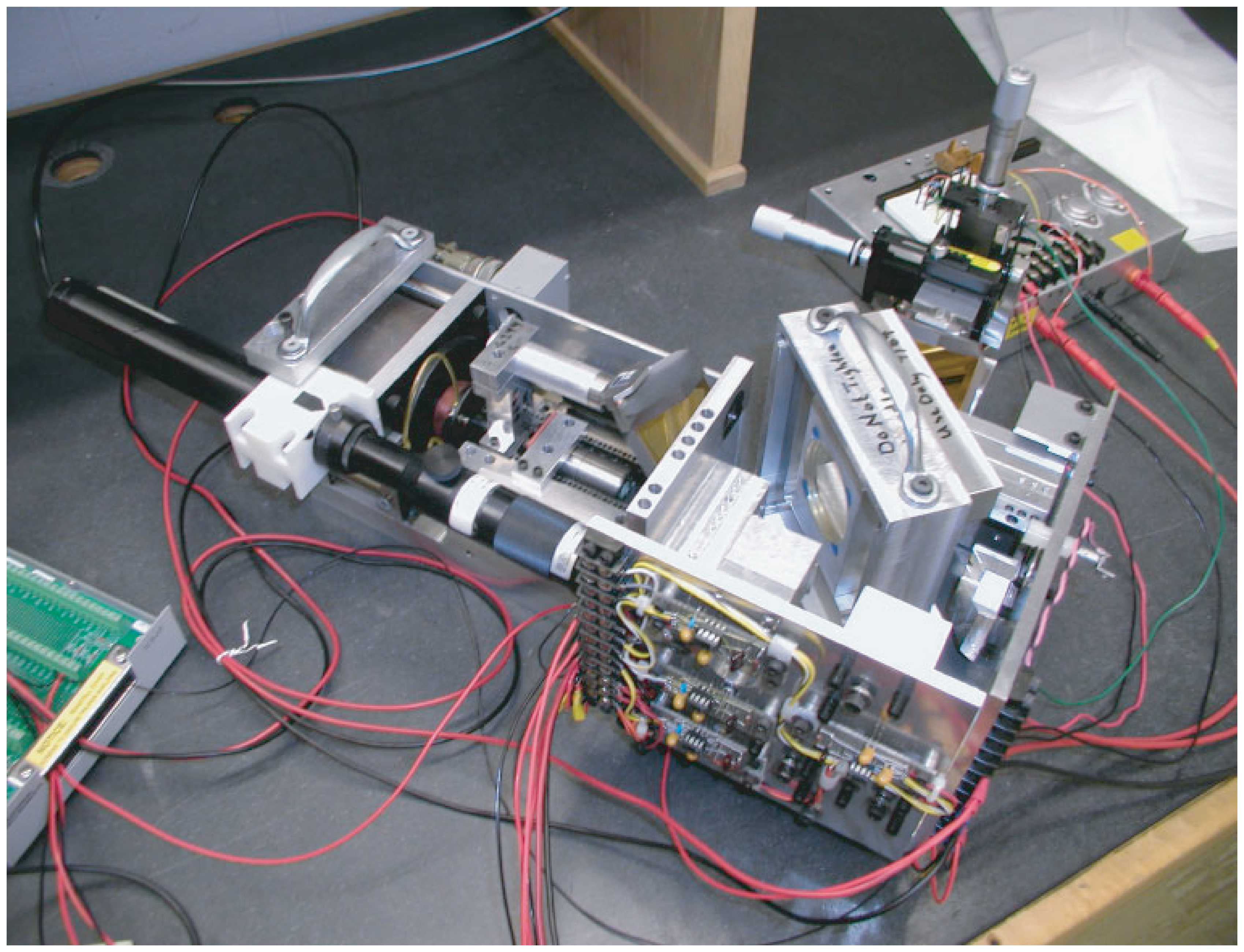
Mid-Infrared Spectropolarimetry of AGB Stars

