Measuring Electron Temperature using Spectral Data and a Collisional Radiative Model for PFRC-II

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August 2020

SULI Summer Program

PFRC-II Pulse

Thank you:
Dr. Sangeeta Vinoth
Dr. Samuel Cohen

This work was made possible by funding from the Department of Energy for the Summer Undergraduate Laboratory Internship (SULI) program. This work is supported by the US DOE Contract No. DE-AC02-09CH11466.

Topics Discussed in this Presentation

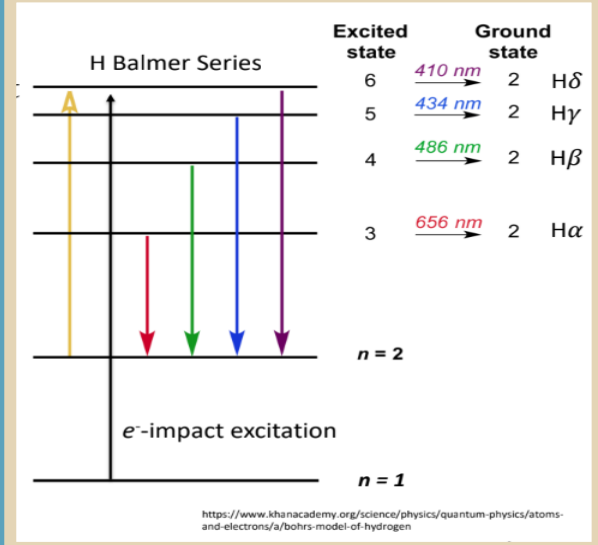
- **What is PFRC-II?**
- **PFRC-II and the need for Spectral Diagnostics**
- **Use of a Collisional Radiative Model to output Electron Temperature Data**
- **Current Observations**
- **Future Work**

PFRC-II

- Princeton Field Revered Configuration (PFRC)
- “High Beta” plasma containment device
- Relies on an Odd-Parity Rotating Magnetic Field
- Comparatively easy to maintain and construct
- Potentially viable for advanced fusion fuel cycles.

Visible Light Emitted by PFRC-II

- Visible light from PFRC-II can be used to analyze certain parameters in the plasma.
- Relating net emissions of the Balmer Series provides incite into the plasma over the course of a pulse.



$$\Gamma_\beta = n(4)A_{4\to2}$$

$H\beta$ photons$/s/cm^3$

Population density of state 4

Einstein coefficient for the 4→2 radiative decay rate

The Collisional Radiative Model and Emission Rates

$$\Gamma_\beta = n_H n_e C_{H,\beta}(T_e, n_e) + n_{H_2} n_e C_{H_2,\beta}(T_e, n_e)$$

Hβ Emission rate

Constants determined by collisional radiative model

$$\frac{\Gamma_\gamma}{\Gamma_\beta} = f\left(T_e, n_e, \frac{n_{H_2}}{n_H}\right)$$

- Collisional Radiative Model:

$$\frac{dn(i)}{dt} = \left(n_e \sum_{k\neq i} n(k)\langle\sigma v\rangle_{k\to i} + \sum_{k>i} A_{k\to i} n(k)\right) - \left(n_e \sum_{i\neq k} n(i)\langle\sigma v\rangle_{i\to k} + \sum_{k<i} A_{i\to k} n(i)\right)$$
$$- n_e n(i)\langle\sigma v\rangle_{i\to \text{ion}} + n_H n_e \langle\sigma v\rangle_{H\to i} + n_{H_2} n_e \langle\sigma v\rangle_{H_2\to i}$$

