Abstract

Understanding power losses and confinement is important to achieving high $ß_t$ plasmas at low aspect ratios in the Pegasus ST and to contributing to the spherical torus database. To that end, new diagnostic systems are being deployed on the experiment. Two tangentially viewing, 16-channel AXUV diode arrays will provide radiation power loss rate profiles in the plasma midplane. This profile is combined with a fitted plasma equilibrium to determine the total radiation losses. A novel silicon-drift-detector-based pulse height analyzer (PHA) will determine the electron temperature by continuum measurements from the 1-3 keV region. Direct digitization and fitting of individual photon events minimize pileup effects and dead-time losses. Count rates up to 1000 kcounts/sec will allow $T_e(t)$ measurements with a few-ms time resolution. A T_e profile can be obtained on a shot-to-shot basis. Finally, the conceptual design of a second generation very-high sensitivity SXR 2-D tangential imaging system is under development for determination of J(r).

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Overview

Approach

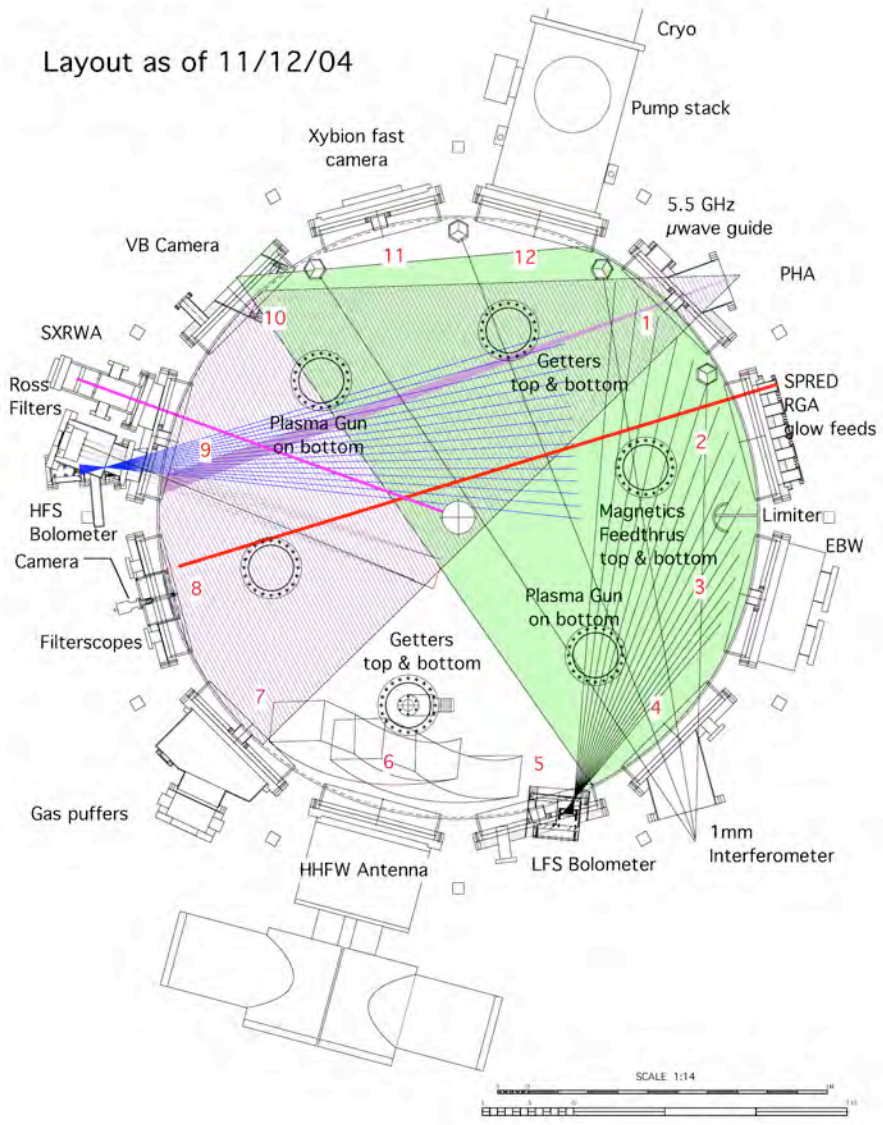
- Document and Understand Power Balance
  - P_{rad} ⇔ Bolometers
  - T_e ⇔ PHA & Ross Filters
  - n_e ⇔ Microwave Interferometer & VB System
  - Impurity Spectrum ⇔ VUV Spectrometer
- Determine τ_e

Pegasus Diagnostic Suite

Diagnostic	Capability	Measures	Status
Core Flux Loops	6	V_L, Y_{pol}	Operational
Wall Flux loops	6	Vessel currents	Operational
Int. Flux loops	20	Y_{pol}	Operational
Rogowski Coils	2	I_p	Operational
Diamagnetic Loop	2	F_{tor} / b_p	Operational
Bp, Mirnov Coils	56	B_r , B_z / MHD activity	Operational
VUV (SPRED)	Central Chord	Relative impurity monitor	Operational
Filterscopes	Central Chord	Oxygen, Carbon, VB, Da	Operational
Interferometer	Single Chord	N_{el}	Debugging
High Res. Camera	1000 fps	Plasma shape / position	Operational
2-D SXR Camera		Internal Shape / q(R)	Development
Poloidal SXR Diode Array	19 chords	MHD Activity	Operational
Tangential PHA	Single Chord	$T_e(t)$	Debugging
Tangential Bolometer Array	32 Chords	P_{rad}	Debugging
Ross Filters	4 Chords	$T_e(t)$	Debugging
Tangential VB Array	20 Chords	$Z_{eff}(R,t)$, $n_e(R,t)$	Debugging
EBW Radiometer		$T_e(t)$	Planned

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Pegasus Diagnostic Layout



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Switching Noise Suppression Recipe

