The Motional Stark Effect (MSE) Diagnostic for the National Spherical Torus Experiment (NSTX)

F. M. LEVINTON

NOVA PHOTONICS, INC.

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Principle of the Motional Stark Effect

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- Based on $\vec{E} = \vec{v} \times \vec{B}$ electric field induced by propagation of a neutral beam across a magnetic field.
- Electric field causes spectral splitting and linear polarization of the emitted radiation known as the Stark effect.
- Background plasma causes excitation of neutral beam atoms and Doppler shifted emission (H_α).
- Good beam penetration.
- Good spatial resolution-intersection of sightline with neutral beam.

Stark Spectra from TFTR

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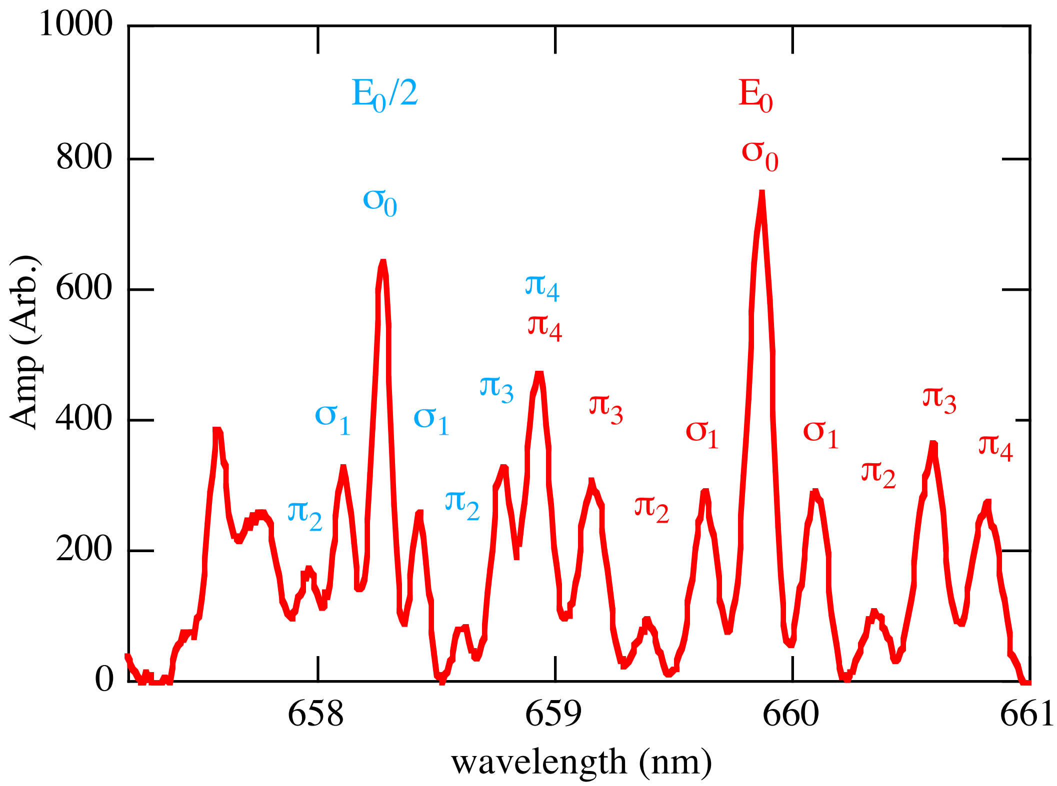

- $\vec{E} = \vec{v} \times \vec{B}$ electric field is $\sim$ 200 kV/cm at 4.5 T, resulting in a large spectral splitting.
- $\Delta m = 0(\pm 1)$, $\pi(\sigma)$ component, are polarized parallel (perpendicular) to the electric field.
- Spectral linewidth is determined by geometric broadening and beam temperature.
- Spectral overlap between π and σ lines reduces polarization fraction and signal-to-noise.

Low Polarization Fraction at Low Field

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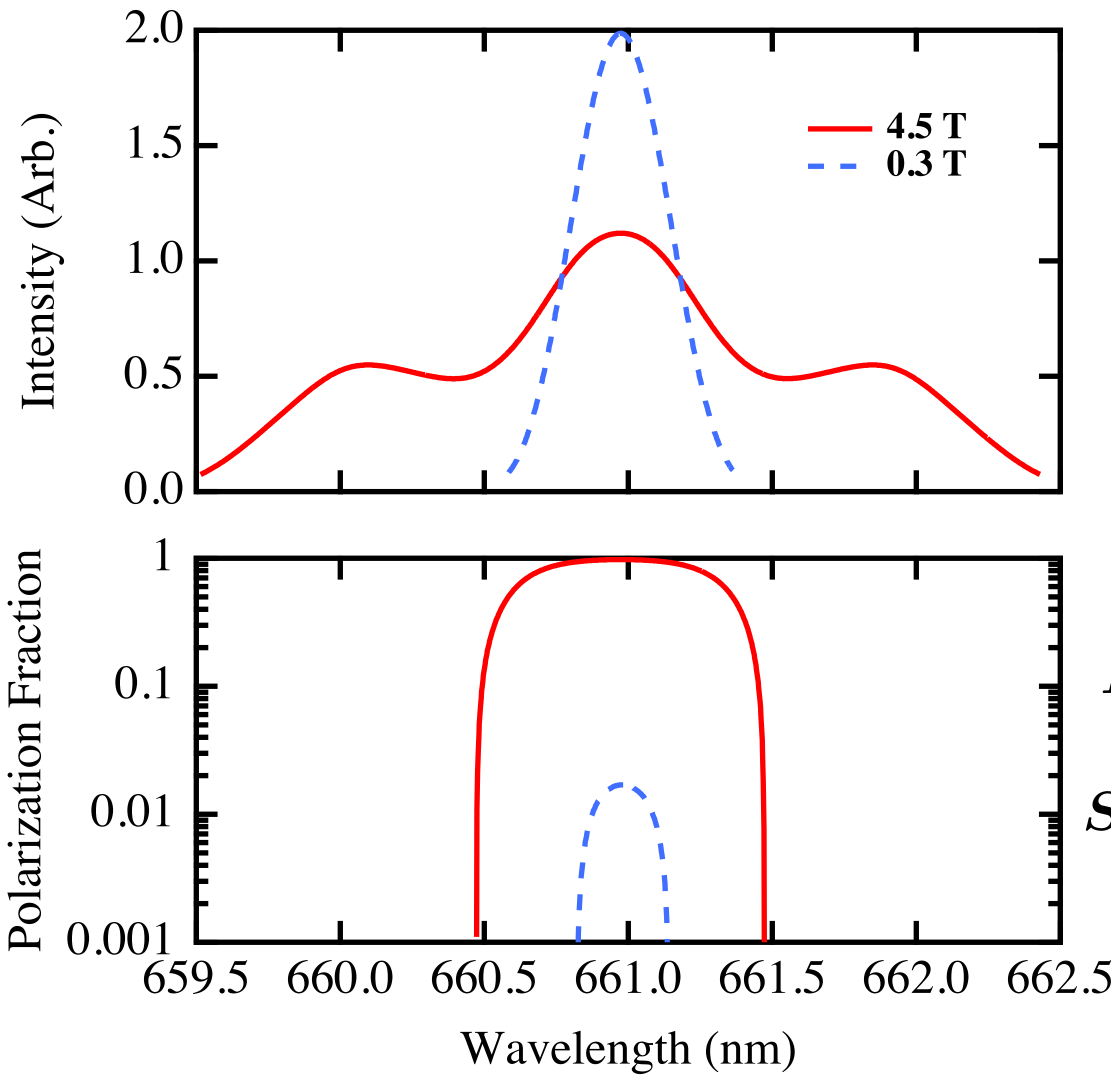

$$P_f = \frac{I_{\parallel} - I_{\perp}}{I_{\parallel} + I_{\perp}}$$

$$S/N \propto P_f \sqrt{N}$$

- **Numerical convolution of the MSE spectra including filter, beam, and optics broadening.**

- **At 4.5 T there is a good separation of the π and σ components. At 3 kG overlap of spectral lines leads to a low polarization fraction.**

MSE at Low Magnetic Field

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Two different approaches to extend MSE to low magnetic fields.