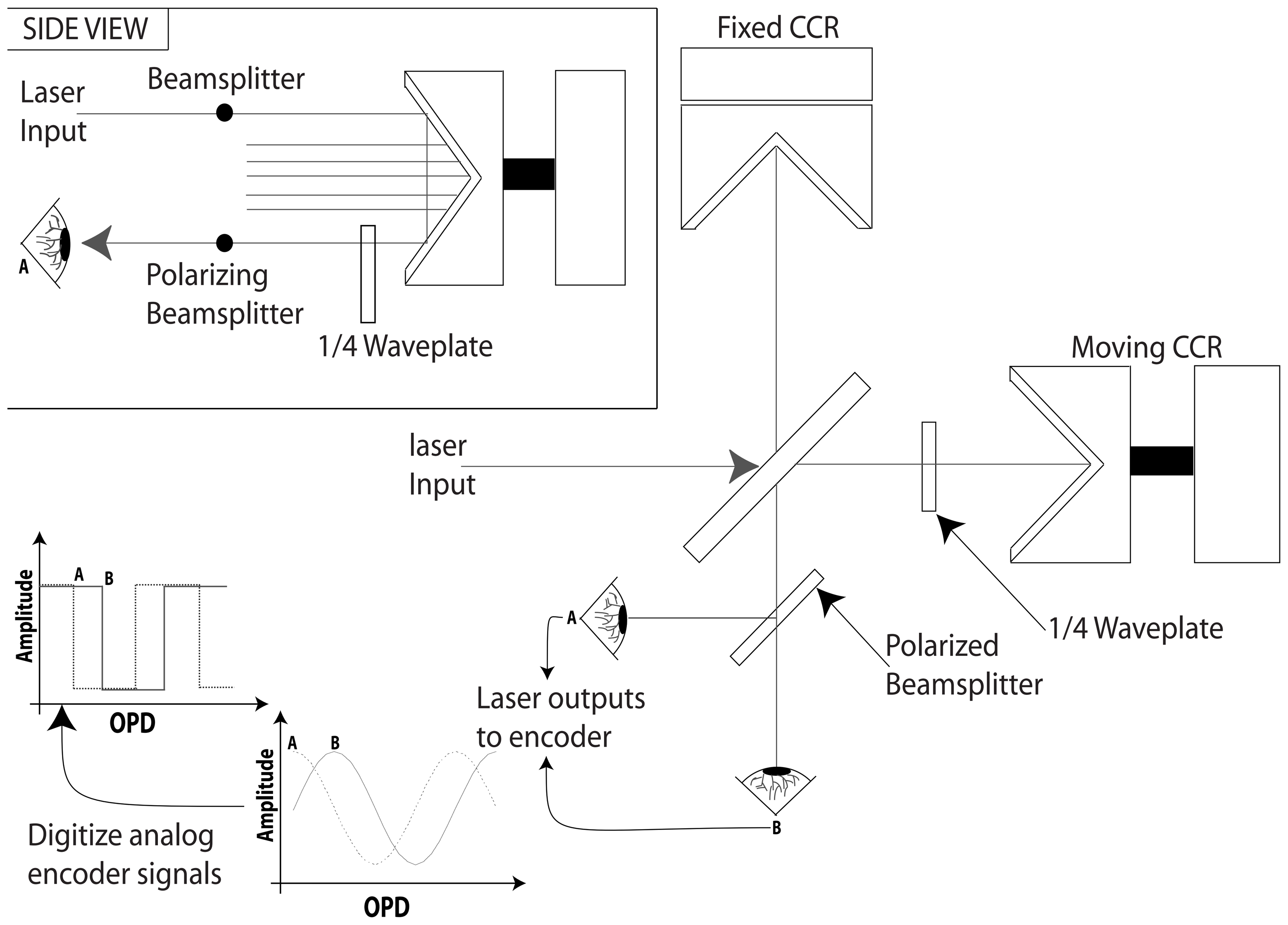
C.A. Jurgenson & R.E. Stencel, University of Denver Observatories

Increasingly, observations of evolved stars suggest that the emergence of asymmetric structure occurs relatively early in evolutionary terms. To explore this phenomenon, we are currently developing an instrument that employs a stepping imaging Fourier transform spectrometer in conjunction with TNTCAM2, a mid-IR imaging polarimeter, capable of a maximum 0.5 cm-1 resolution (R = 2000 at 10 µm). The FTS component enhances TNTCAM2, giving the instrument a high-resolution component capable of sampling mid-IR resonance features due to dust grains. Currently, polarization analysis will only be possible in the 8 to 15 µm region due to the waveplate/wiregrid characteristics, but the FTS ultimately has the ability to sample the spectrum in the near-IR down to 2 µm (max R = 10000). We seek to demonstrate whether grain shape and composition correlates with mass loss dynamics. We would like to acknowledge the estate of William Herschel Womble, Sigma Xi grants in aid of research, and NASA's Rocky Mountain Space Grant for support of this endeavor.