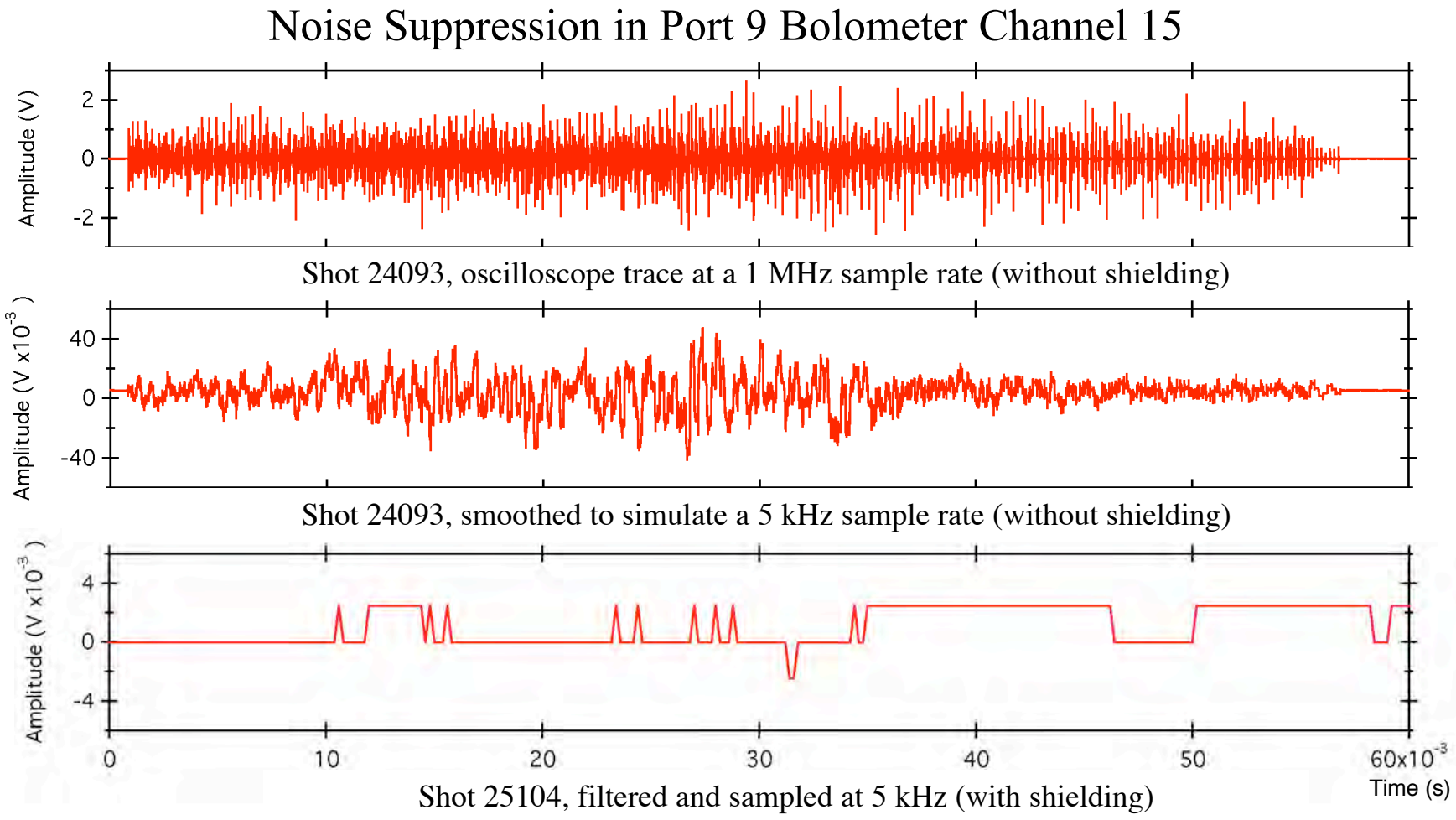
Source of Noise:

- New Programmable, High Power, IGBT & IGCT switches (See **PP1.019**)
- Produce electromagnetic pulses at 5 kHz
- Generates noise on any unshielded circuit
- Characteristics are time variable (can't subtract)

Noise Suppression Recipe:

- Electrically isolate the diagnostic from the vacuum vessel
- Shield diagnostics with Faraday cages
- Cages at screen room ground via shielded conduit
- Screen room ground as a single point diagnostic ground

Switching Noise Suppression Results



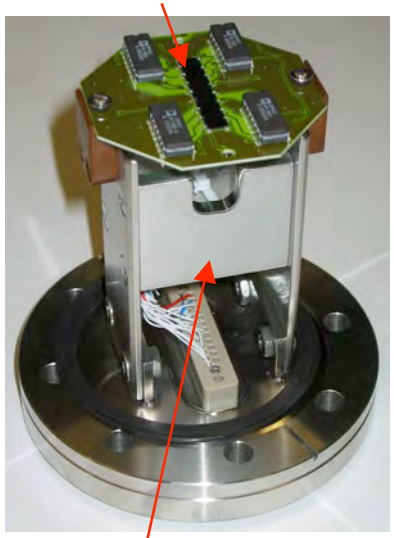
The bottom trace indicates noise has been reduced by a factor of ~ 1000

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Two 16-Channel AXUV Bolometers

Two 16-channel AXUV silicon photodiode detectors have been constructed to spatially and temporally resolve mid-plane radiative power losses in a discharge.