Collisional excitation/deexcitation into state i

Radiative decay into state i

Collisional excitation/deexcitation out of state i

Radiative decay out of state i

Ionization of state i

Ground state H excitation to state i

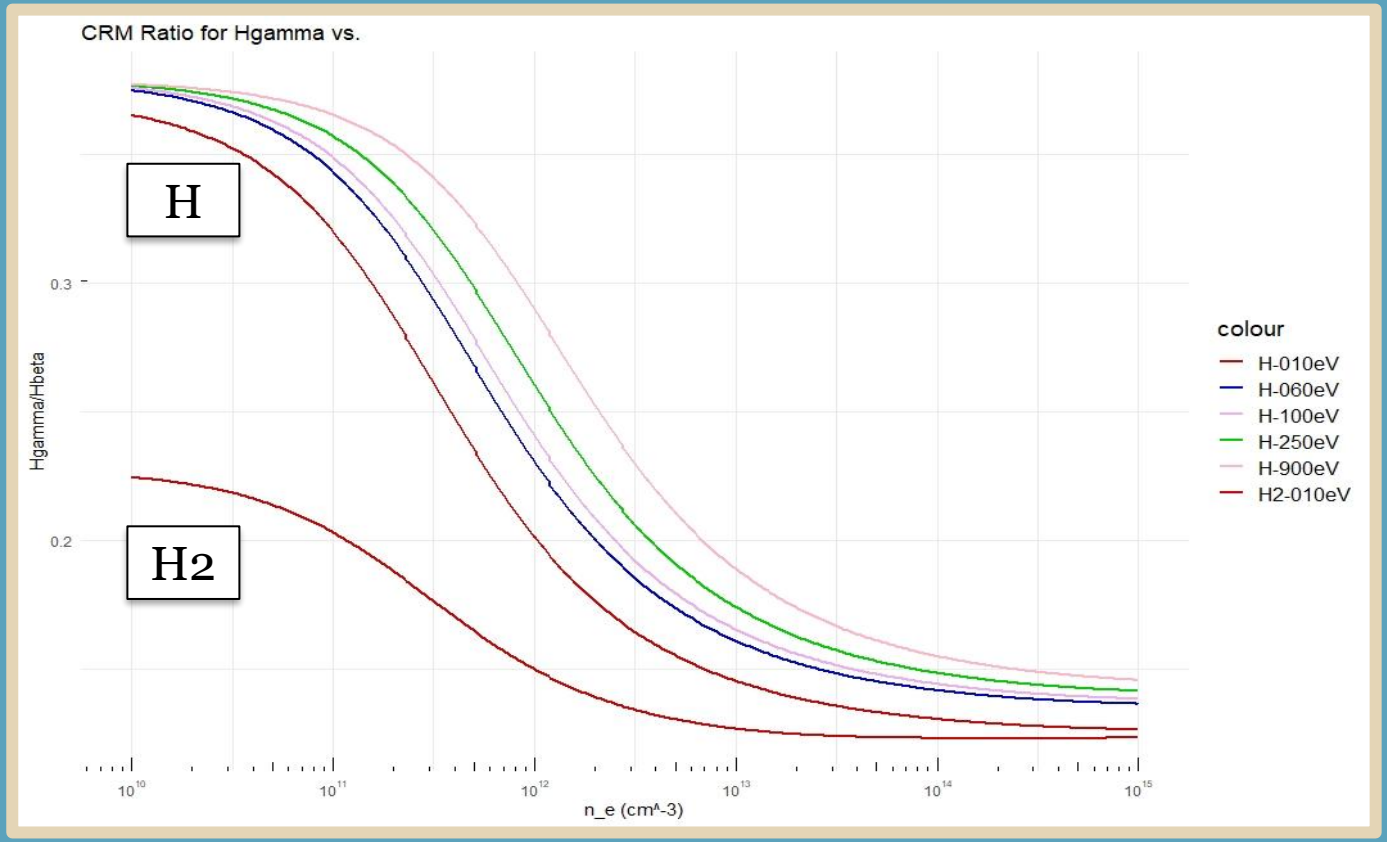
Population via H_2 dissociation

---- Input ----	---- Output ----
• Ratio of H & H2 • Range of Electron Densities • Range of Electron Temperatures	• Emission Constants for Balmer Series • Ratio between Emission Rates

