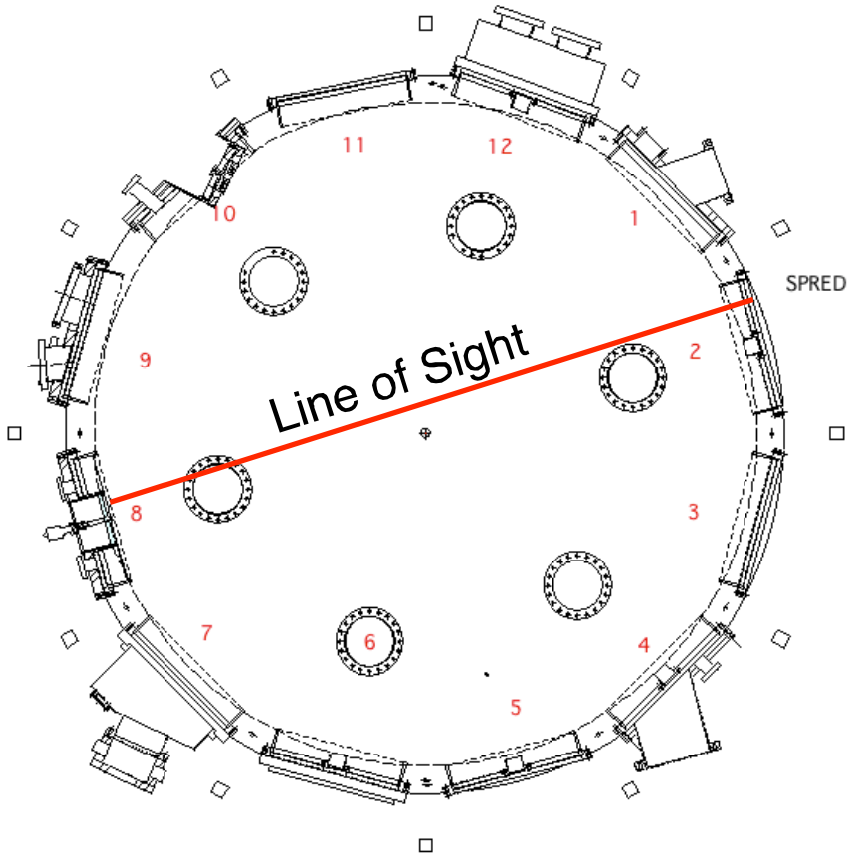
Chord Mapping on PEGASUS

SPRED on PEGASUS

- Observes spectra vs. time for plasmas in the 10-110 nm range
  - Line of sight across 20 cm tangency radius
  - Time Resolution ~0.2 ms



SPRED on PEGASUS

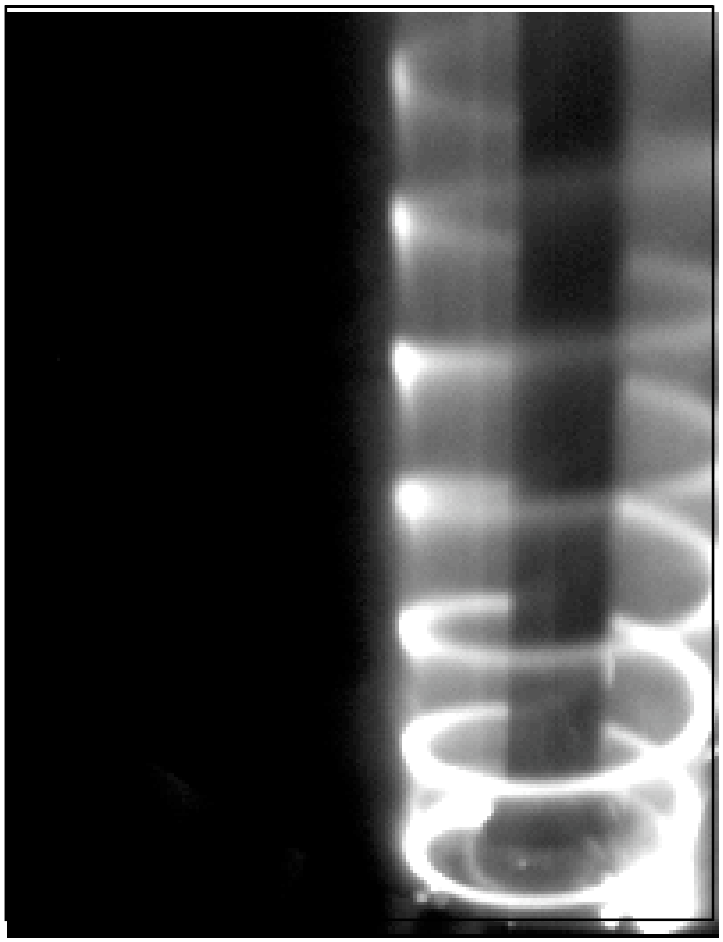


PEGASUS ST Vessel

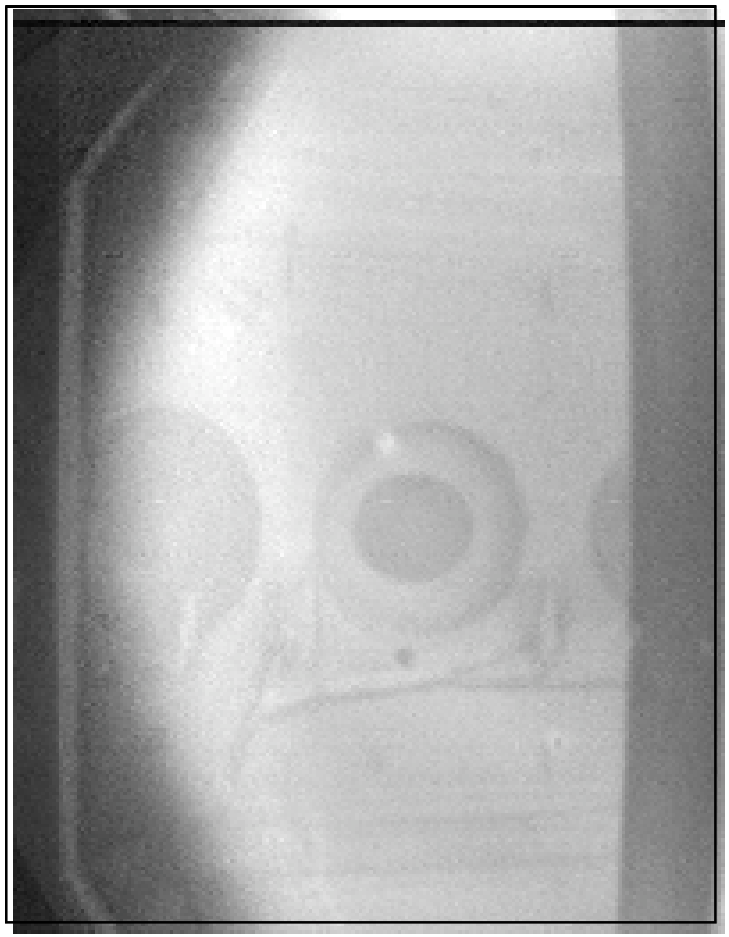
Helicity Injection with an Electrostatic Plasma Gun