Int. Array/Pre-amp

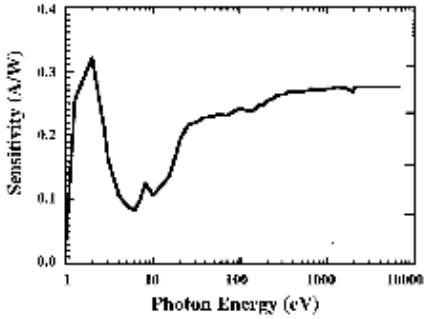


Mount Structure



Bolometer Shield

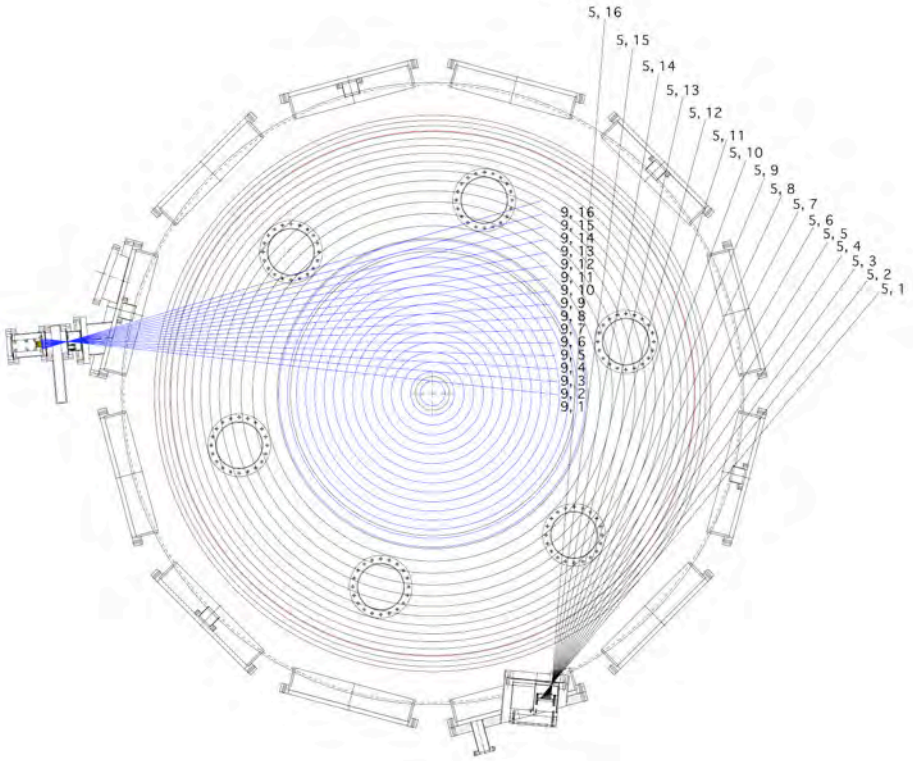
- Integrated Photodiode Array and Pre-amp Assembly
- Responds to visible light through soft x-rays[1].
- Spatial resolution ~ 2 to 4 cm
- Temporal resolution of 200 μs



[1]R.L. Boivin *et al.*, Rev. Sci. Instrum. **70**, 260 (1999).

AXUV Bolometer Tangency Radii

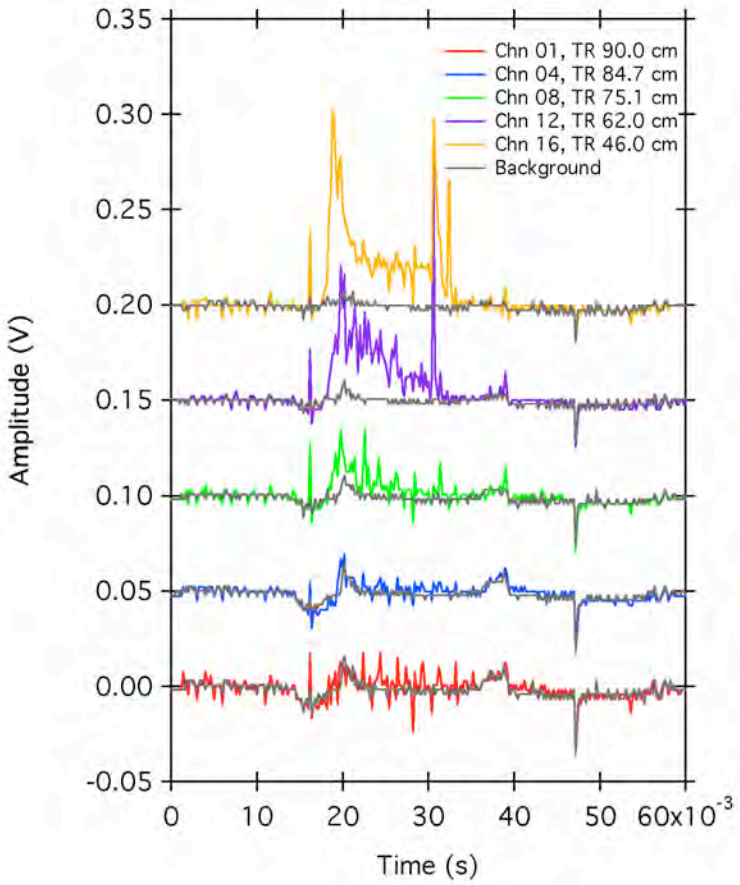
Bolometer arrays provide full cross-section coverage



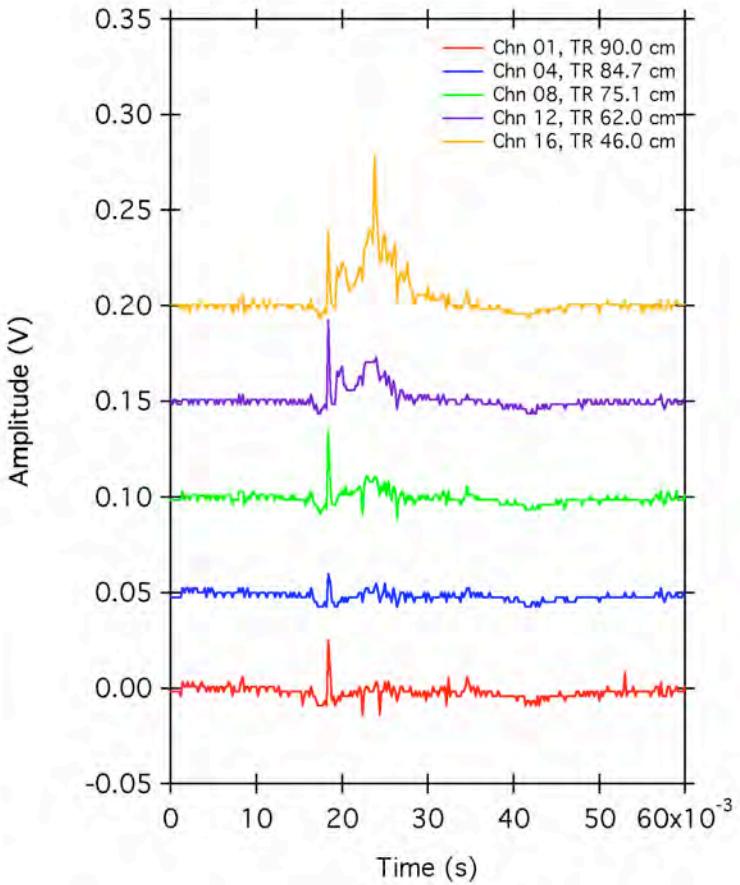
channel	Tangency Radius
5,01	90.0 cm
5,02	88.4 cm
5,03	86.7 cm
5,04	84.7 cm
5,05	82.6 cm
5,06	80.3 cm
5,07	77.8 cm
5,08	75.1 cm
5,09	72.1 cm
5,10	68.9 cm
5,11	65.6 cm
5,12	62.0 cm
5,13	58.2 cm
5,14	54.3 cm
5,15	50.2 cm
5,16	46.0 cm
9,01	4.0 cm
9,02	7.1 cm
9,03	10.2 cm
9,04	13.3 cm
9,05	16.4 cm
9,06	19.6 cm
9,07	22.7 cm
9,08	25.8 cm
9,09	29.0 cm
9,10	32.0 cm
9,11	35.1 cm
9,12	38.1 cm
9,13	41.1 cm
9,14	44.0 cm
9,15	46.9 cm
9,16	49.7 cm

Ohmic and Gun Discharge Bolometer Data

Bolometers observe weak radiation signals from gun and ohmic discharges.



