SIFTIR: Spectro-polarimetric Imaging Fourier Transform spectrometer for the InfraRed

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1 Background

Observations of evolved stars in the infrared are well suited for studies of dusty environments, providing a wealth of absorption and emission bands with which to diagnose grain characteristics. We are currently developing an instrument that will employ a Fourier transform spectrometer in conjunction with TNTCAM2 (Klebe et al. 1998), an imaging polarimeter. The FTS component will enhance TNTCAM2, giving the instrument a maximum resolution of 2000 at 10 μm. The FTS is capable of operating between 2-15 μm, but polarimetry for the instrument is limited to the 8-15 μm region due to waveplate/wiregrid characteristics.

SIFTIR, the Spectro-polarimetric Imaging Fourier Transform spectrometer for the InfraRed, will build upon the results of TNTCAM2 (Jurgenson et al. 2003). Imaging polarimetry has the potential to trace polarization magnitude and P.A. changes throughout an extended region of interest. TNTCAM2, though capable of a fair degree of spatial resolution, lacked spectral resolution needed to carry out the analysis for approximating grain shapes (e.g. Hildebrand & Dragovan 1995). Holloway et al. (2002), established correlations in polarization magnitude and position angle between the 10 μm silicate feature and the 3 μm water ice feature in a small sample of YSO's. The existence of a correlation makes plausible the argument that silicate grains might provide nucleation sites for grain growth in a core-mantle arrangement. SIFTIR not only has the capability to cover both the near and mid-IR spectral regions to check for polarization correlations, but will also have the resolution necessary to characterize the grain shapes.

2 SIFTIR Control Aspects

SIFTIR was designed with the intent to provide not only the spectral resolution needed to carry out investigations such as those discussed above, but also maintain the imaging capability already provided for in TNTCAM2. Figure 1 shows the FTS component that will be mated with TNTCAM2, built by Idealab of Franklin, Massachusetts. This component will have the ability to operate in a step scan mode as well as in continuous scan with a maximum optical path difference (OPD) of 2 cm. Designed to operate between 2-15 μm, with a resolution up ot 10,000 at 2 μm.

Fig. 1. The FTS component of SIFTIR

The stepping mode will allow for background subtraction and waveplate rotation at each step with enouph rapidity to avoid atmospheric changes. Four background-subtracted interferograms are then produced, one for each waveplate position, from which Stoke's parameters are calculated. The number of steps over the course of a single scan is determined by the bandwidth of the observation and the resolution. The resolution is determined by the maximum travel of the moving mirror, and the bandwidths will be the filters in TNTCAM2. Figure 2 depicts how the control system will use two HeNe laser signals that are 90 degrees out of phase with one another to provide relative positional feedback.

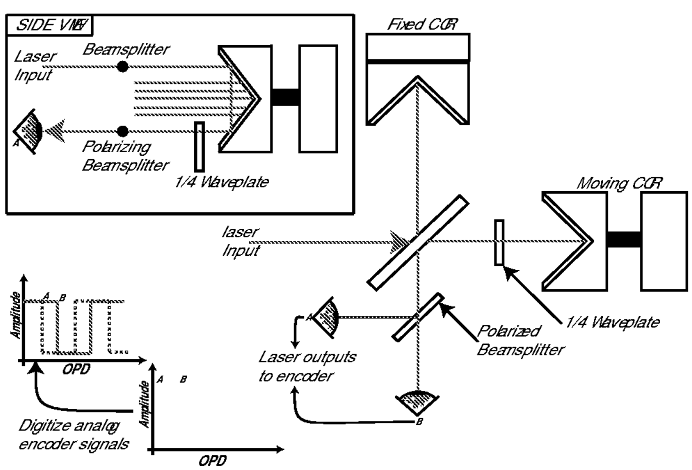

Fig. 2. This schematic represents relative positional feedback

A 45-degree polarized laser (shown parallel to moving mirror in figure 1), enters the interferometer, is split into two directions by the beamsplitter, each traveling either to a stationary or moving corner cube reflector. The beam that travels to the moving mirror passes once through a quarter waveplate (resultant is 90 degrees out of phase relative to the stationary mirror beam) before recombining at the beamsplitter. The recombined beam then travels to a polarizing beamsplitter cube, separating the two orthogonal components of the recombined beam and sending each to its own encoder. Two analog input channels of a field programmable gate array (FPGA), produced by National Instruments, square up the waves, compute the logical AND from the two square waves, and the number of high/low toggles are counted and used to trigger sampling and/or stepping. This is the relative positional feedback mentioned above. An analog output signal from the FPGA commands the motor to stop, go, or turn around for a specified number of toggles, as well as control the array readout. Figure 3 is the overall control scheme for SIFTIR.