- A Plasma Gun is used to form a tokamak like Plasma

Before Flux Reversal

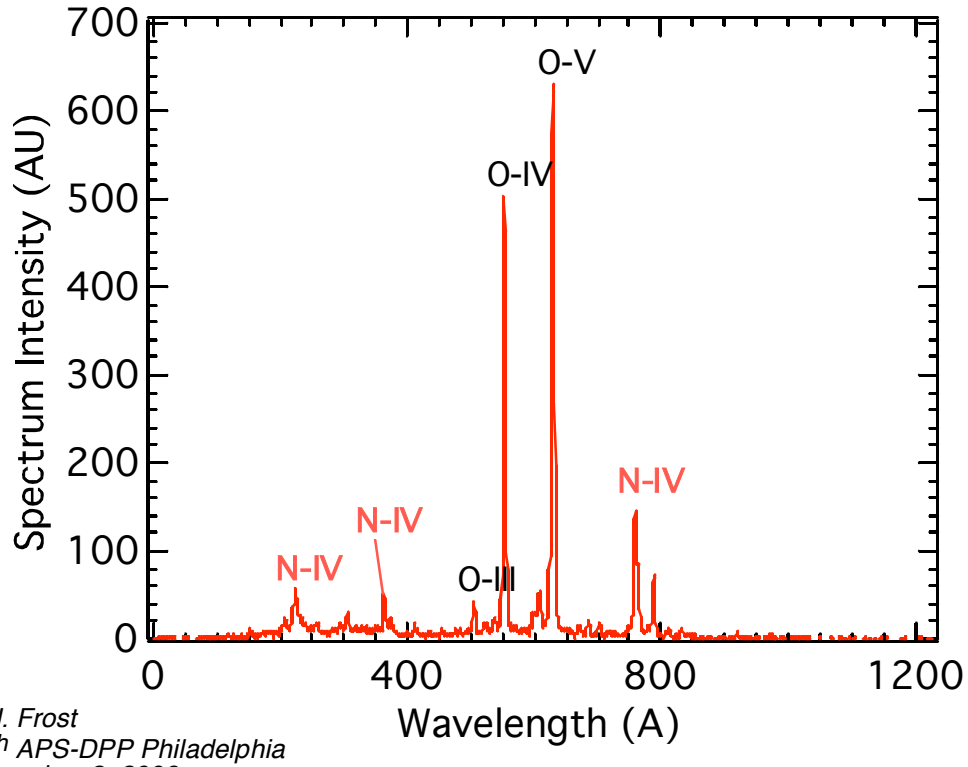


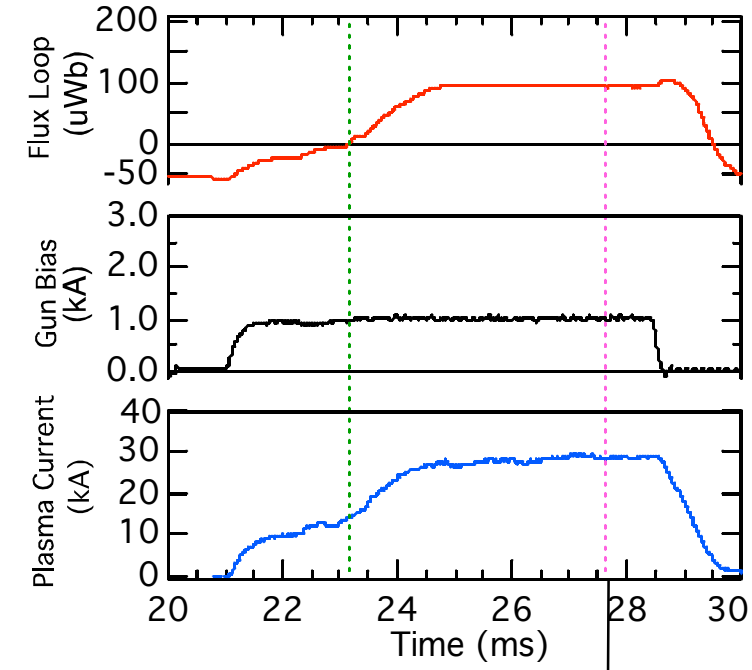
After Flux Reversal



Smaller 1cm Aperature Gun Injects Nitrogen Impurities

- At an arc current of 1 kA, and a 1 cm gun aperature
  - Injections show Oxygen impurities typical of ohmic Discharges
  - Nitrogen is more prevalent

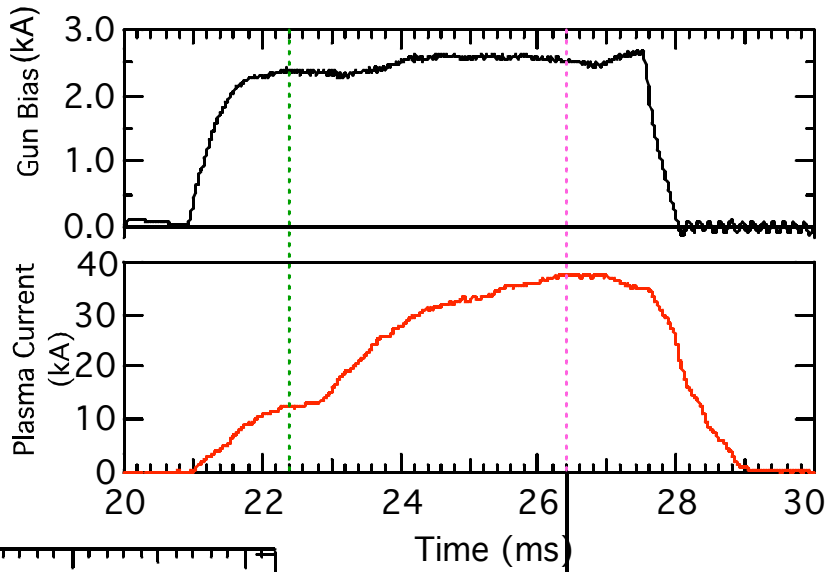




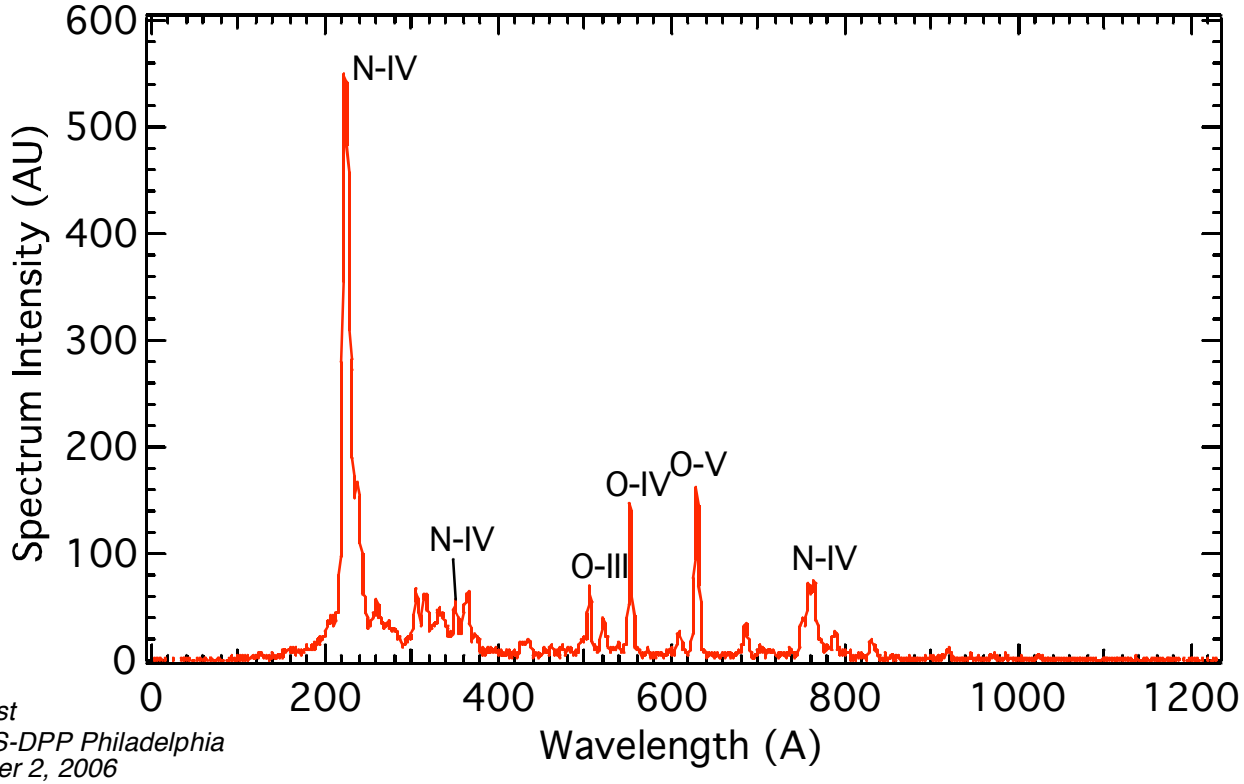
Time of Spectrum

Higher Power Gun Injects More Nitrogen Impurities

- A proto-type high-power gun at an arc current of 2.7 kA, and a 2 cm aperature
  - Plasmas have even more Nitrogen impurities
  - Oxygen lines still prevalent