Gun Discharge
Shots 25560 (GD) & 25561 (B)

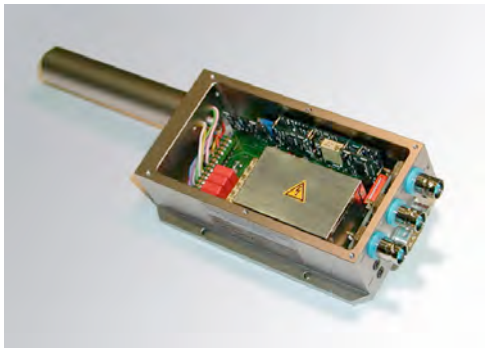


Ohmic Discharge
Shot 25398 (OHD)

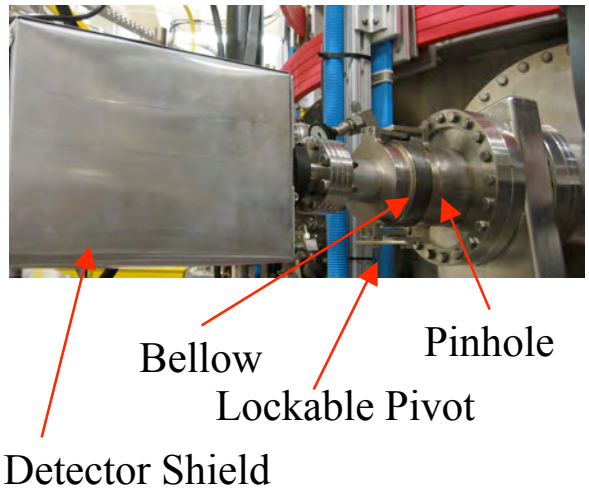
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SXR Pulse Height Analyzer

An electron temperature measurement based on a windowless single channel KETEK AXAS (Analog X-Ray Acquisition System) 5 mm^2 Silicon Drift Detector with integrated pulse shaper.

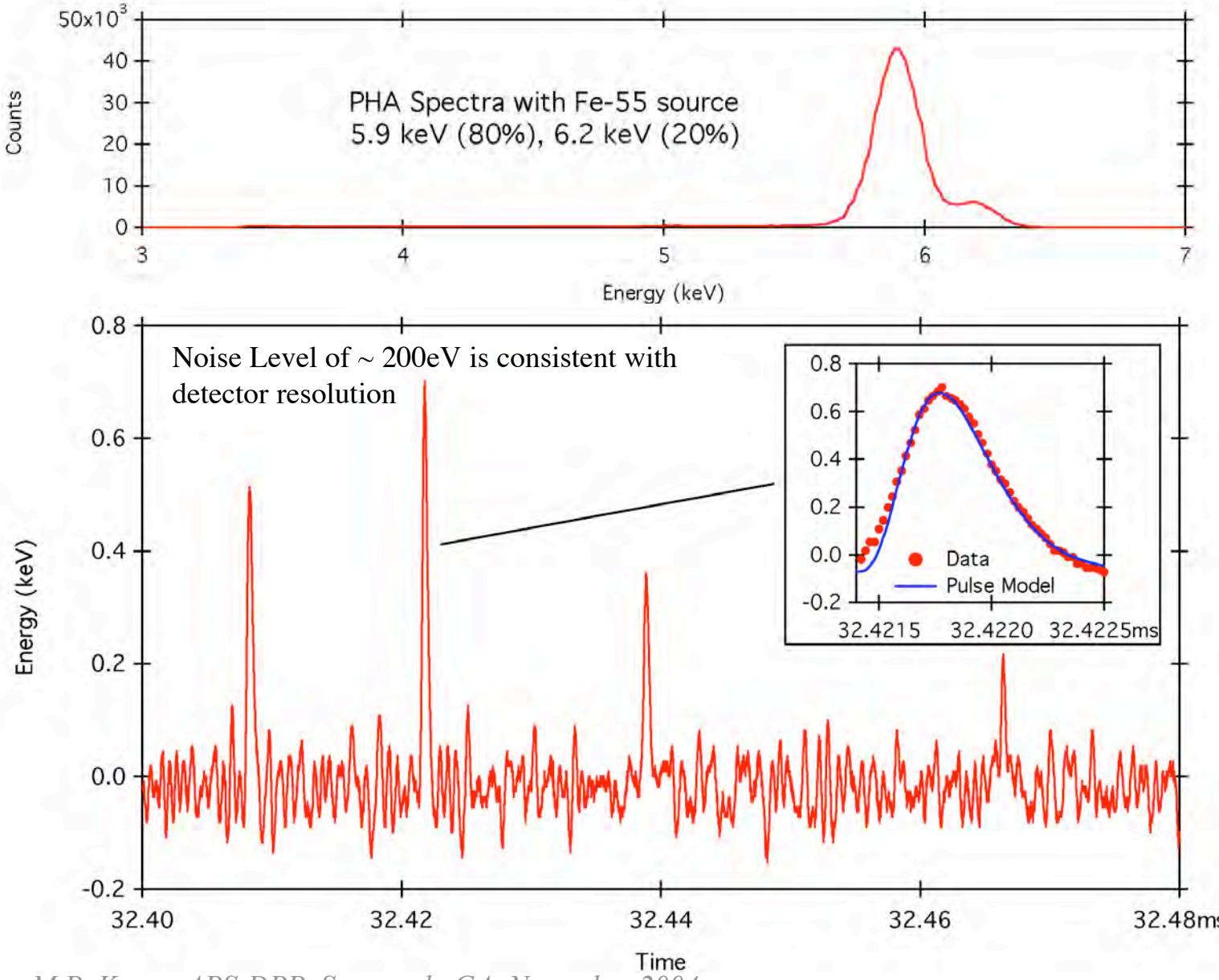


AXAS (www.ketek.net)