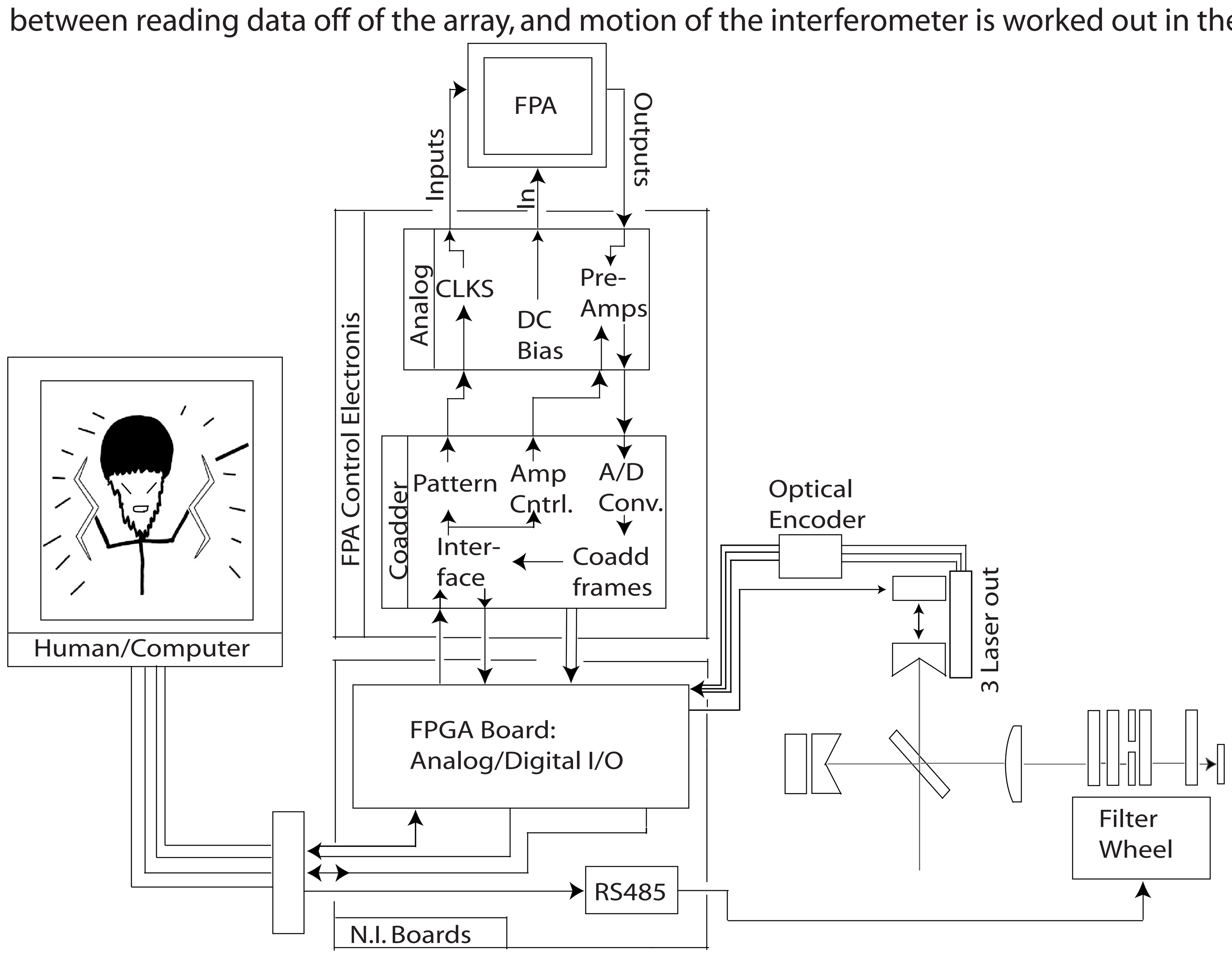
Pictured below is the FTS component that will be mated with TNTCAM2, built by Idealab of Franklin, Massachusetts. This component will have the ability to operate in a step scan mode as well as in continuous scan with a maximum optical path difference (OPD) of 2 cm. SIFTIR, the Spectro-polarimetric Imaging Fourier Transform spectrometer for the InfraRed, will build upon the results of TNTCAM2 (Jurgenson et al. 2003). Imaging polarimetry has the potential to track polarization magnitude and P.A. changes throughout an extended region of interest. TNTCAM2, though capable of a fair degree of spatial resoltion 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 P.A. 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 has the capability to cover the near & mid-IR spectral regions, to check for polarization correlations, and the resolution to estimate grain shapes.