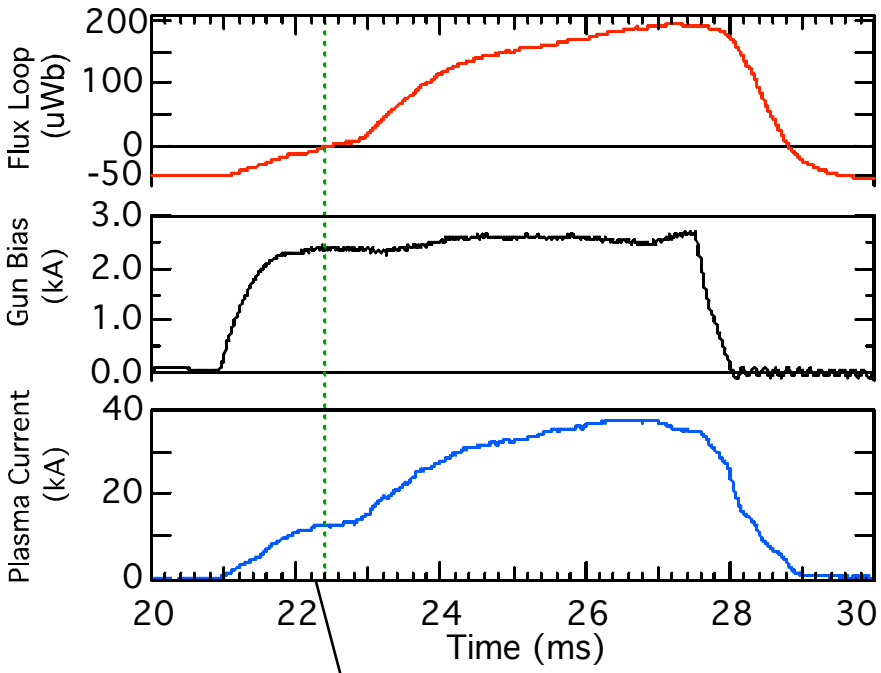


Time of Spectrum



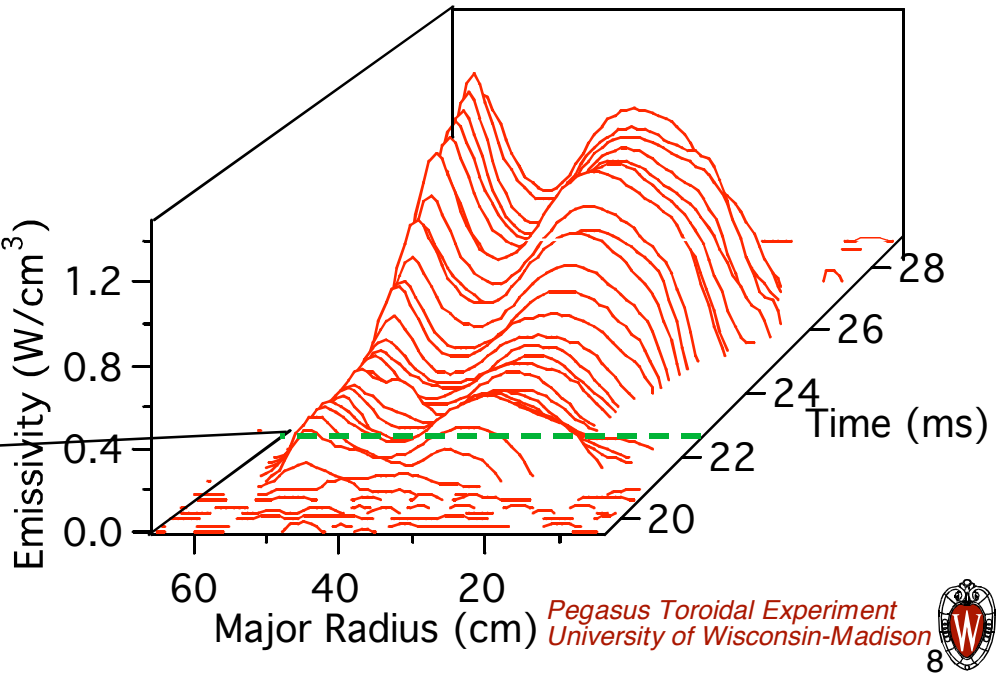
Suggestion of Radiation Burn Out after Flux Reversal

- A higher-power gun with an arc of 2.7 kA, injects a flux-reversed plasma
  - Data only available to Major Radius of 49 cm
  - Clean up of signal at R > 49 cm needed



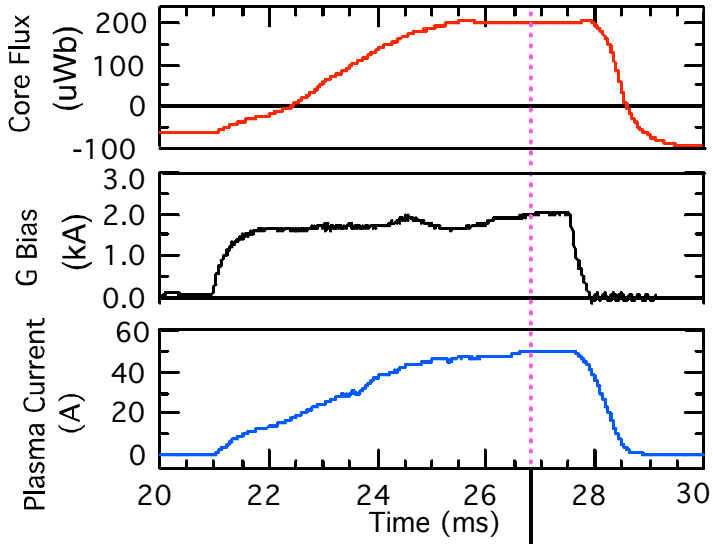
- Abel Inverted data is representative of interior radii
- Profile Suggests the beginnings of a burned out plasma

Time of Flux Reversal

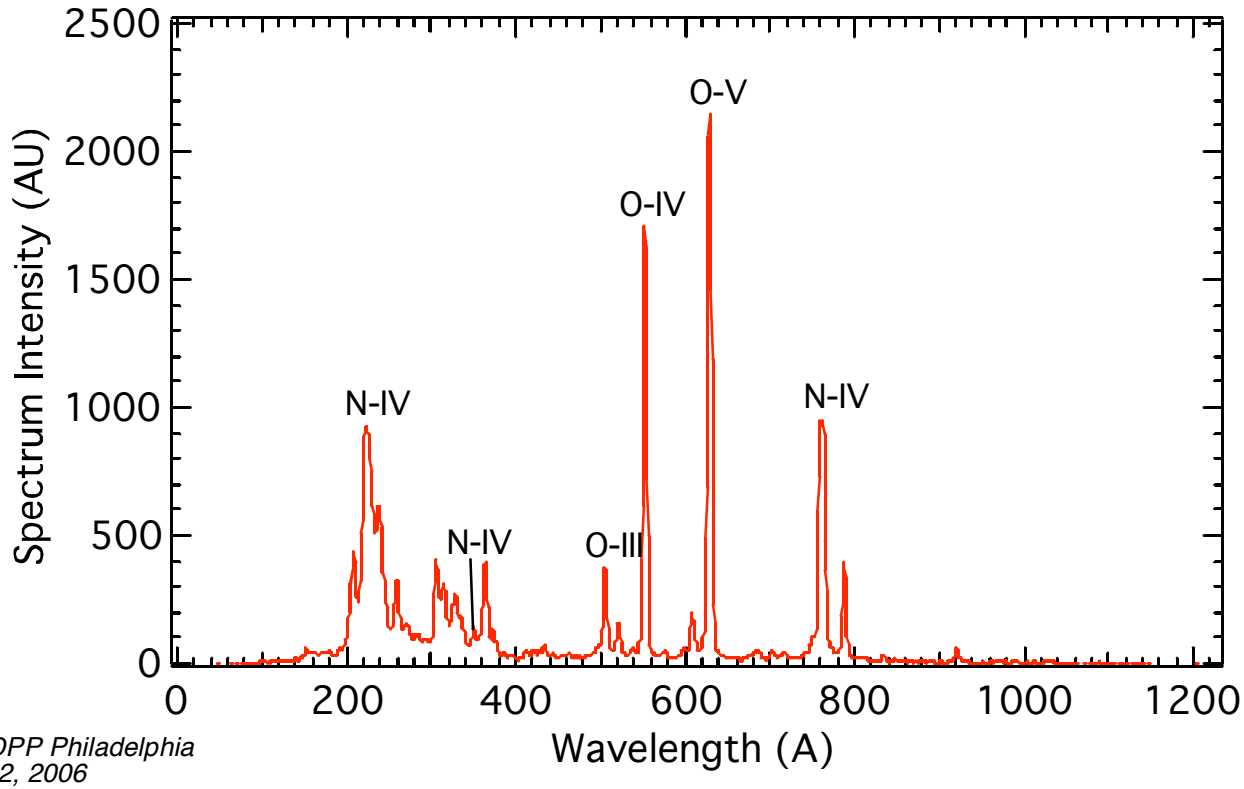


Two Guns Yield More Current

- Two prototype high-power guns at an arc current of 2.0 kA, and a 2 cm aperature
  - Nitrogen lines still prevalent, but not as much as with 2.7 kA arc current