- Energy resolution of <= 200 eV @ 5.9 keV
- Shaping time of 150 ns.
- Counts rates nearing 1 MHz
- Aided by pulse pile-up correction software
- Spatial resolution of ~ 5 cm
- Temporal resolution of ~ 1 ms

PHA Initial Spectra



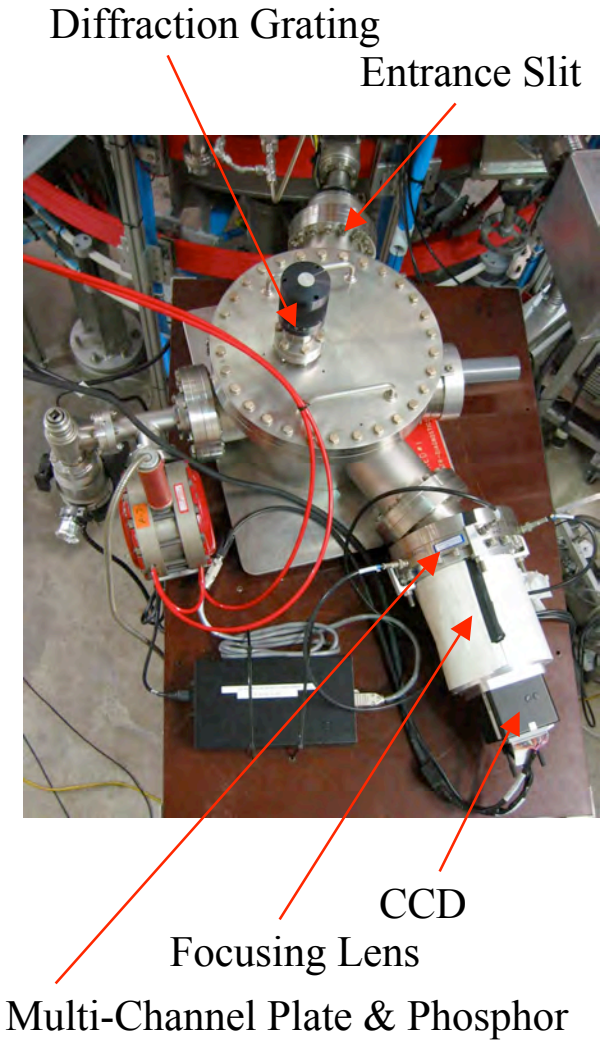
Fe-55 Source Calibration Check

Shot 25560
Low Density & Temperature Ohmic Discharge

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SPRED - VUV Spectroscopy System

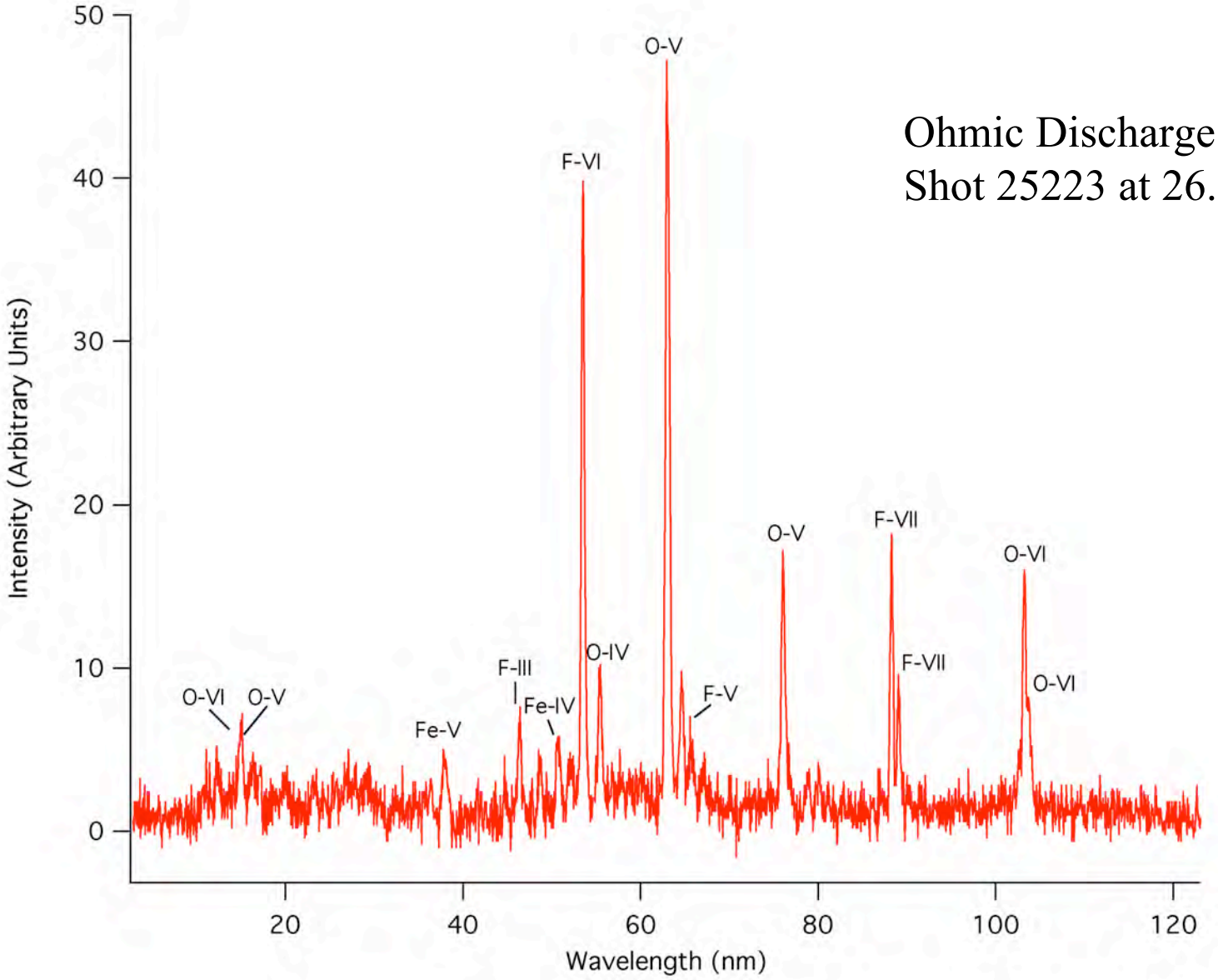
SPRED is a vacuum ultraviolet spectrometer providing time-resolved impurity spectra in the range of 10 to 110 nm with a resolution of ~ 0.2 nm.