1. Optimize optics to reduce geometric spectral broadening.
   - Spectral broadening is from the finite optics and image size. Optimization of the optics can reduce the spectral width.
   - Development of high resolution, high throughput filter to extend measurements to ~ 0.3 T.
2. Laser induced fluorescence (LIF).
   - Optically pump $n = 2 \longrightarrow n = 3$ and observe fluorescence with separate optical system.
   - This is estimated to work at fields as low as ~ 0.1 T.

Proposed MSE-LIF Layout on NSTX

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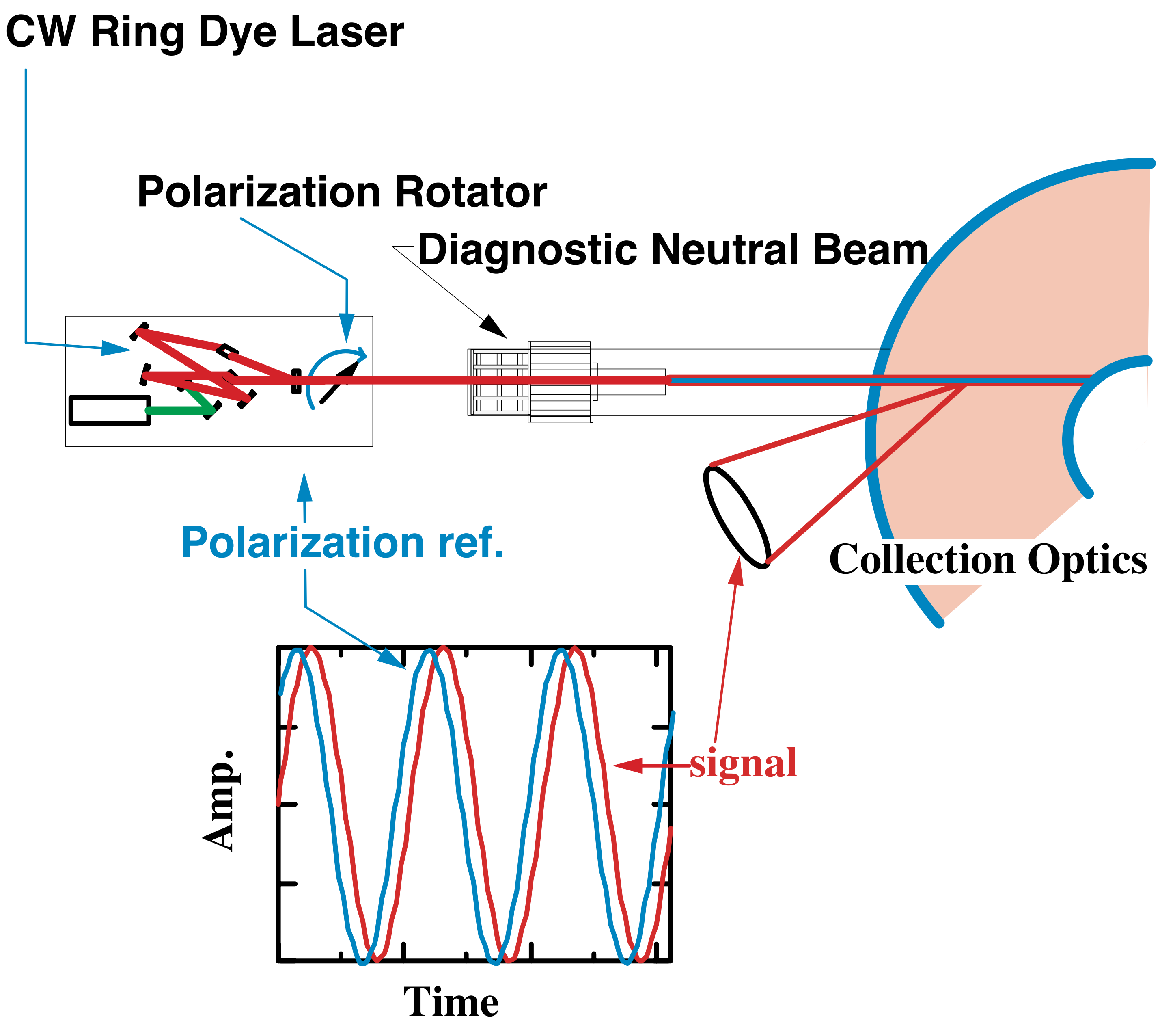