CRM Generated Emission Rates of H gamma and H beta

H2 – All Molecular Hydrogen

H – All Atomic Hydrogen

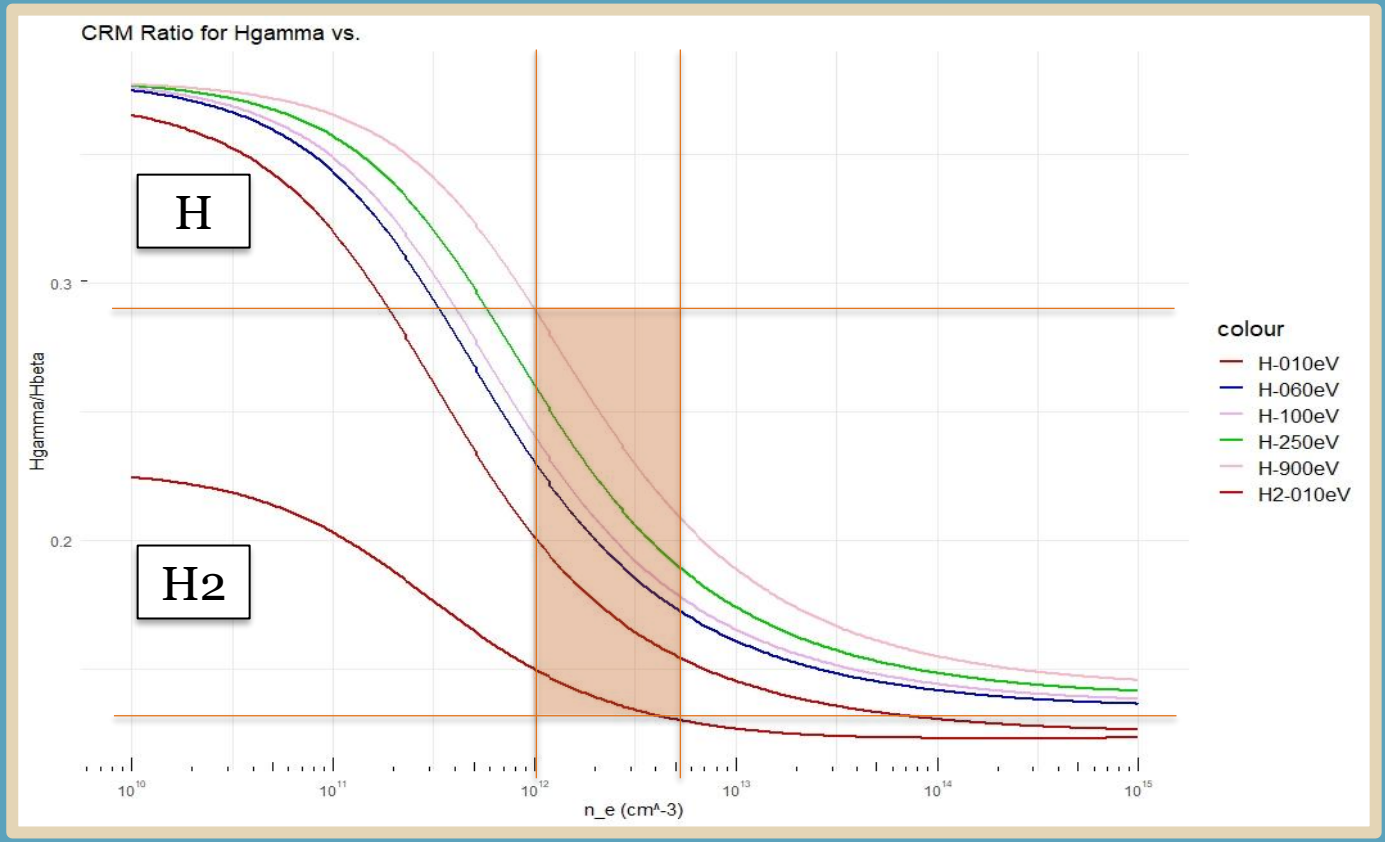


CRM Generated Emission Rates of H gamma and H beta

H2 – All Molecular Hydrogen

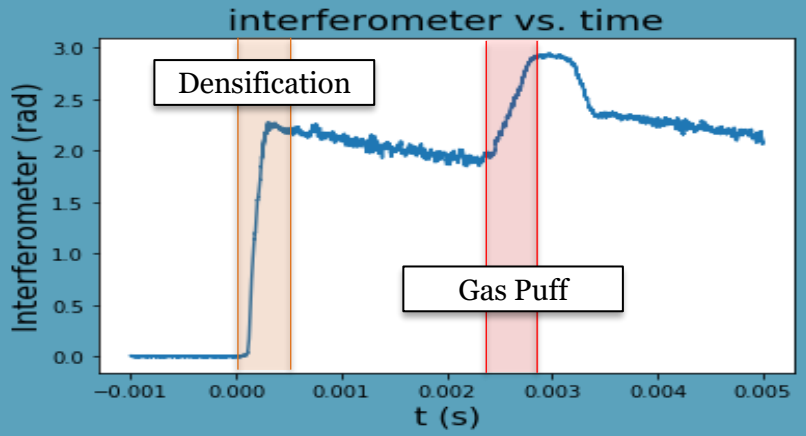
H – All Atomic Hydrogen

Expecting a Hgamma-Hbeta ratio between 0.29 – 0.13



PFRC-II Pulse Aspects

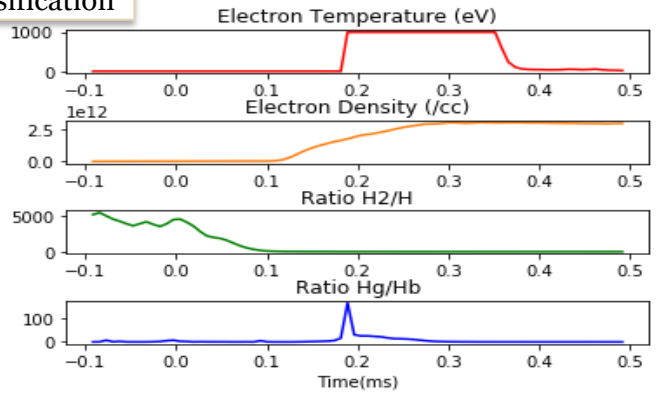
- The graph shows the plasma density over the duration of a PFRC-II pulse.
- Densification caused by acceleration and heating due to the Rotating Magnetic Field.