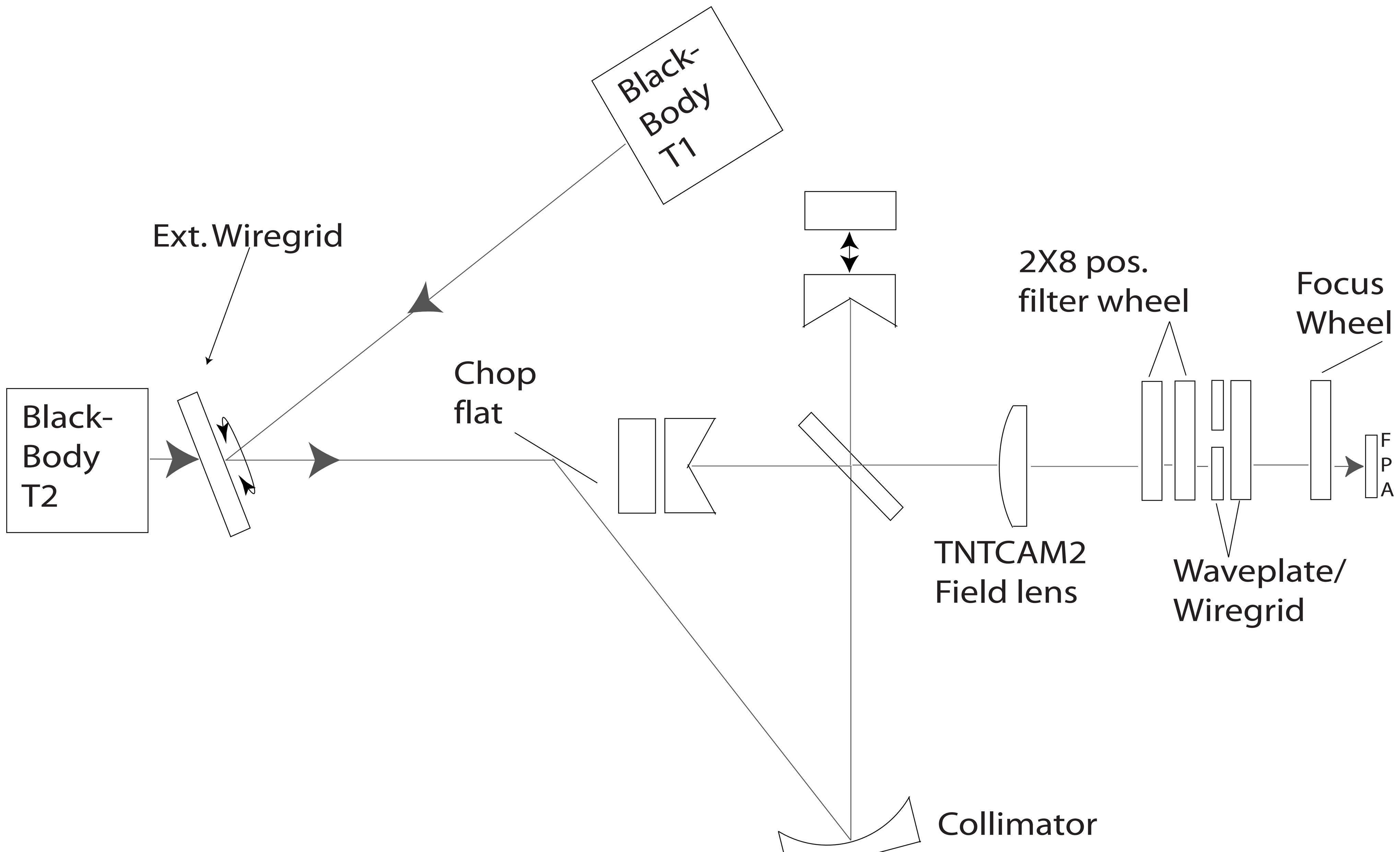
Below depicts relative positional feedback for the control system, with two HeNe laser signals 90 degrees out of phase. A 45 degree polarized laser enters the interferometer, is split in two directions by the beamsplitter, with each traveling to a stationary or moving corner cube reflector. The beam that travels to the moving mirror passes once through a 1/4 waveplate (thus 90° out of phase wrt stationary mirror beam), before recombining at the beamsplitter. A polarizing beam-splitter cube separates the two orthogonal components of the recombined beam sending each to its own encoder. The signals are digitized, the logical AND is computed, and the number of high/low toggles are counted and used to trigger sampling/stepping.



At lower left is the overall control scheme for SIFTIR. 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, consisting 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 turn-table that rotates at the sidereal rate. After checkout, SIFTIR can travel to larger telescopes such as the 2.3 m telescope at the Wyoming InfraRed Observatory.