- Range includes major transitions of common impurities such as B, C, N, O, F, Cl, Ti and Fe.
- Upgraded intensified CCD detector
  - 1D 2048 Pixel Array
  - 4800 frames/s
- Single channel view to plasma center

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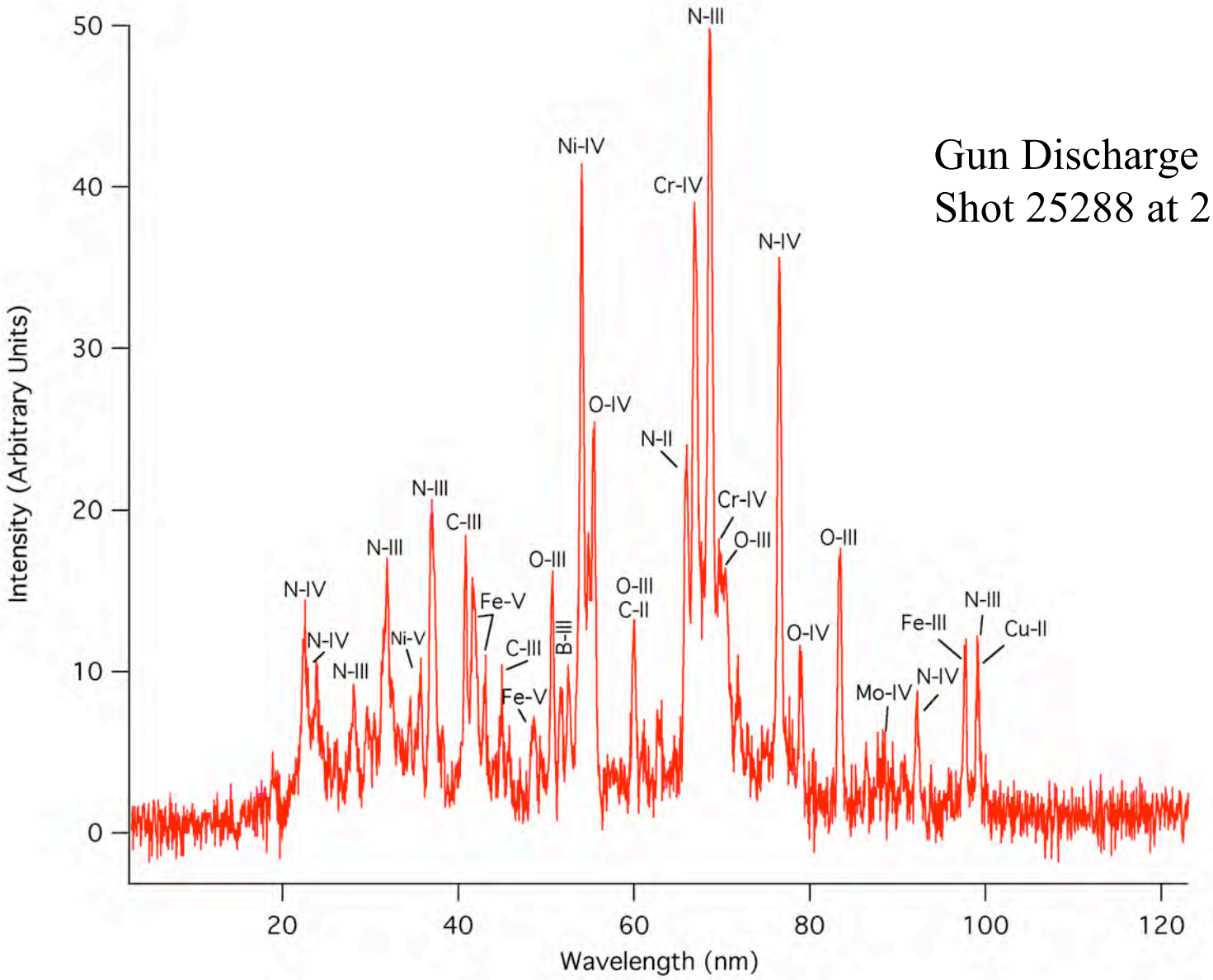
SPRED Ohmic Discharge Spectra



Ohmic Discharge
Shot 25223 at 26.00 ms

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SPRED Gun Discharge Spectra

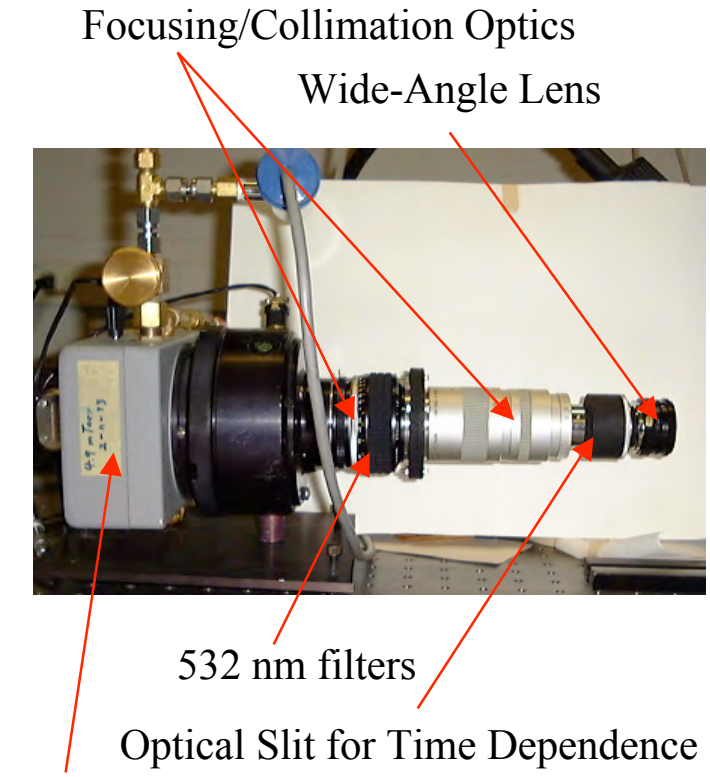


Gun Discharge
Shot 25288 at 27.04 ms

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VB (Visible Bremsstrahlung Imaging)

Relative Electron density profile can be estimated from the spatial distribution of Bremsstrahlung continuum radiation.