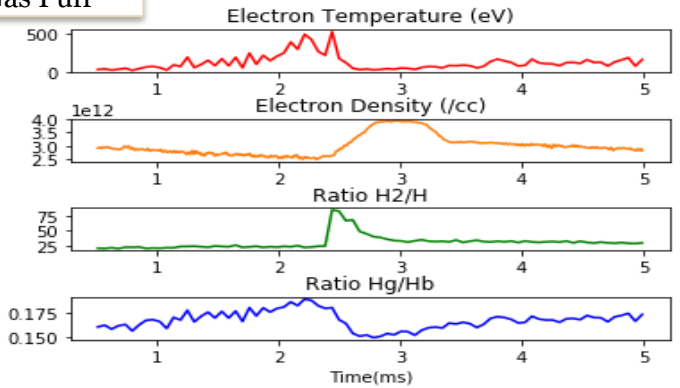
Plasma Data during PFRC-II Pulse

- The graphs show electron temperature and the three parameters of the CRM over time around the densification and gas puff stages of a PFRC-II pulse.

Densification



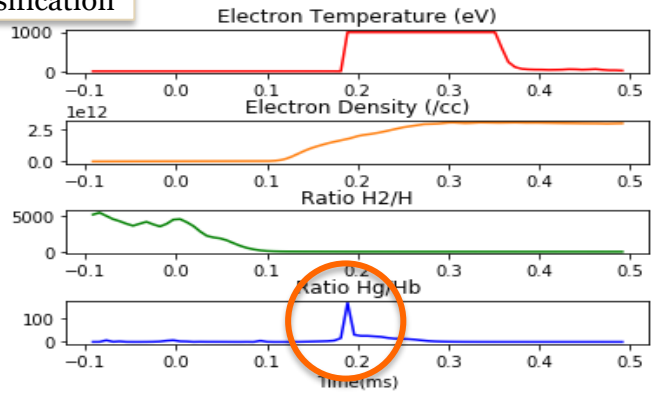
Gas Puff



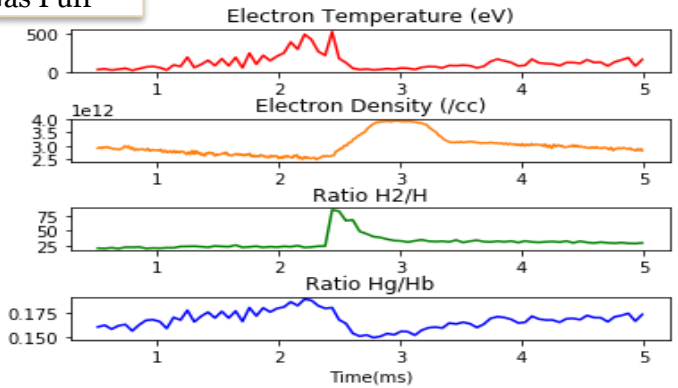
Plasma Data during PFRC-II Pulse

- The graphs show electron temperature and the three parameters of the CRM over time around the densification and gas puff stages of a PFRC-II pulse.
- Significant issue with the Ratio between Hg/Hb during densification.