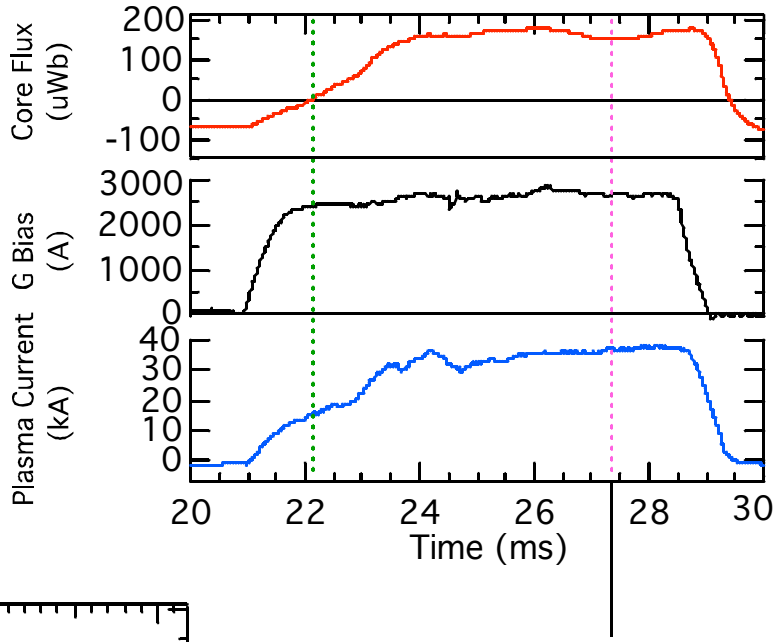


Time of Spectrum

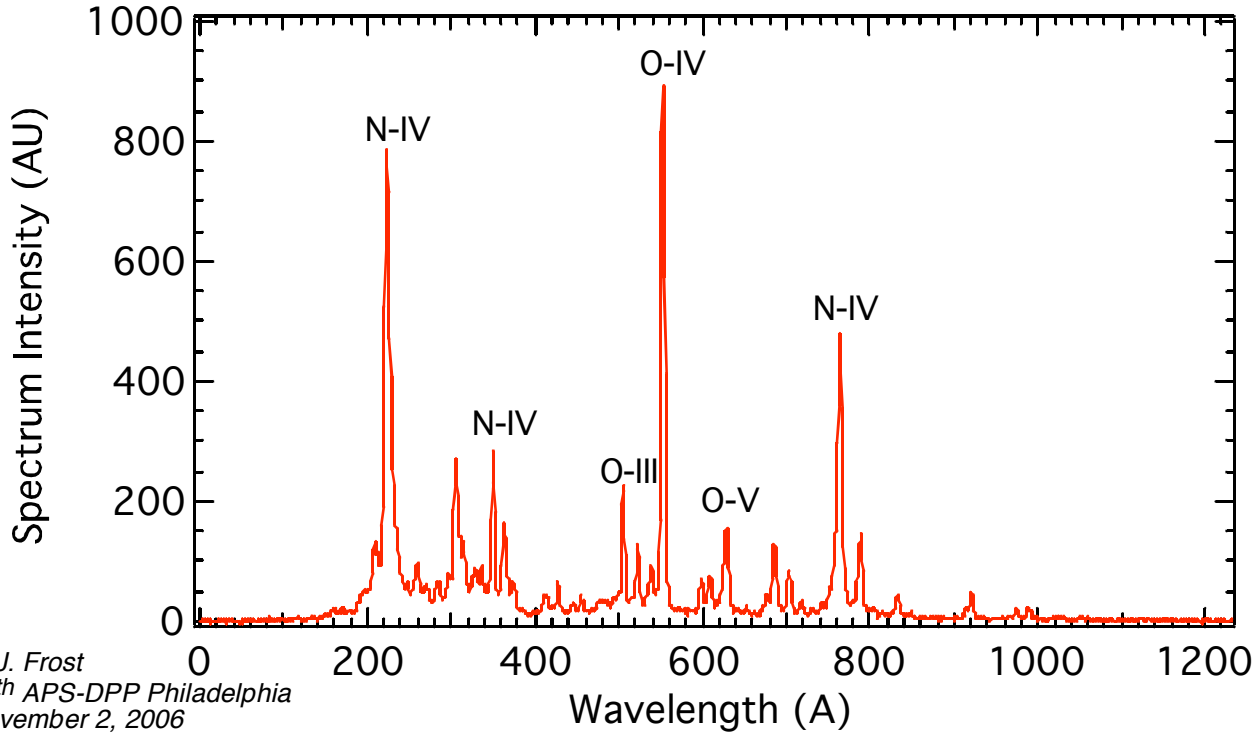


Higher Arc Current Yields More Intense Nitrogen Lines

- Two prototype high-power gun at an arc current of 2.7 kA, and a 2 cm aperature
  - Nitrogen Dominated Plasmas Observed
- Nitrogen Lines traced to Internal Arcing
  - Boron Nitride Insulation
  - To be addressed in next generation