• Spectral emissivity function of the radiation:

$$\varepsilon \sim 9.5\times10^{-13}\frac{n_e^2 g_{ff} Z_{eff}}{T_e^{1/2}\lambda}\exp\left(\frac{-12400}{\lambda T_e}\right)\left[\frac{\gamma}{s}\frac{1}{cm^3}\frac{1}{nm}\right]$$

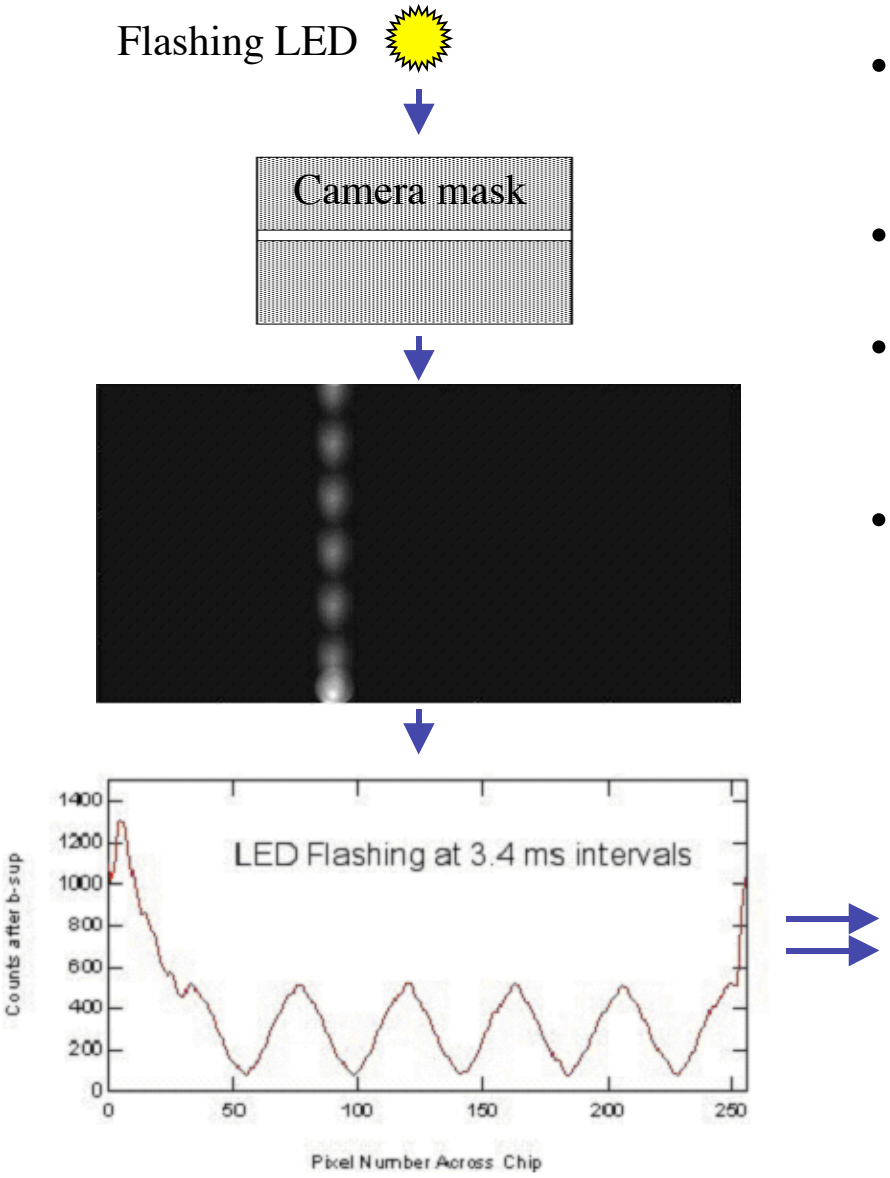
• In visible regime $h\nu << KT_e$, thus $\varepsilon \sim \frac{Z_{eff} n_e^2}{\sqrt{T_e}}$

• Assuming a constant Z_{eff} profile and using SXR PHA measurement of T_e, a relative density profile can be determined.

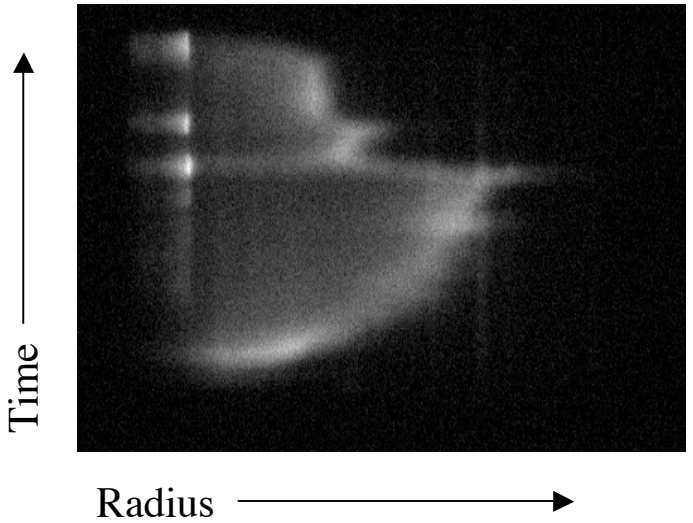
• Using the average density measurement from the microwave interferometer and calibration measurements, an absolute density measurement may be possible.

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VB Time Evolution

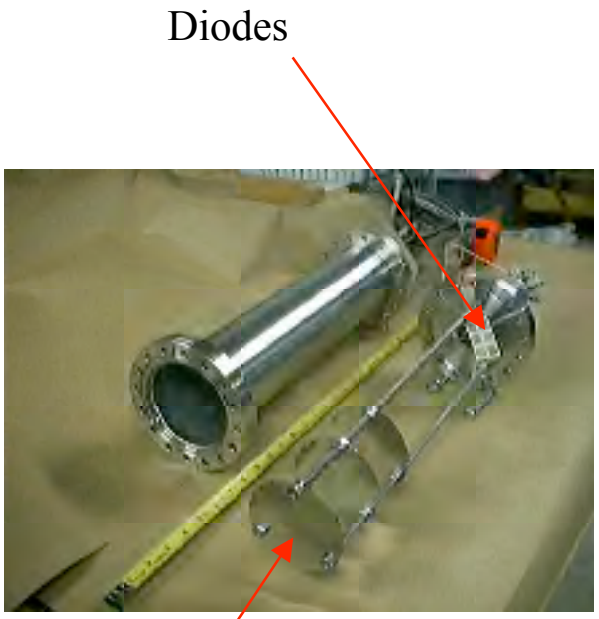


- Pixel lines shift behind the mask and are exposed when passing the slit
- Line shift rate of 77 μs
- Can obtain a 20 ms time record of the midplane intensity profile
- Below, time evolving radial cross section of visible emission from plasma in PEGASUS



Ross Filters

The Ross Filter system detects T_e dependent soft x-ray using AXUV photodiodes.