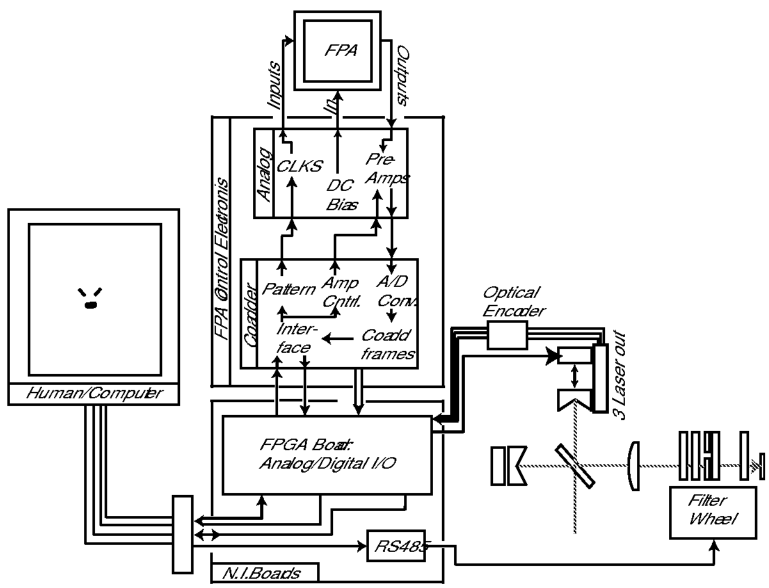

Fig. 3. SIFTIR control schematic

The FPGA also has ninety-six digital I/O lines as well as the analog, thirty-one of which will be used to communicate with the array electronics. All signals either come or go through the FPGA, so that the timing between reading data off of the array, and motion of the interferometer is worked out in the Labview software. Filter wheel control, though not done through the FPGA, still exists in the main control program. Light coming in from the telescope will be collimated into the interferometer, and re-focused upon exit, and enter into TNTCAM2.

Initial testing of the instrument will take place at the University of Denver's Student Astronomy Laboratory, which consists of a 76.2 cm afocal Mersenne telescope (Mellon et al. 2002) on the roof of the Physics and Astronomy building. The light path from the telescope gets sent into a laboratory beneath it where the FTS will sit horizontal on a turntable that will rotate at the sidereal rate. After checkout, SIFTIR can travel to larger telescopes such as the 2.3 m telescope at the Wyoming InfraRed Observatory.

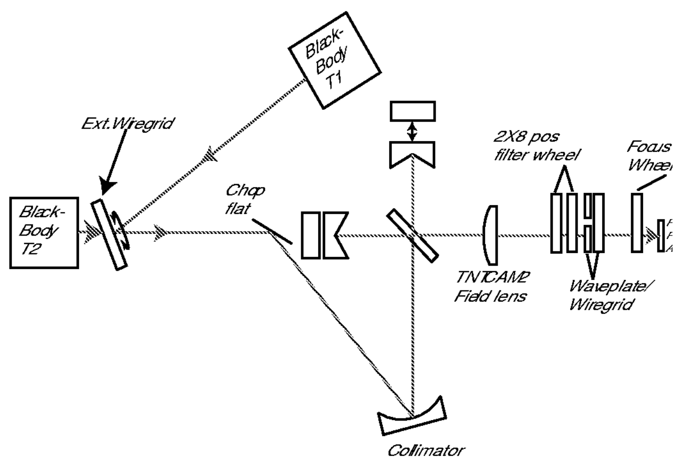

Fig. 4. SIFTIR calibration schematic

In order to adequately account for instrumental polarization, a Calibration scheme developed by the Optical Sciences Instrumentation Group at the University of Alabama, Huntsville (Smith et al. 2000) will be used (figure 4). The method consists of two blackbody sources at different temperatures and an external wire grid. Radiation from source 1 gets reflected, while that from source 2 is transmitted. The two rays, polarized 90 degrees relative to one another, produce a partially polarized beam from which to calibrate the instrument. Instrumental polarization can then be subtracted out during reduction of data.

References

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