MSE-LIF Diagnostic Development

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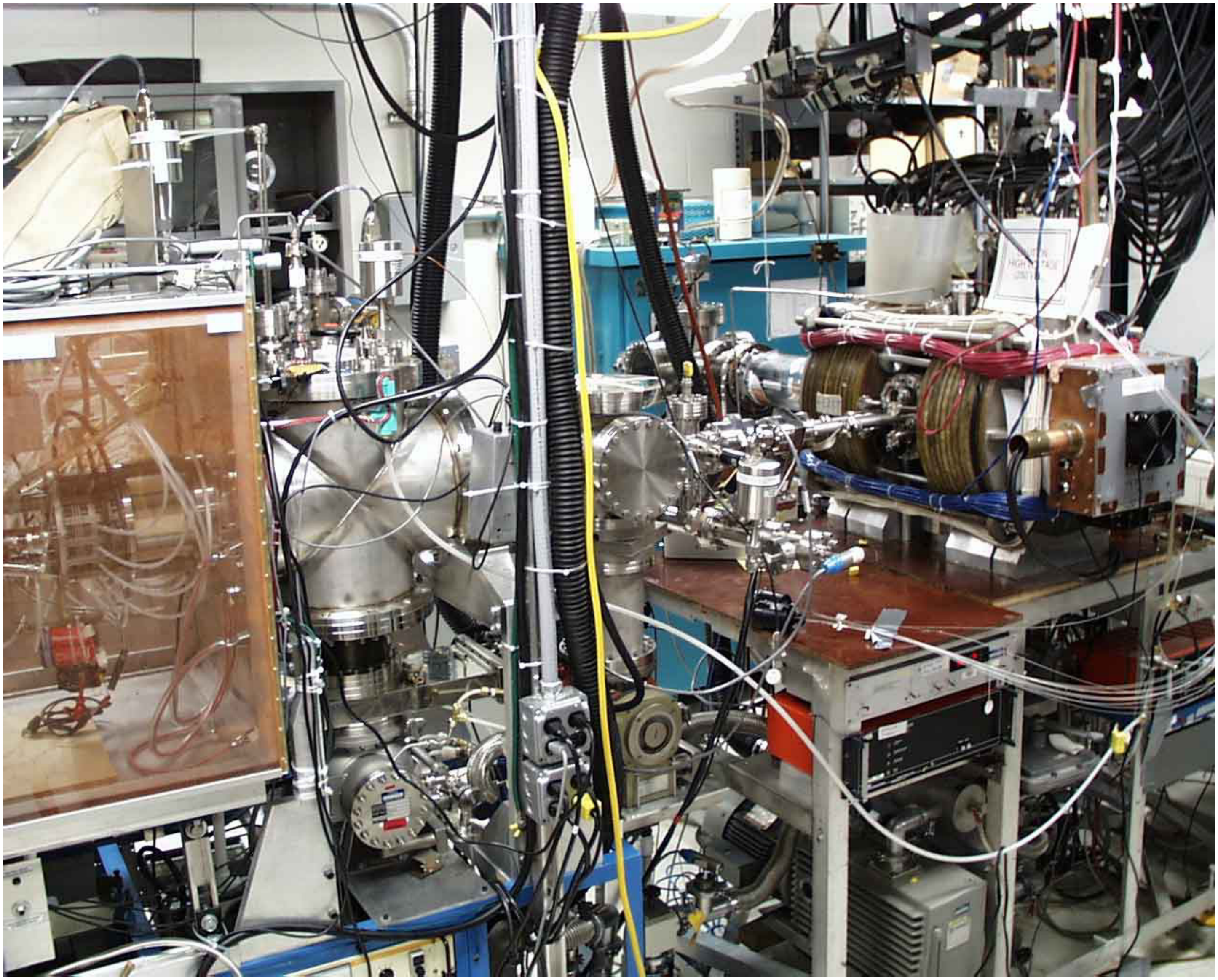
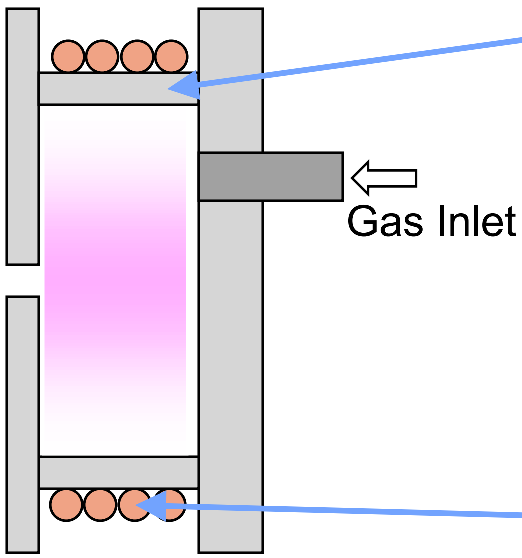
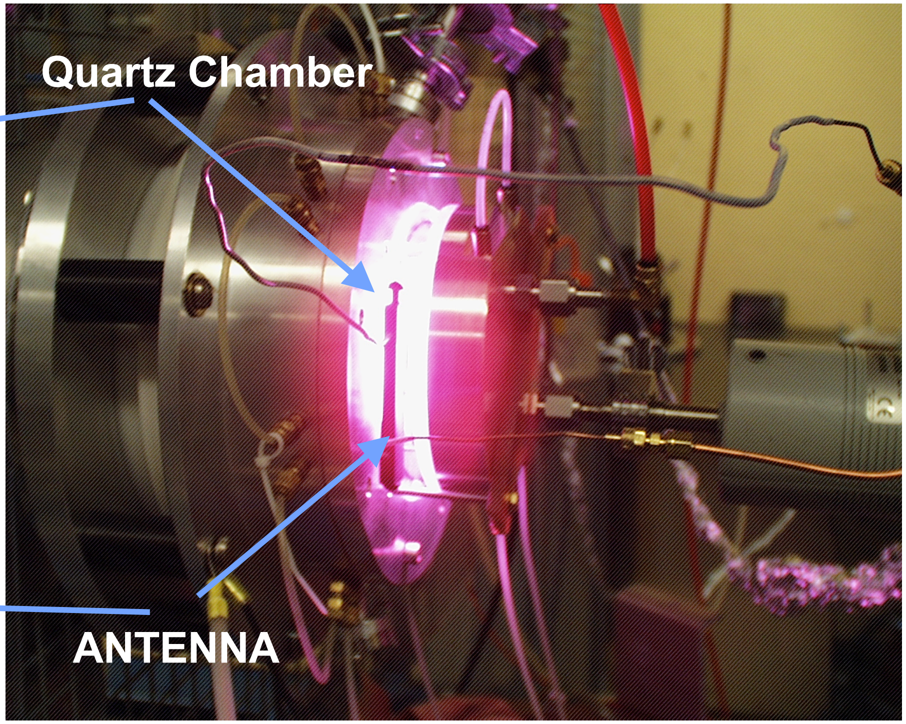


- **MSE-LIF development in laboratory.**
- **Utilizes helicon plasma source for testing and proof of principle.**

RF Source with External Antenna





Hydrogen plasma at 1 kW RF power

- Low power
- Low contamination
- Scalable to large size
- Long lifetime for antenna

Reduction of Geometric Broadening

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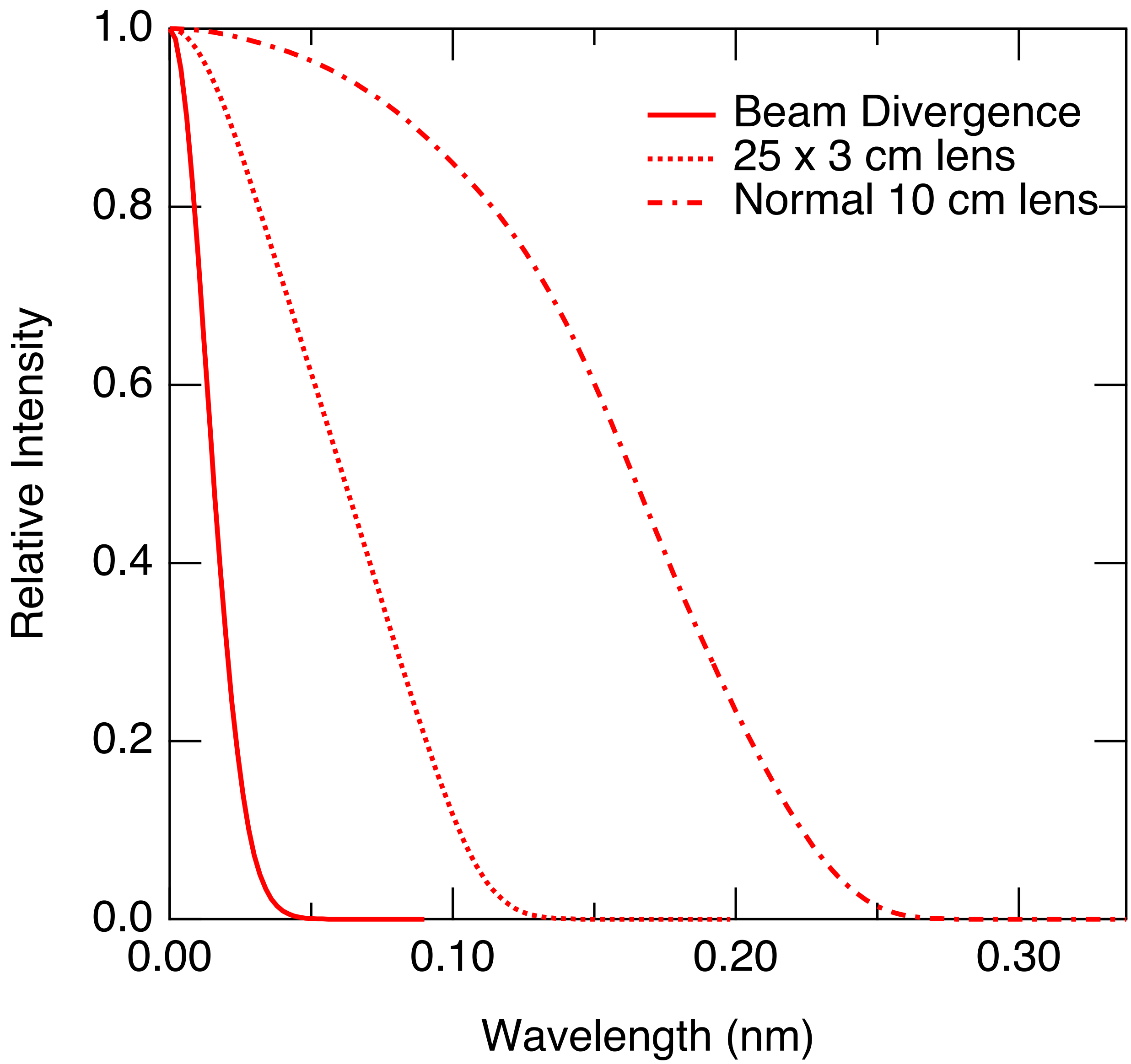