Densification

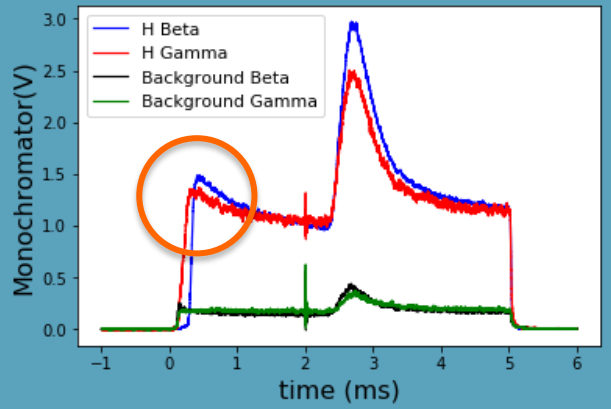


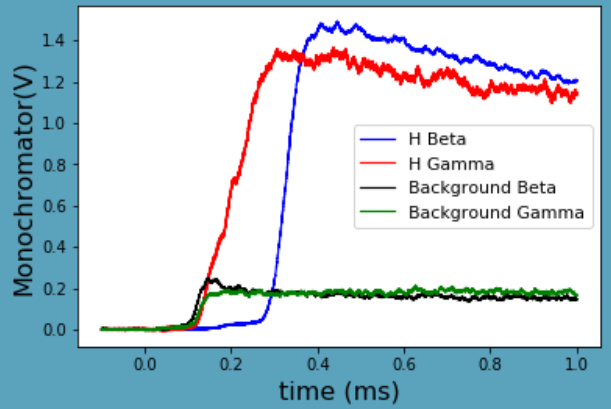
Gas Puff



Monochromator Alignment Issues

- Data generated by the monochromator during the PFRC-II pulse.
- H Gamma should happen after H beta since H Gamma since H Gamma is

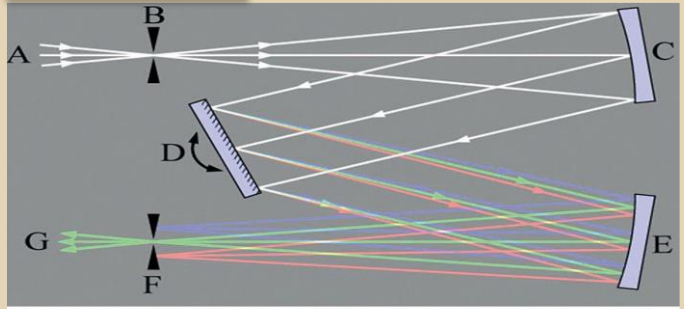




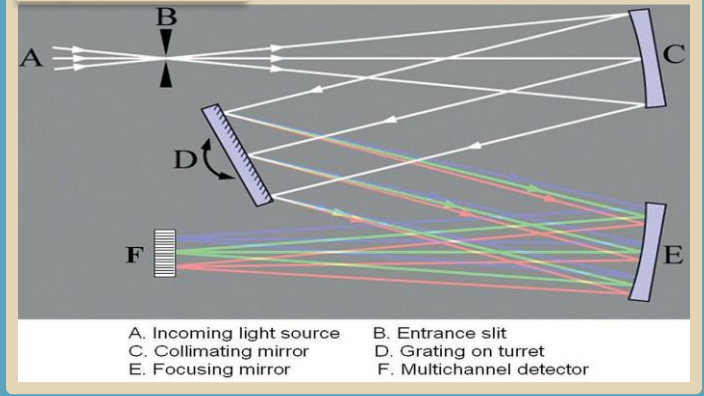
Replacing Monochromator with Spectrometer

- The Czerny-Turner Monochromator is in the process of being replaced by a Spectrometer.
- Visible light of various wavelengths will be collected at the same time.
- Eliminates alignment issues with emission measurements.

