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# Large-aperture imaging spectrometer to enhance resolution of solar observations

**Brian Robinson, K.S. Balasubramaniam, and G.A. Gary**

*An instrument consisting of three large-aperture Fabry-Pérot filters in series within a telecentric optical system would allow high spatial and spectral resolution solar observations by the Advanced Technology Solar Telescope.*

High-resolution observations of the solar atmosphere are important for developing accurate models of space weather to protect space and ground-based military and civilian assets. A large-aperture solar telescope, such as the proposed four-meter Advanced Technology Solar Telescope (ATST),[1,2] can present a problem to designers of precision instruments when the size of imaging instruments scale with the size of the telescope.

The size of the ATST presents a novel problem in the area of imaging spectrometers. Currently, the largest solar telescopes are approximately 1.5m in diameter. Using the smaller-aperture Fabry-Pérot (F-P) filters found at some contemporary facilities would result in lower spectral resolution. Alternative instrument types do not provide the needed tunability and throughput.[3] The solution is to design an imaging system around the filters that is compact enough to be practical while maintaining high resolution, and to work with industry partners to develop larger-aperture F-P filters.

Our approach is to employ a triple etalon F-P filter in a telecentric configuration, so that the pupil is collimated in the image space where the filter is located. This results in a uniform spectral response across the field of view. However, to maintain high spectral resolution, the beam incident on the filter must be very slow (F/300) to achieve the desired 20mA passband width. This, in turn, results in a very long optical path length within the system. The solution is to use reflective optics in the design, which serve the dual purpose of folding the system and providing focal power.[4] The acute folding angles also minimize the impact of the system on the polarization of the incoming light.

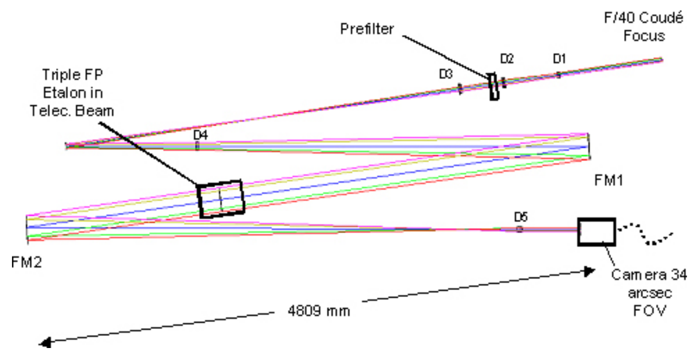


***Figure 1.*** *Triple Fabry-Pérot tunable imaging spectrometer optical layout.*

The triple F-P interferometer is a tunable imaging spectrometer. By its very nature, its spectral and imaging performance are intertwined and rely heavily on the design of the supporting optics. To maintain uniform spectral performance across the field of view, the system must be configured so that the etalons are in a telecentric image space. In this configuration, however, the spectral resolution is degraded as the F/# of the incident beam decreases. To achieve the desired resolution, an F/300 beam is required. In turn, the optical invariance demands a very large 200mm etalon aperture to obtain a 34 arcsecond field of view. Faster beams also result in a chromatic apodization of the exit pupil and image degradation.

In our work,[5] we employed a hybrid reflective/refractive optical design to provide diffraction-limited imaging in a package compact enough to fit comfortably within the Coudé room of the ATST (see Figure 1). In addition, we modeled the effect of the pupil apodization on the imaging performance of the spectrometer and found that it is negligible for the F/300 case, but quickly becomes appreciable in lower F/# configurations, even for F/#s as high as 150 (see Figure 2).

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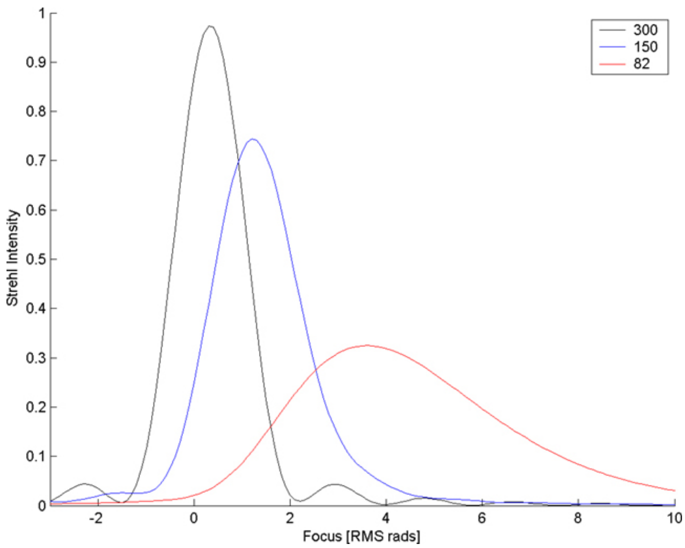


*Figure 2.* *Through-focus Strehl intensities for various telecentric beam F/#s (centered at 500nm wavelength and integrated across the instrument passband).*

The triple F-P tunable filter, when coupled with the ATST and its adaptive optics, will afford solar physicists the ability to perform high-resolution solar observations and study fundamental physical processes on finer spatial scales than are currently possible. With its high-transmittance, narrow-band performance, high spatial resolution, and superior out-of-band rejection, this instrument will offer an unprecedented opportunity to understand the coupling between the magnetic and hydrodynamic fine structure at the photosphere and their relationship to the dynamic processes in the interior of the sun and corona.

An optical design that incorporates three large-aperture filters and mirrors that fold the system into a compact size has met the challenges associated with large-aperture, ground-based telescopes. The result is an instrument that will possess high spectral resolution and will be capable of observing extended areas of the solar atmosphere on very fine spatial scales. Subsequent work should include a physical optics model of the system from the primary mirror of the ATST to the focal plane of the instrument and further optimization of the F-P filters.

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