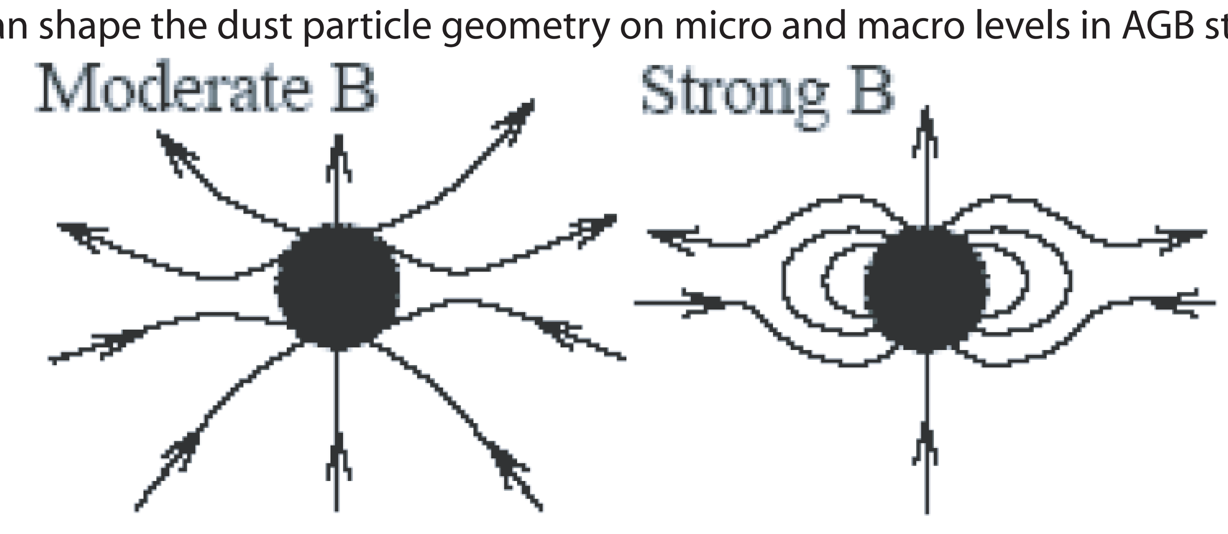


In order to adequately account for instrumental polarization, a Calibration scheme developed by the Optical Sciences Instrumentation Group at the University of Alabama, Huntsville (Smith et al. 2000 will be used. The method consists of two blackbody sources at different temperatures and an external wiregrid.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



SCIENCE RATIONALE: Other than the pioneering, classic near-IR polarimetry of AGB stars by Johnson and Jones (1990), one of the key diagnostics of the dynamics of circumstellar envelopes is the maser emission from SiO molecules (v=1, J=1-0 and J=2-1) detected at 43 and 86 GHz. Recently, improvements in polarization calibration at high frequencies and total intensity multi-dish interferometric observations have demonstrated the SiO masers spots are confined to a narrow ring like morphology (tangentially amplified, cf. Diamond et al. 1994) around many late type stars, indicating orderly motions and systematic velocity distributions in the 1 to few stellar radius domain. As the SiO molecule is nonparamagnetic, if exhibits significant linear polarization in the presence of a magnetic field, enabling determination of magnetic field strength in this key region. Kemball and Diamond (1997) deduced a line of sight field strength in the Mira TX Cam of 5-10 gauss. Vlemmings et al. (2002) have compiled this and related magnetic field strength determinations for related stars using SiO as well as H2O and OH masers at correspondingly greater distances to indicate an inverse square law like variation of magnetic field strength with distance around evolved stars, and that the magnetic pressure dominates the thermal pressure by a factor of more than an order of magnitude.

This clearly indicates how the dynamics can be affected by the magnetic field, much as proposed by Matt et al. (2000) with a "simple, robust mechanism by which an isolated star can produce an equatorial disk. The mechanism requires that the star have a simple dipole magnetic field on the surface and an isotropic wind acceleration mechanism. The wind couples to the field, stretching it until the field lines become mostly radial and oppositely directed above and below the magnetic equator, as occurs in the solar wind. The interaction between the wind plasma and magnetic field near the star produces a steady outflow in which magnetic forces direct plasma toward the equator, constructing a disk. In the context of a slow (10 km/s) outflow (10-5 Mo/yr) from an asymptotic giant branch star, MHD simulations demonstrate that a dense equatorial disk will be produced for dipole field strengths of only a few Gauss on the surface of the star. A disk formed by this model can be dynamically important for the shaping of planetary nebulae." Similarly, we ask and plan to investigate with IR spectro-polarimetry whether these types of conditions can shape the dust particle geometry on micro and macro levels in AGB star outflows.



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