Monochromator

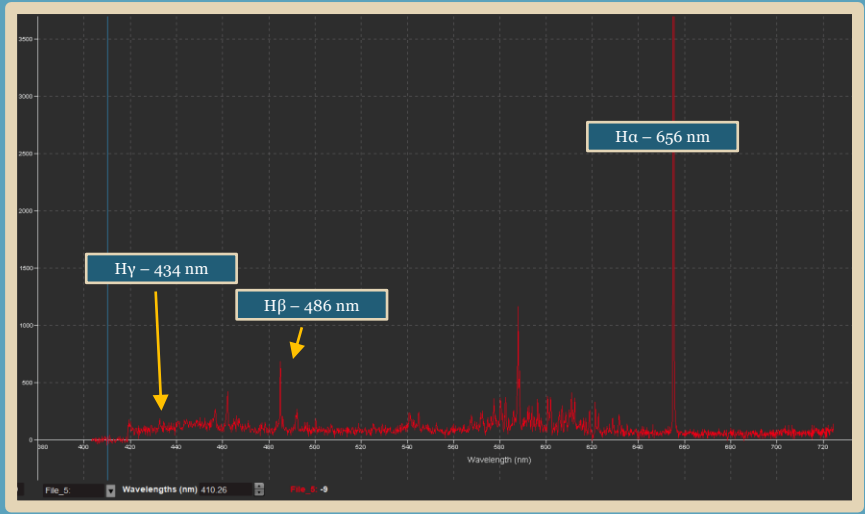


Spectrometer



Future Work and Data Verification

- Ocean Optics Spectrometer is now installed and will be collecting data.
- Scripts have been updated to take in data in its new format.
- Data needs to be taken to ensure the spectrometer fixes the alignment issue with emission data.
- Comparing Electron Temperature values from H beta and H alpha ratio to H gamma and H beta ratio.



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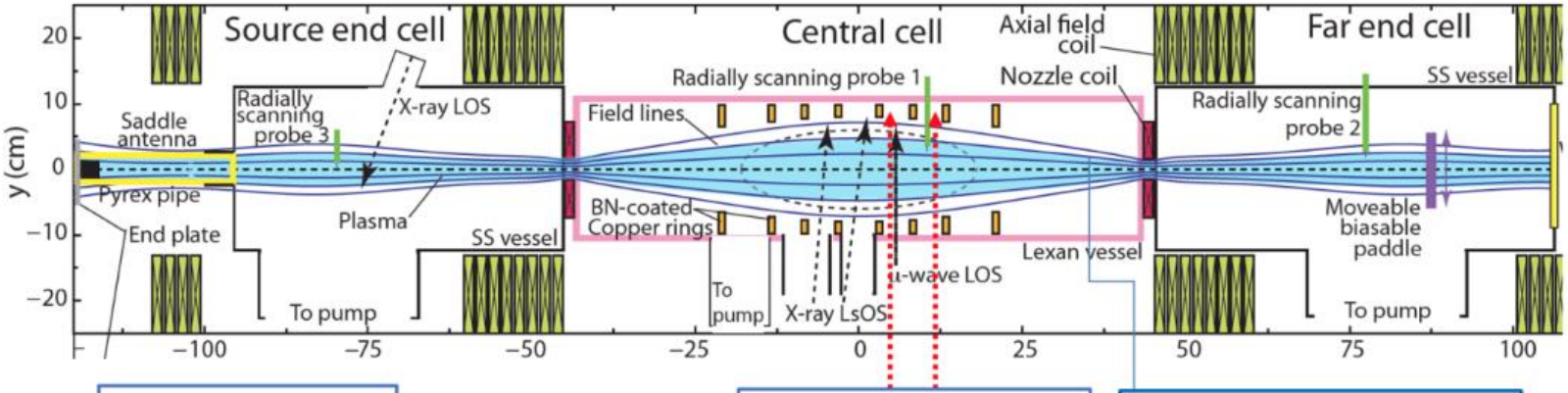
Optical Diagnostics Schematic for PFRC-II (Extra)



Preamp (Gain: ~10x)

Photomultiplier Tube (~1 k V)

Czerny-Turner Monochromator

Optical Fiber

Focusing Lenses at z=5cm and z=11cm

TALIF –neutral Atomic H density and CCFB

For future testing, the Monochromator will be replaced by an Ocean Optics Spectrometer