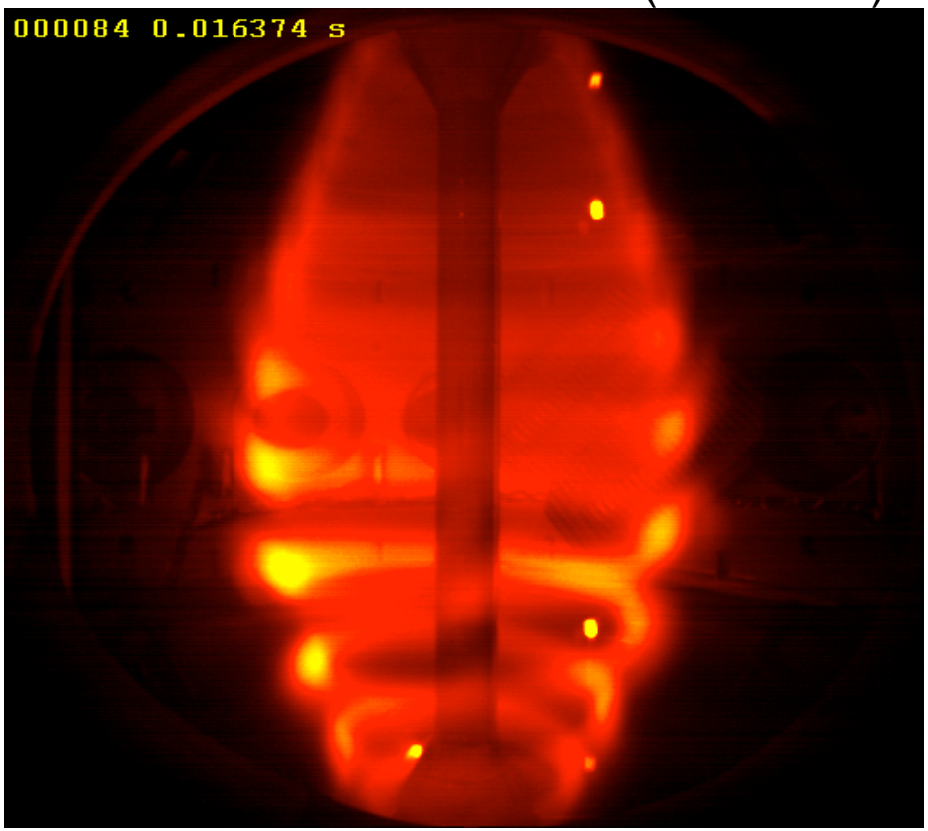
Time of Spectrum



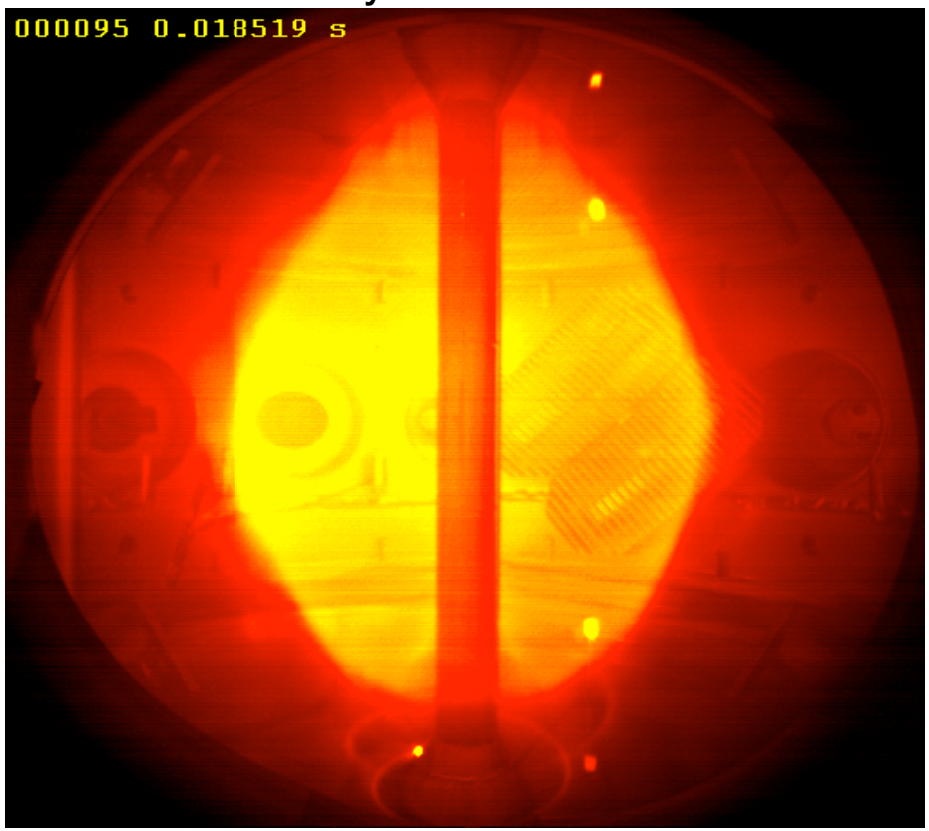
Plasma Gun Injection with Ohmic Drive

- A plasma gun injection near the diverter as a pre-ionization source
  - Allows plasma formation at low B_T, with no poloidal null required
  - To date, Nitrogen impurities entering plasma
    - Plasma hits Boron Nitride Insulation
    - Internal arcing to be addressed in the next generation

Discrete Current Filaments (No Ohmic)

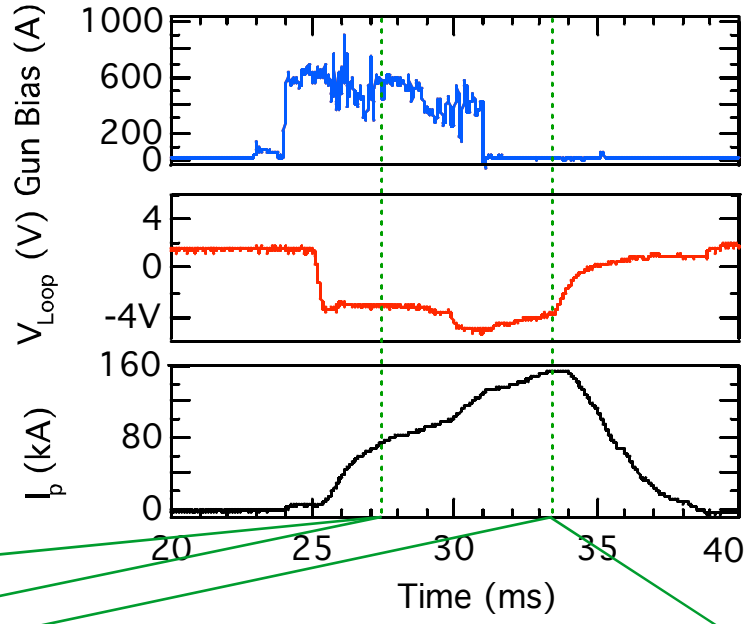


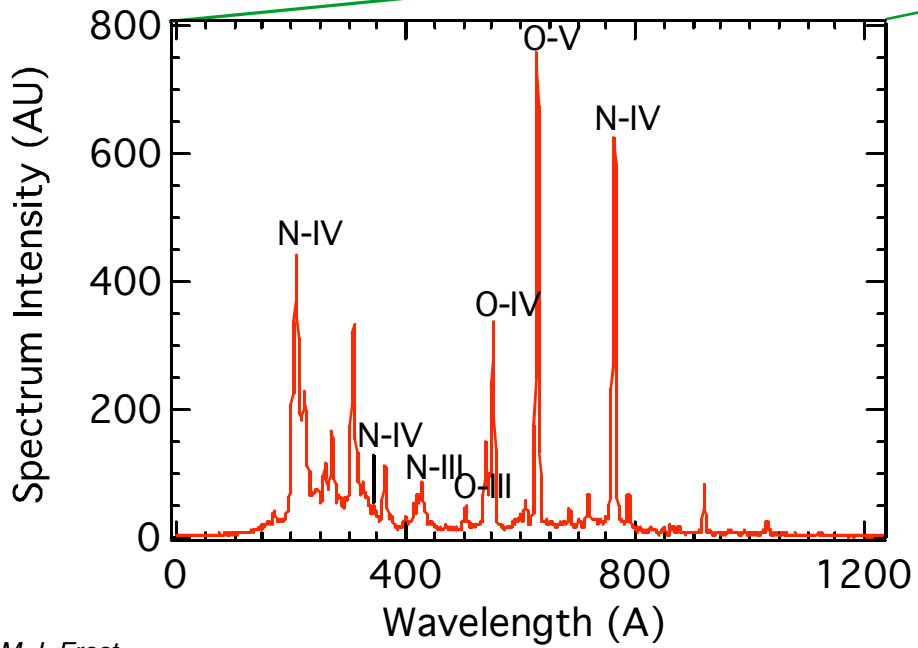
Ohmically Driven ST Plasma

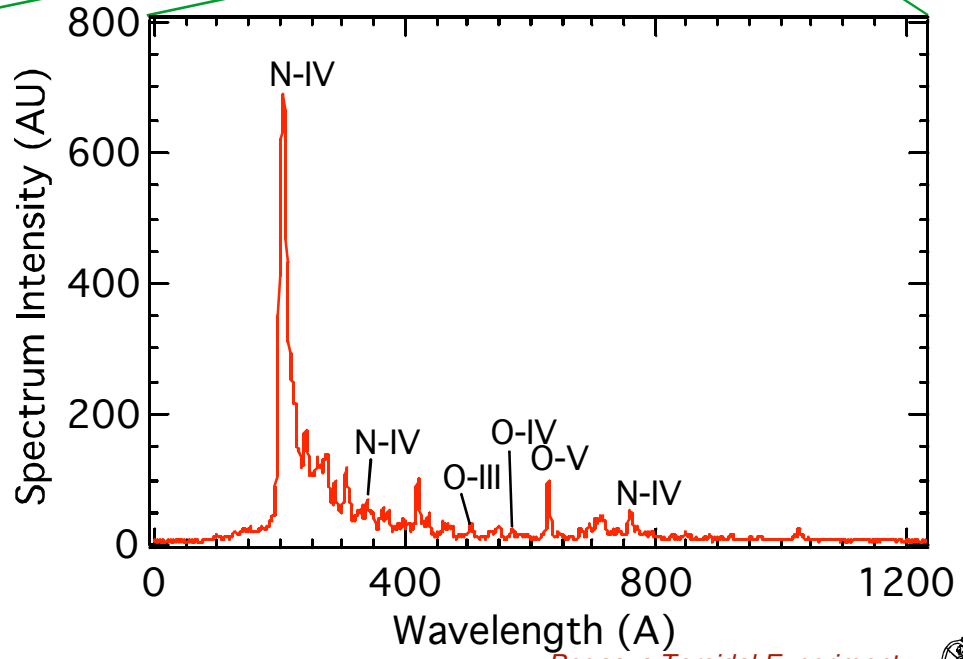


1 kA Plasma Gun Pre-Ionization has Impurities

- Gun pre-ionization sources nitrogen to plasma
- Even after gun has turned off, Nitrogen Impurities remain, along with expected Oxygen spectra