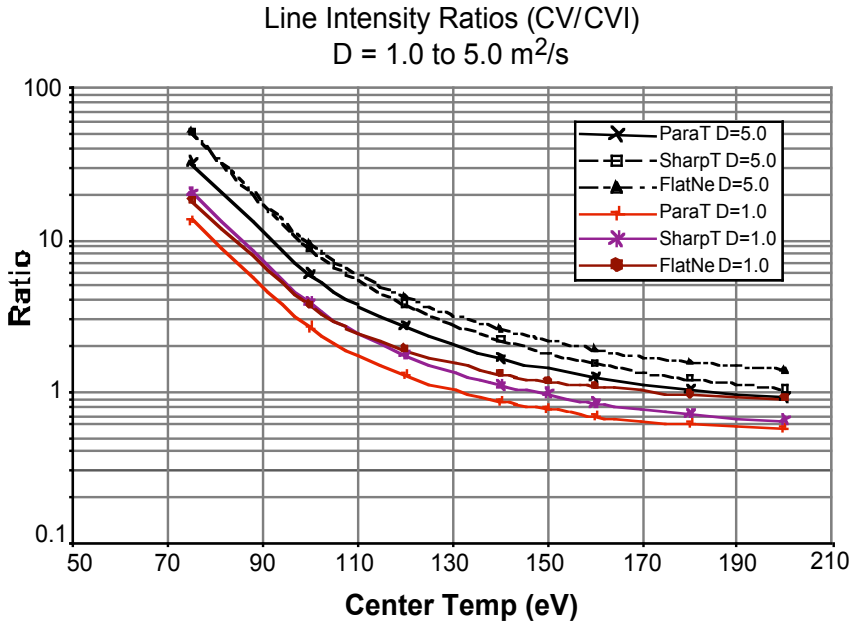
- Set of six AXUV-100 diodes installed on PEGASUS for T_e estimates
- 10 x 10 mm active area per diode
- Filters isolate: Lyman-α line of each ion

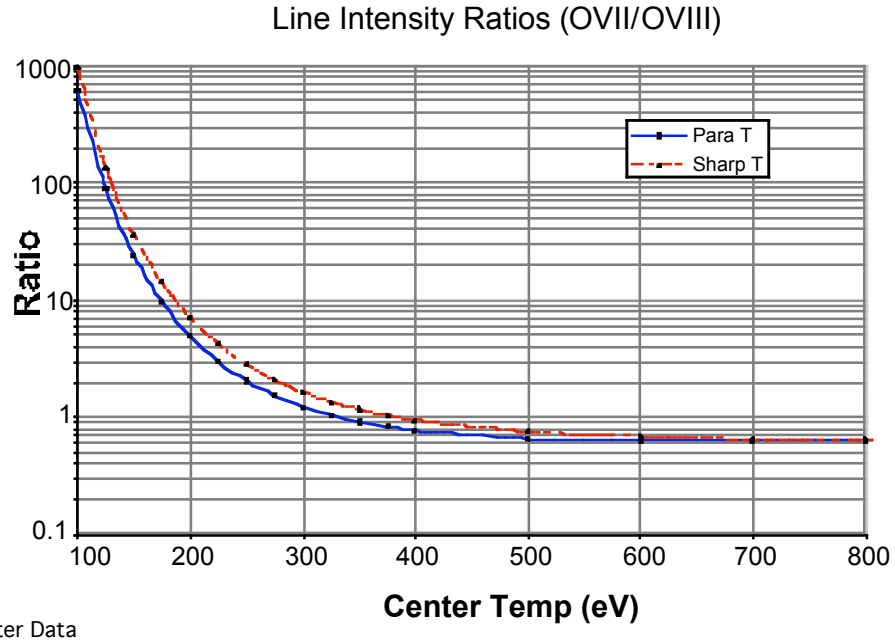
C-V	200 nm Al, 250 nm Ag, 1 μm CaF_2
C-VI	400 nm Al, 600 nm V
O-VII	500 nm Al, 500 nm Mn
O-VIII	400 nm Al, 450 nm Fe

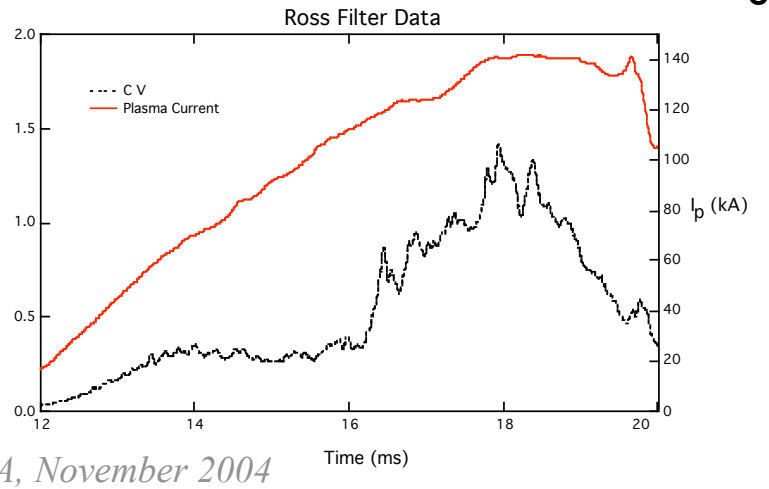
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Ross Filter T_e Range

- MIST results indicate applicable range of $T_e(0)$ for each species:
  C → 70 to 150 eV & O → 150 to 400 eV







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Summary

- General noise suppression recipe has been established and is being implemented
- New diagnostics are coming online to measure plasma parameters
  - T_e via PHA & Ross Filters
  - n_e via Microwave Interferometer & VB System
- Initial data has been acquired
  - P_{rad} via Bolometers
  - Impurity Spectrum via VUV Spectrometer
- Diagnostics are ready for high power operations