# SH31A-11 The Facility InfraRed Spectropolarimeter for the Dunn Solar Telescope

# http://kopiko.ifa.hawaii.edu/firs/

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1. Introduction

## 2.1 Description of the Instrument

This instrument will provide simultaneous spectral coverage at visible (3,500 - 10,000 Å) and infrared (9,000 - 24,000 Å) wavelengths through the use of a unique dual-armed design. The geometry of the spectrograph has been specially designed to capture the Fe I 6302 Å and 15648 Å lines with maximum efficiency. In addition, the spectrograph operates in a multiple slit mode. By using narrow band filters, the spectra from four consecutive slit positions can be imaged at once on the same detector. This feature greatly reduces the time necessary to raster scan across a large area

# 2.2 Current Capabilities

FIRS is assisted by the High-Order AO system developed by NSO (Rimmele et al. 2004) to perform telescope diffraction-limited imaging spectropolarimetry. The t/36 feed optics yield a 172" x 75" field of view (FOV) for studies requiring large FOV. Alternatively, an f/108 feed can also be used for observation requiring only a small FOV (57" x 25") with a high time cadence. It can observe the photospheric Fe I 6302 Å and 15648 Å lines, and the chromospheric He I 10830 Å lines in multi-slit mode. Additionally, a Ca II 8542 Å beam splitter allows for simultaneous observation of the Ca II 8542 Å line using the IBIS instrument (Cavallini 2006). Thus, FIRS and IBIS can be combined to provide the following two spectral line combinations:

1. Simultaneous Fe I 630 nm, Ca II 8542 Å, and Fe I 15648 Å coverage, or

2. Simultaneous Fe I 630 nm, Ca II 8542 Å, and He I 10830 Å coverage The current capabilities of FIRS and a comparison with the Fe I 6302 Å spectropolarimeter onboard the Hinode satellite is summarized in Table 2. Figure 3 shows an example of the 6302 Å Stokes spectra and line-integrated maps of an active region obtained with an experimental f/72 setup. Figure 4 shows an example of the 15648 Å Stokes spectra and line-integrated maps of an active region obtained with the default f/36 feed optics.

#### 2.3 Status

The performance and functionalities of the visible and IR spectropolarimeters have been verified. The final system integration is being conducted, and the training of the NSO observers will commence in the Fall quarter of 2008. We expect to release the instrument to the user community following the first quarter of 2009.



The Facility IR Spectropolarimeter is a multi-slit spectropolarimeter designed for the Dunn Solar Telescope at the National Solar Observatory on Sacramento Peak in New Mexico to study magnetism on the solar surface. The instrument samples adjacent slices of the solar surface using four parallel slits to achieve high cadence, diffraction-limited, precision imaging-spectropolarimetry. Due to the versatile, multi-armed design of the spectrograph, up to four spectral lines at visible and infrared wavelengths, covering four different heights in the solar atmosphere, can be observed simultaneously. In this poster-paper we will describe the design, capabilities, and performance of the instrument.

### Table 2: Properties of FIRS

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Property	FIRS f/36*	FIRS f/108**	Hinode SOT/SP
Telescope	76.2 cm Solar Tower		50 cm Aplanatic Gregorian
Rayleigh limit @ 6302	0.21″		0.32″
Rayleigh limit @ 15648	0.52″		
Field	172″ x 75″	57" x 25"	160" (320" max) x 151"
6302 Spatial Sampling	0.22" x 0.08"/pix	0.11" x 0.03"/pix	0.15" x 0.16"/pix
15648 Spatial Sampling	0.22" x 0.15"/pix	0.11" x 0.05"/pix	
Scan Time***	18 min	12 min	83 min
6302 Spectral Resolution (Sampling)	0.03 (0.01) Å		0.03 (0.02) Å
10830 Spectral Resolution(Sampling)	(0.04) Å		
156548 Spectral Resolution (Sampling)	0.17 (0.06) Å		

\*Assuming use of a 30 µm slit (0.22") \*\*Assuming use of a 45 µm slit (0.11")

\*\*\*Assuming a 5 sec scan step cadence

#### 3. Future

The following upgrades have been planned to extend the functionality of FIRS: 1. Acquisition of additional IR and CCD cameras to enable simultaneous observation of four spectral lines (Fe I 630 nm, Ca II 854 nm, He I 1083 nm, and Fe I 1565 nm)

2. Acquisition of new Wollaston prisms to enable implementation of a spectral mask at the spectrograph focal plane to provide enhanced field of view coverage (172" x 150" for f/36, 60" x 50" for f/108).

3. Implementation of a super-achromatic dual-waveplate polarization modulator to allow for a synchronized exposure for all wavelengths. Acquisition of additional DWDM filters to expand the multi-slit capability to other interesting spectral lines.

#### References

Cavallini, E. IBIS: A New Post-Focus Instrument for Solar Imaging Spectroscopy, SoPh. 236, 415 Lin, H., ATST Near-IR Spectropolarimeter, 2003, SPIE, 4853, 215 Rimmele, T. R. et al., First Results from the NSO/NIIT Solar Adaptive Optics System, 2004, SPIE, 5171, 179

Socas-Navarro, H., The Three-Dimensional Structure of a Sunspot Magnetic Field, 2005, ApJ, 631, 167

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Figure 4. FIRS Infrared data from NOAA 10953 taken on 30 April 2007. (Left) 15648 Å Stokes spectrum from one step in the raster scan. (Right) Maps of the continuum intensity and the wavelength-integrated Q, U, and V parameters of the Stokes vector for the 15648 Å Fe I ==3 line

6302 3 Wavelength (Å 6302 3 Wavelength (Å)

#### Table 1: Description of FIRS

and release the magnetic energy which drives explosive flares and CMEs (coronal mass ejections).

This paper describes the design, current capabilities, and future upgrade path of the instrument.

The Facility Infrared Spectropolarimeter (FIRS) for the Dunn Solar Telescope (DST) is a new instrument specifically designed to

address these important problems. It employs an achromatic reflecting Littrow spectrograph design (see Figure 1) to allow for

simultaneous observations of photospheric and chromospheric spectral lines. A new multiple-slit design has been adopted to better

utilize the modern large format detector arrays and to achieve a four-times enhancement of the system throughput when compared

to conventional single-slit spectropolarimeters (see Lin 2003 for details). Figure 2 shows the four slit dual beam spectra. The

instrument is currently undergoing the final integration and is expected to be released to the user community in the near future.



The detector for the infrared arm of the spectrograph is a Raytheon Virgo IR Focal Plane 1024 x 1024 HgCdTe array

Observations of the static and dynamic properties of solar magnetic features in the photosphere and chromosphere can yield

information critical to the ultimate resolution of a broad range of problems in modern solar physics research. For example, a complete, three-dimensional picture of the magnetic field, thermal, and dynamic properties of a sunspot (e.g. Socas-Navarro 2005) may shed light on how sunspots are formed, how they maintain a quasi-static configuration against the highly dynamic plasma of the photosphere, and how the normal and inverse Evershed flows are driven. A time sequence showing the photospheric and chromospheric magnetic field evolution of a complex active region may finally allow us to identify the mechanisms that build up on the sun, making it an ideal instrument for the study of quickly developing active regions