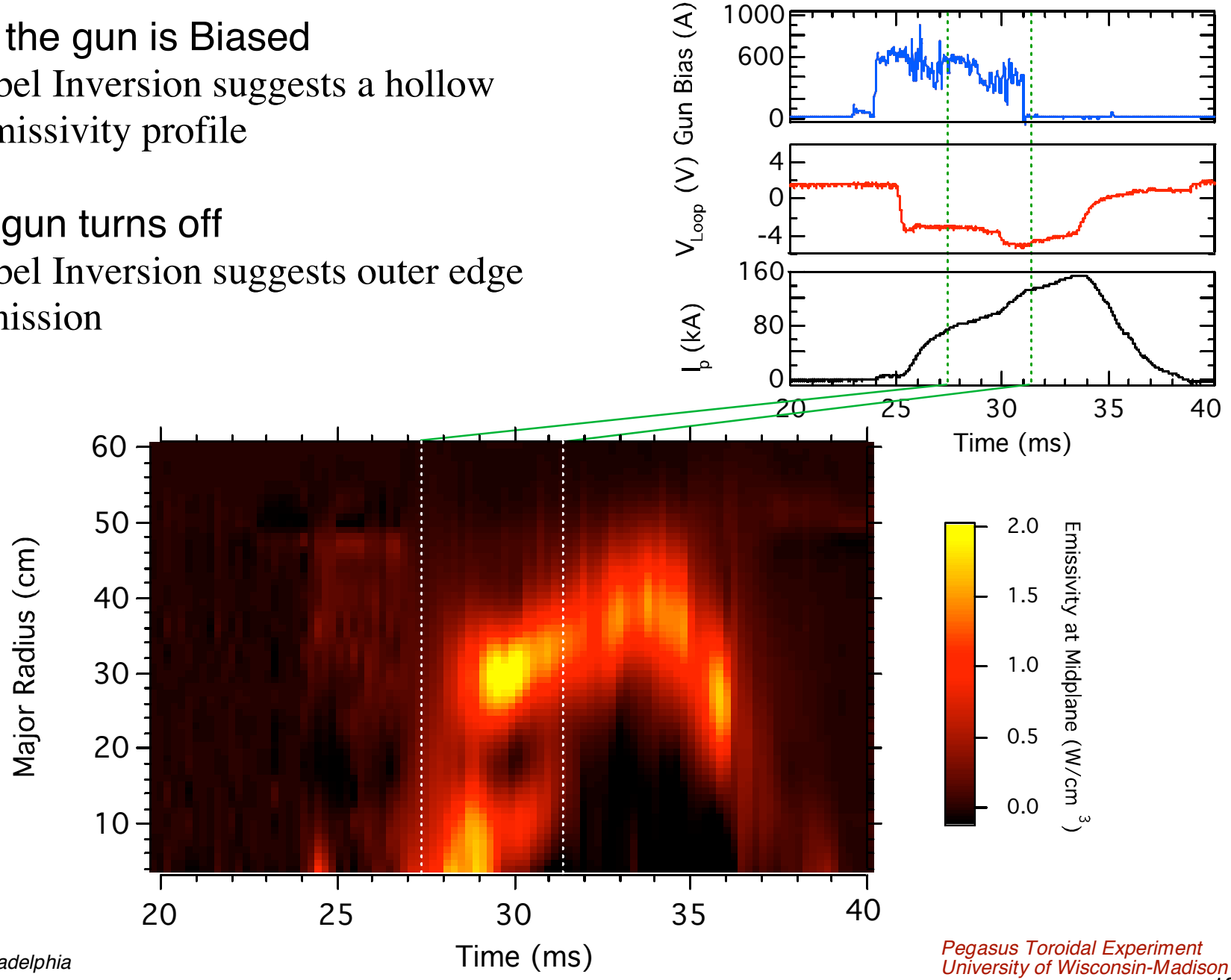






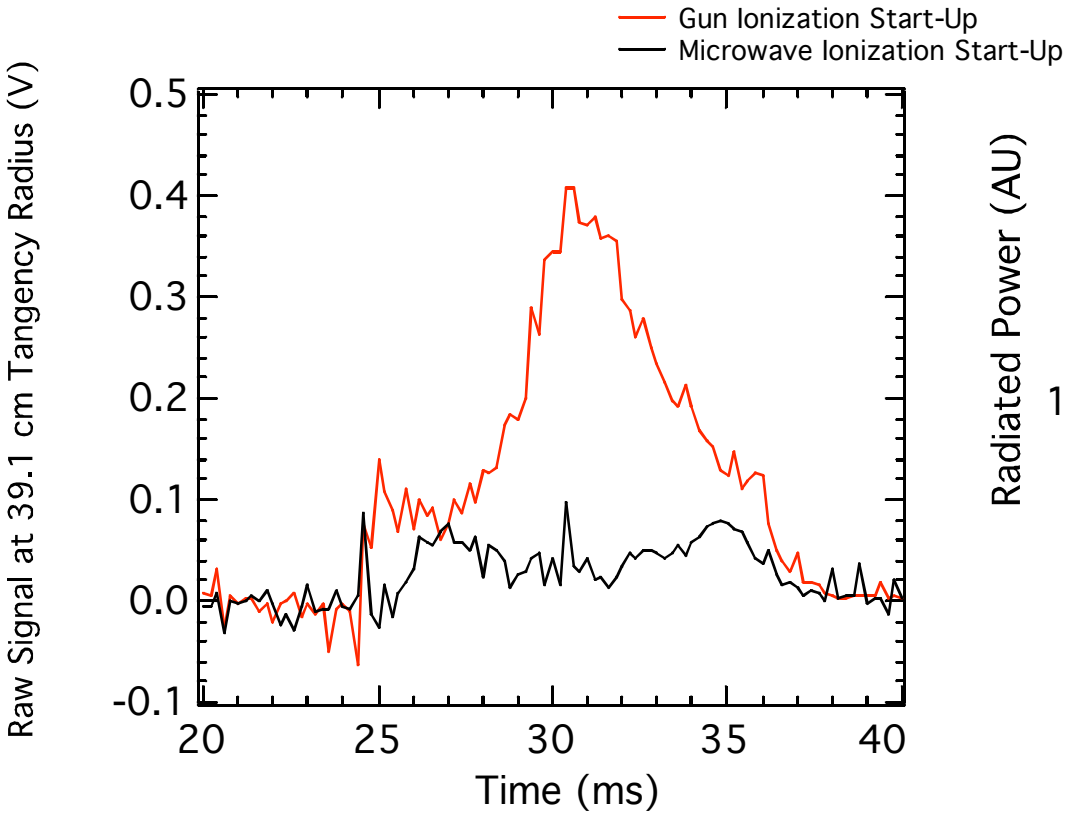
Pre-Ionization + Ohmic Drive Yields Edge Radiation