- **Reduction of geometric broadening is one key element to the successful implemention of MSE-CIF.**

Lens Aperture to Reduce Geometric Broadening

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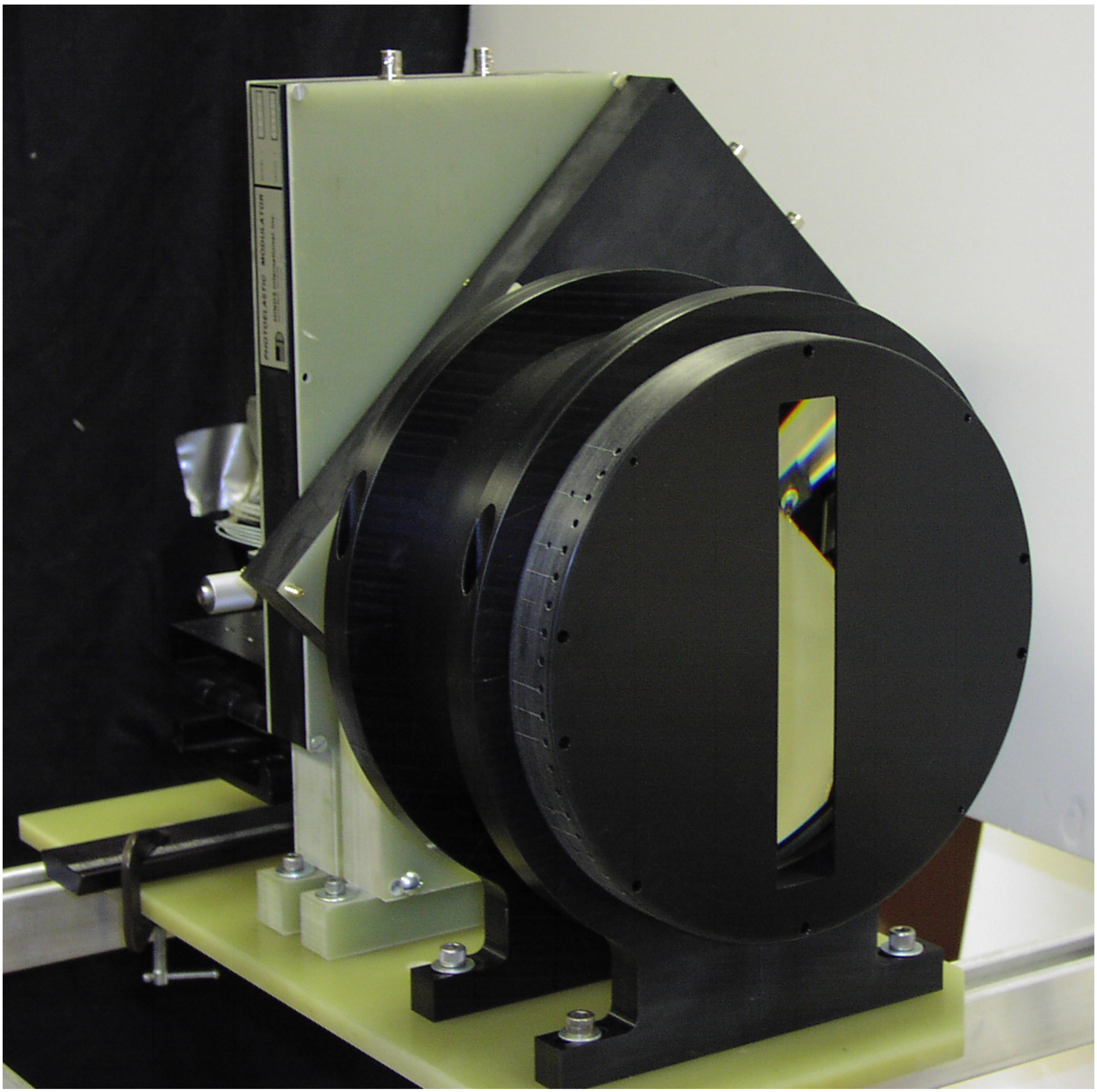

High Resolution Lyot Spectral Filter

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- **To obtain a good signal-to-noise ratio a spectral filter with both high throughput and high resolution is required.**
- **This can be obtained using a wide angle Lyot filter.**
- **This uses a birefringent crystal with its optic axis oriented at 45° with respect to a pair of polarizers.**
- **The phase retardation is; $\Gamma = (2\pi/\lambda)\Delta n d$.**
- **The transmitted intensity; $T = cos^2\Gamma/2$.**
- **A tunable multiple stage filter has been developed for MSE-CIF.**

Lyot Filter

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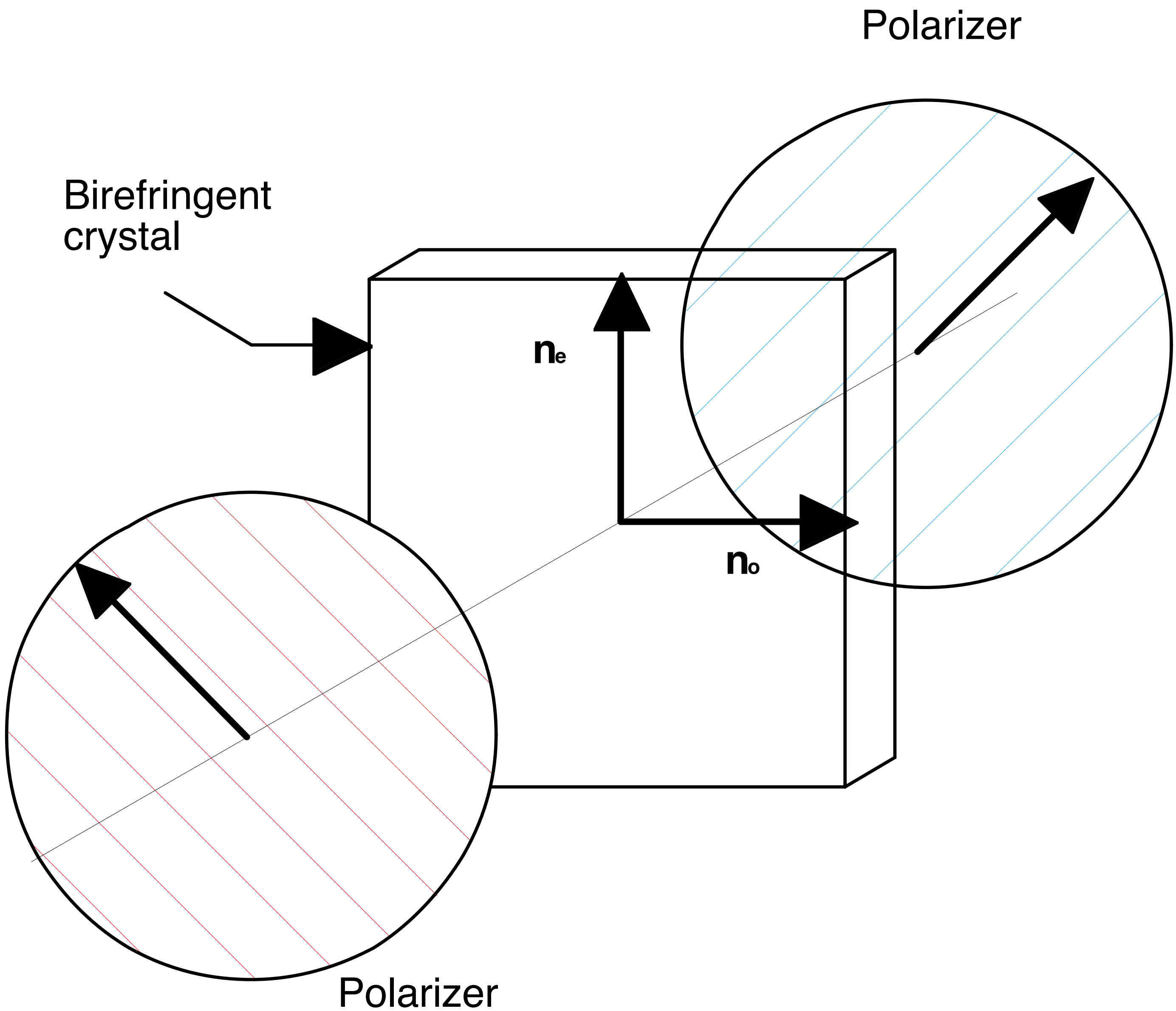

Development of a High Resolution Spectral Filter for MSE-CIF

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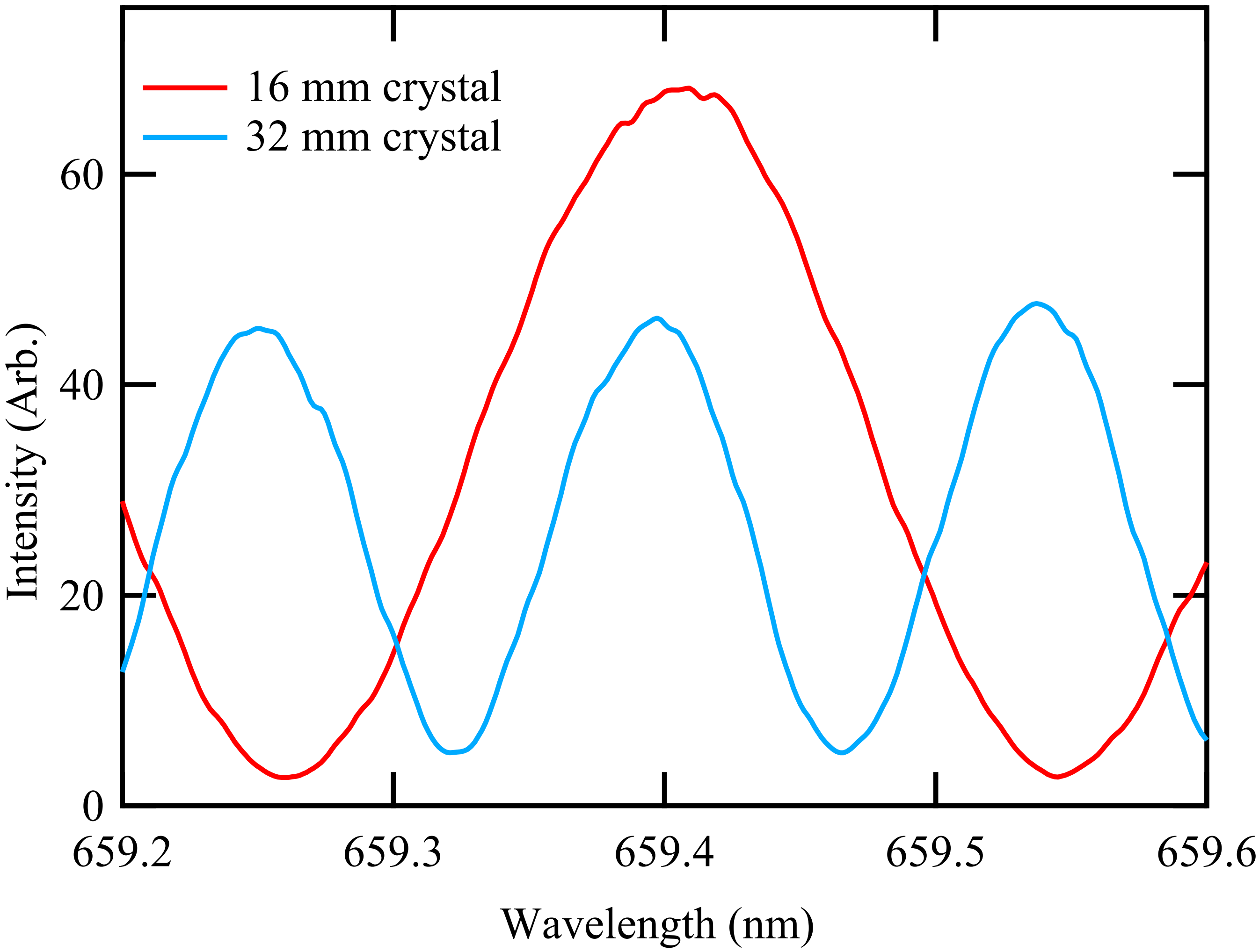

- **Lithium Niobate crystals used for filter.**
  - **Birefringence homogeneity meets requirements.**
  - **Temperature controlled to ±.01° C.**
  - **Wavelength tuned electro-optically.**