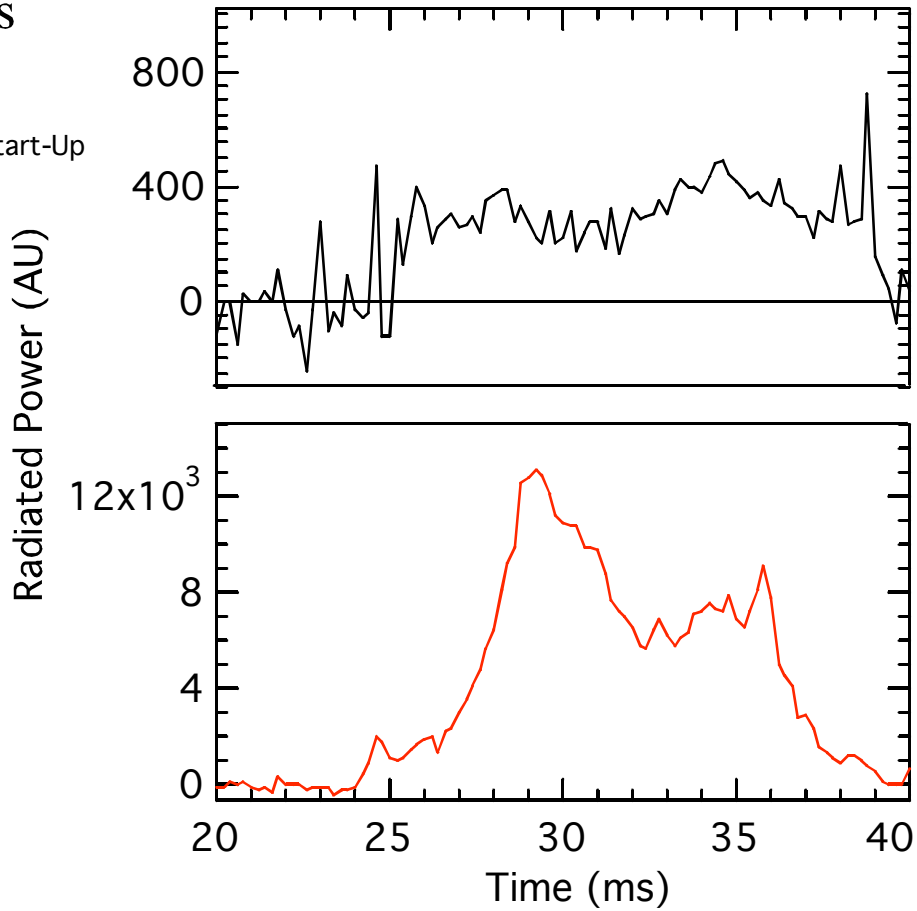
- While the gun is Biased
  - Abel Inversion suggests a hollow Emissivity profile
- Once gun turns off
  - Abel Inversion suggests outer edge emission



In Contrast, Ohmic Plasmas Not as Emissive

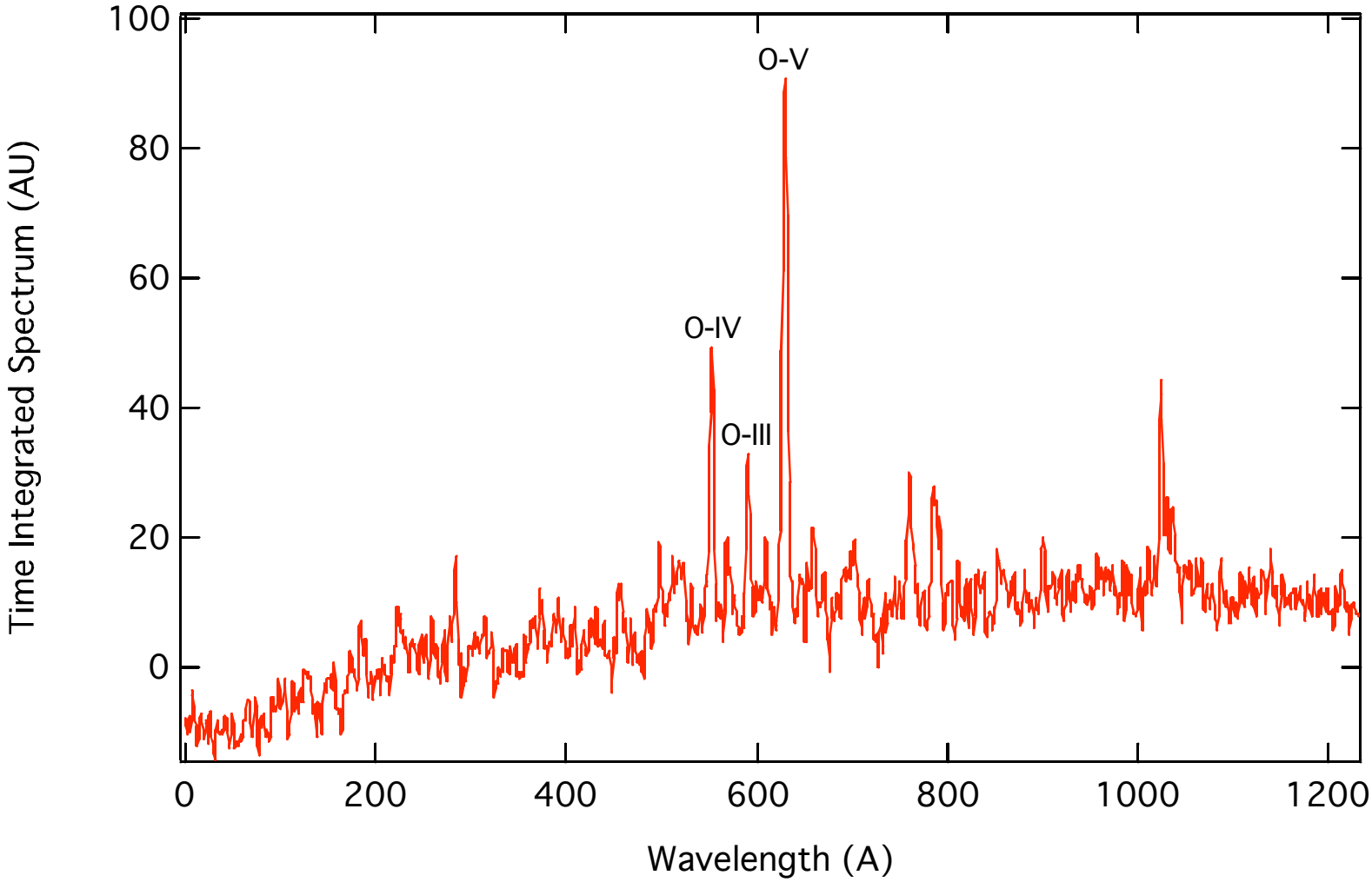
- Microwave-Ohmic Startup Plasmas show little signal
  - Bolometers have < 10:1 Signal:Noise
    - *Compare to > 30:1 for Gun plasmas*
  - Radiated Power Measurement Shows an Order of Magnitude more power radiated from gun plasmas