Four Stage Filter for MSE-CIF

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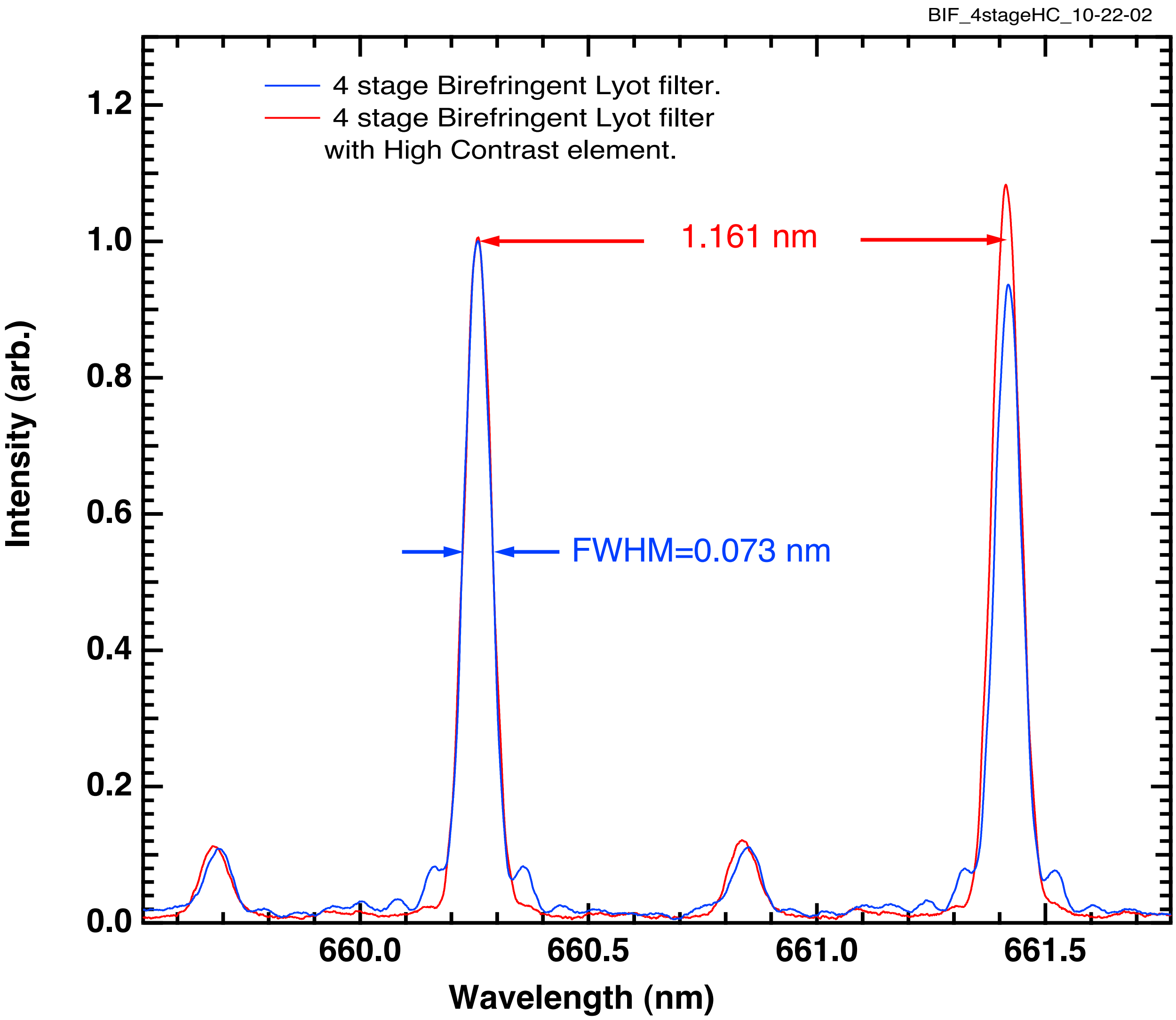

- **Four stage prototype completed.**
- **Wavelength tuned electro-optically.**

Prototype Filter and Optics Enclosure

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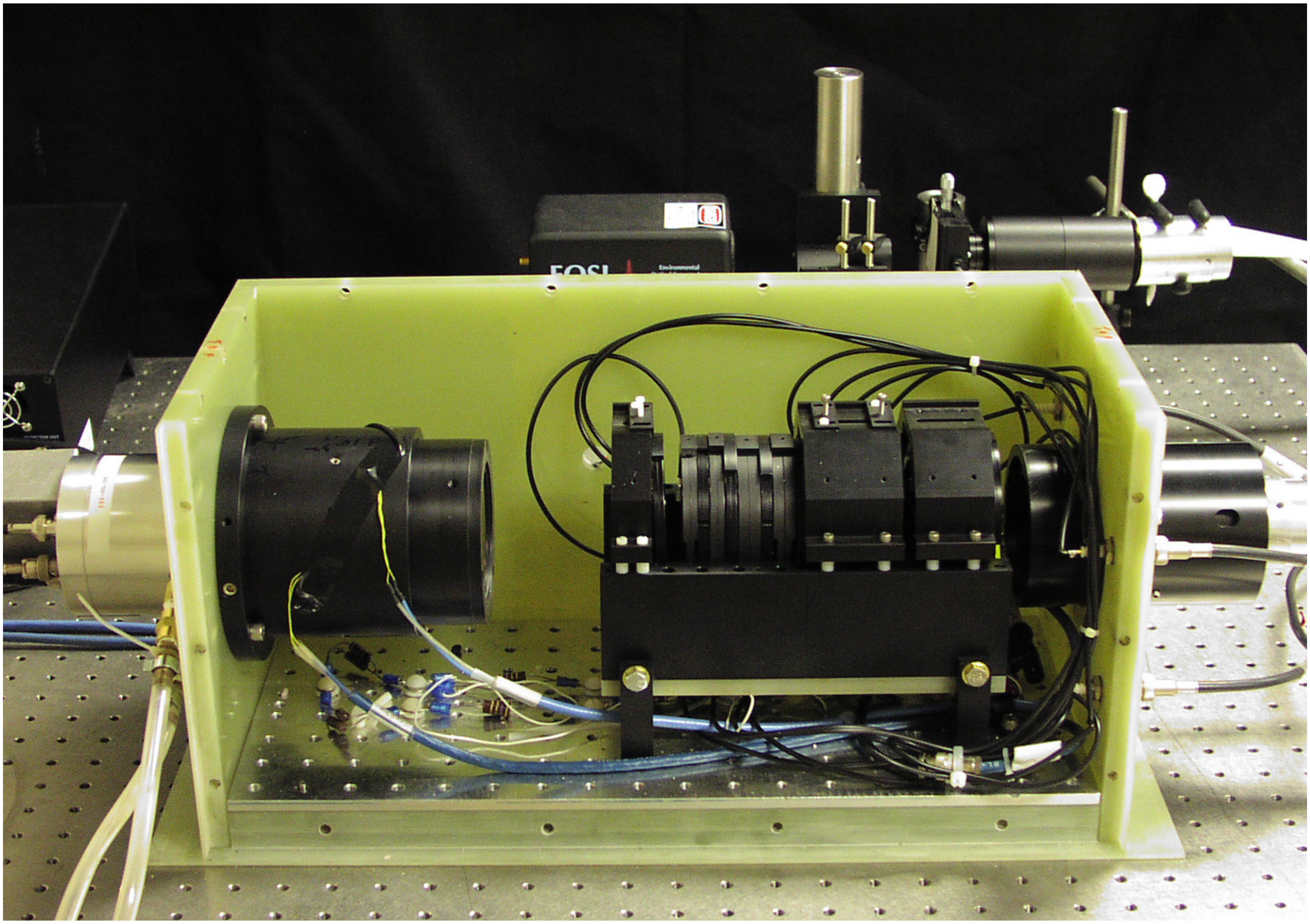

- **Enclosure contains collimating and focusing optics, APD detector, and temperature control.**
- **Tuning is done electro-optically.**

Output Fiber Optic Holder

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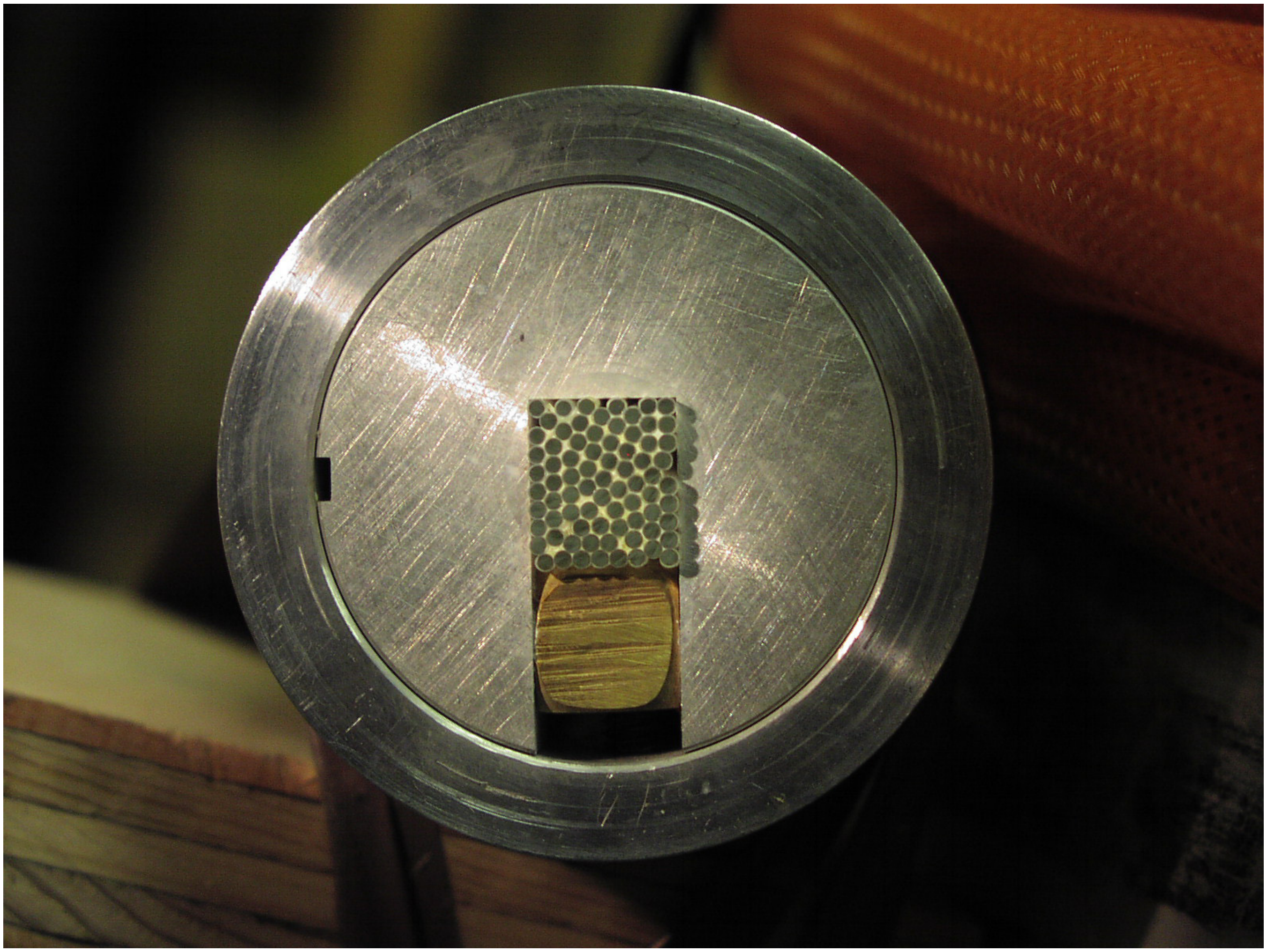

MSE & CHERS Fiber Optic Holder

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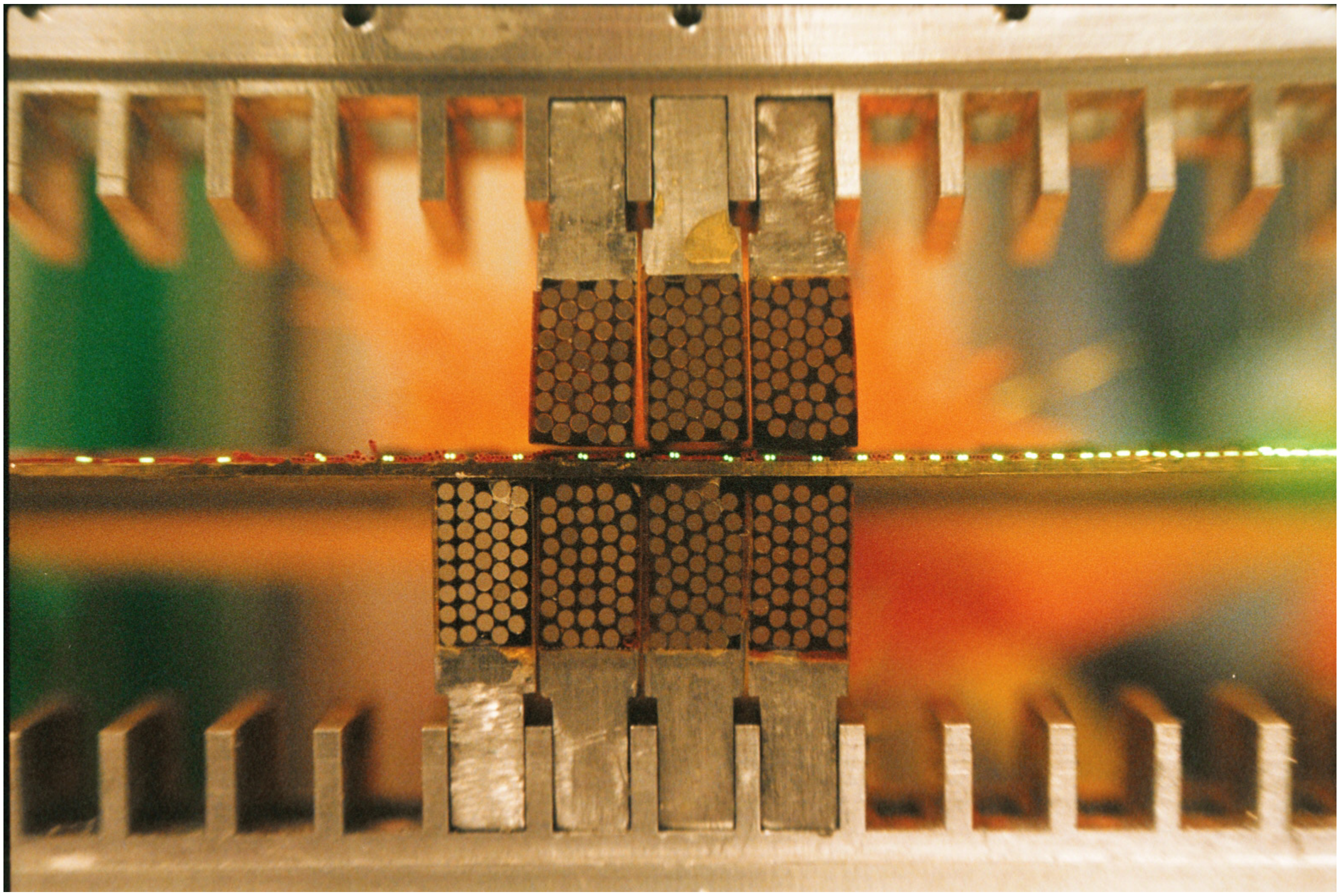

- View of fiber holder with a few MSE fiber ferrules installed.
- CHERS fibers are the small fibers in the midplane. Ratio of light collection is about 1000:1.