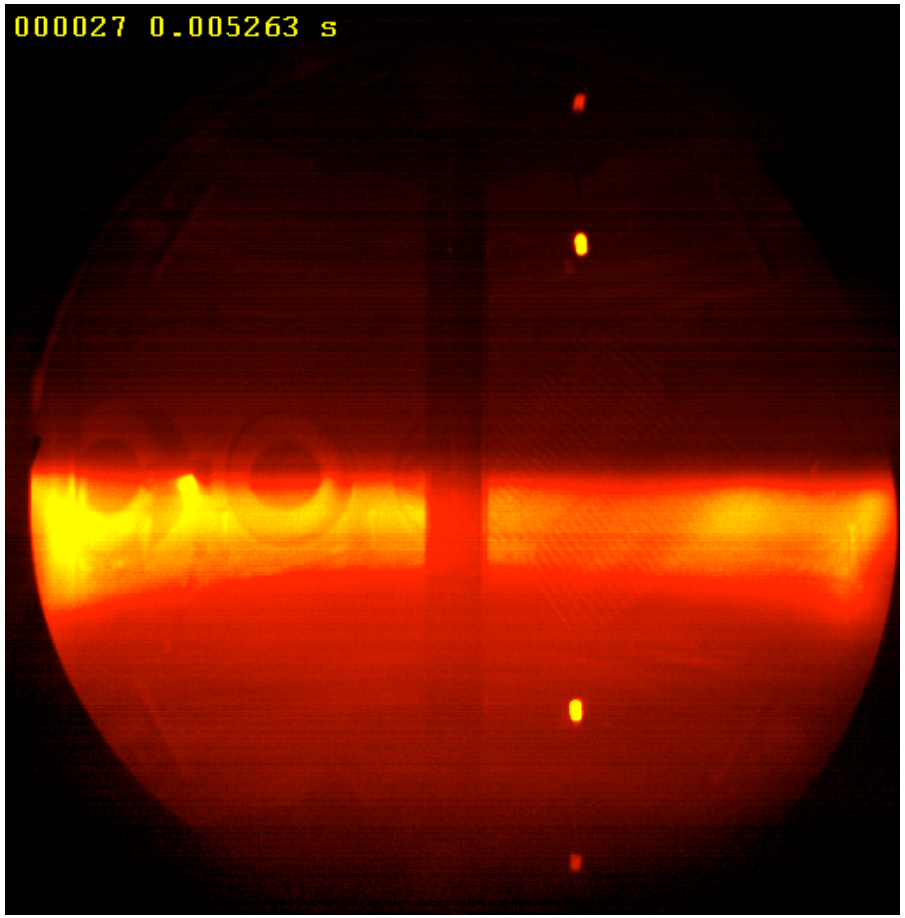
Ohmic Plasmas Lack Intense Spectra

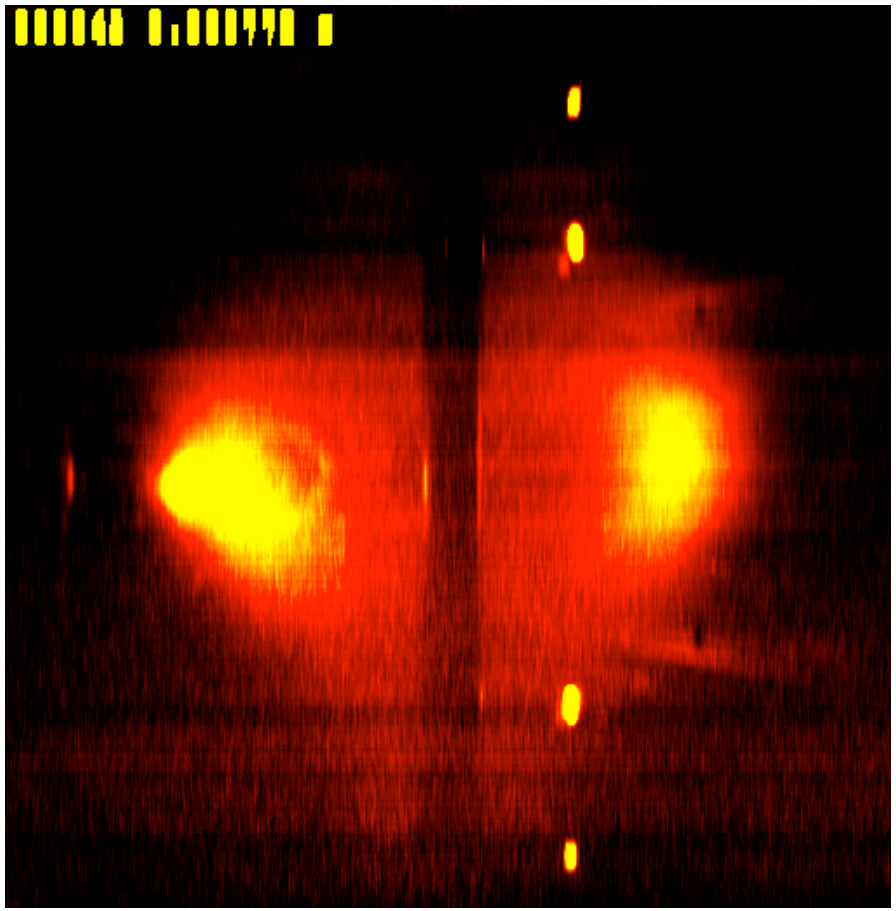
- Microwave-Ohmic start-up plasmas Oxygen dominated
  - Little to no Nitrogen Impurities present
  - Suspect low plasma density



Non-Inductive Start-up Using a Mid-Plane Gun

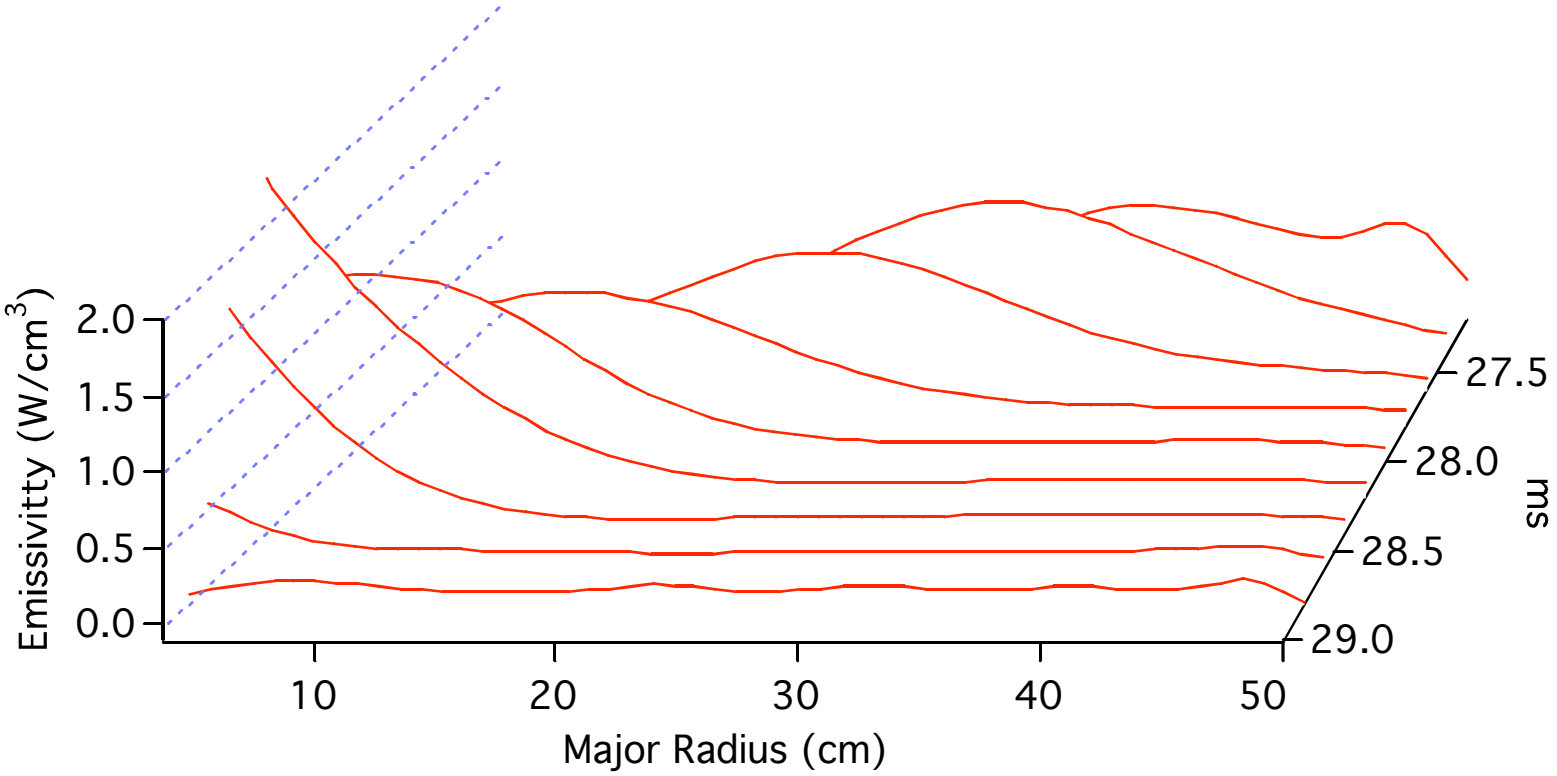
• A plasma is created by mid-plane gun injection and compressed into a Lower aspect ratio





Compression Observed after Start-up

- Just after structured plasma is formed, it collapses into the center stack
  - Emissivity Profiles Suggest a collapse over ~1 ms



Summary

- Bolometery and Spectroscopy are used to diagnose different plasmas on PEGASUS.

- Helically injected plasmas are observed to be well formed but very radiative and high in Nitrogen impurities.
  - Plasma impact with Boron Nitride
  - Internal arcing of gun structure
  - Next generation to address impurity reduction

- Plasma Gun Pre-Ionization shows high emissivity and intense SPRED spectra due to impurities compared to microwave ionization plasmas.
  - Ohmic plus microwave pre-ionization suggests typical Oxygen radiation at lower intensities

- Mid-Plane Gun Plasma emissivity profiles are seen to collapse into the center column, thus showing compression into low-aspect ratio from initial non-inductive start-up.
  - See poster *Garstka et al,* Poster Session *VPN.00002* .

Reprints