MSE-CIF Layout on NSTX

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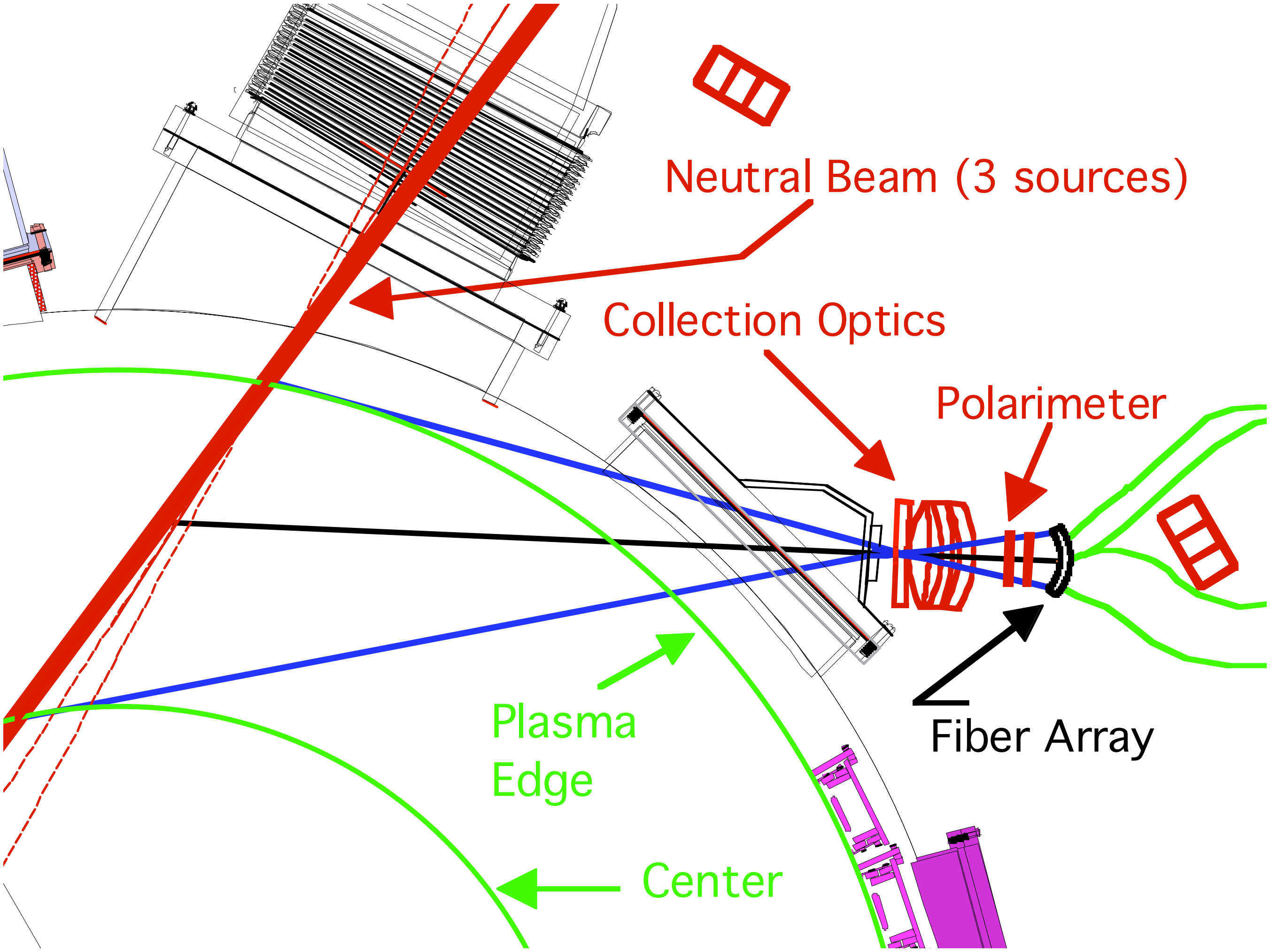

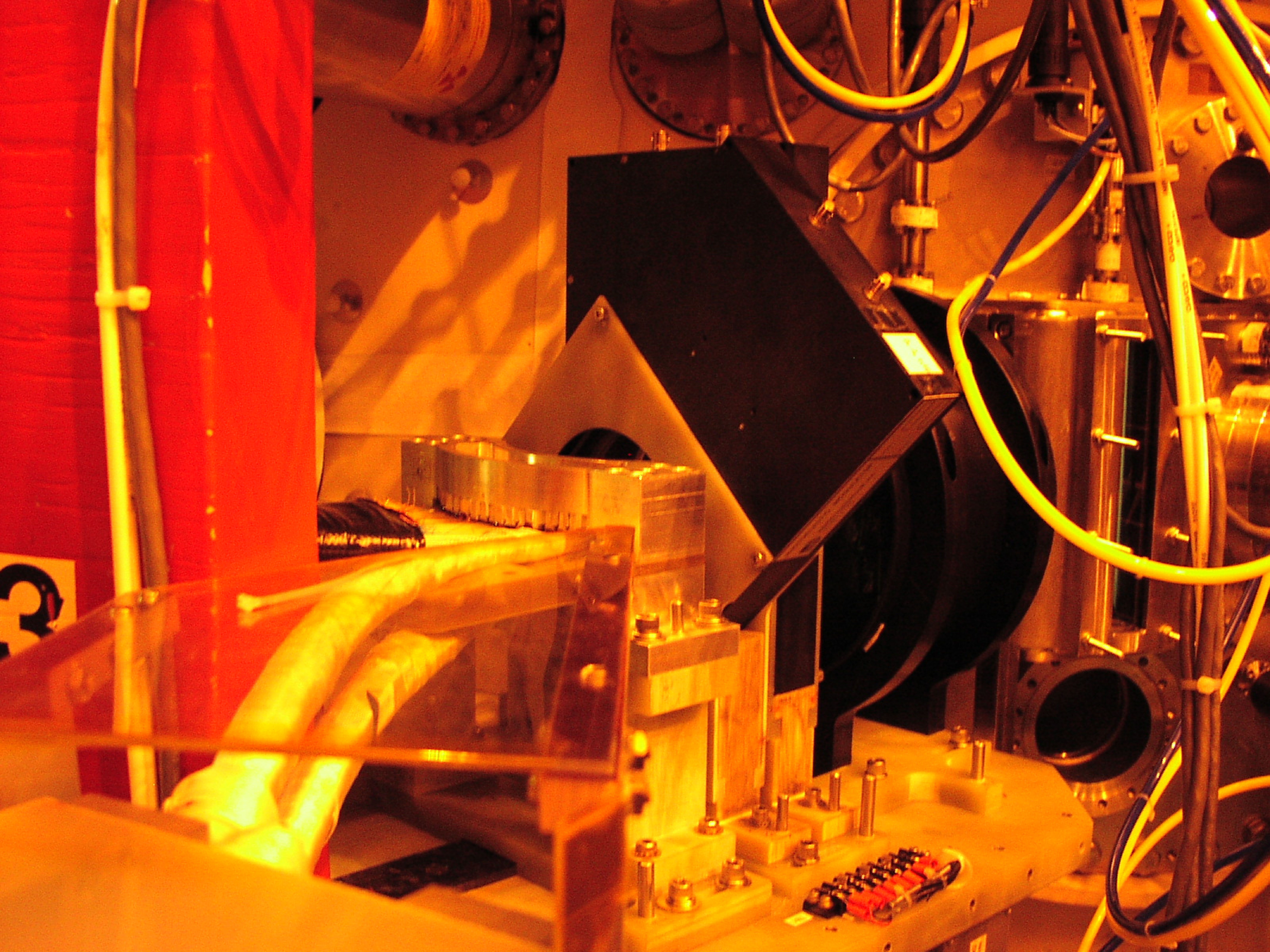

Status and Summary

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- **Installation of collection optics and fiber optics is complete.**
- **Development of a *tunable*, *high resolution*, *high throughput* spectral filter is complete.**
- **First light $\approx$ in early 2003.**
- **Goal: 10 channels operating during next NSTX run and 19 channels in 2004.**