Design of a Mid-IR Polarimeter for SOFIA

Mid-infrared polarimetry remains an underexploited technique; where available it is limited in spectral coverage from the ground, and conspicuously absent from the Spitzer, JWST and Herschel instrument suites. The unique characteristics of SOFIA afford unprecedented spectral coverage and sensitivity in the mid-infrared waveband. We discuss the preliminary optical design for a 5-40µm spectro-polarimeter for use on SOFIA, the SOFIA Mid-InfraRed Polarimeter (SMIRPh). The design furthers the existing 5-40µm imaging and spectroscopic capabilities of SOFIA. We discuss the use of polarization gratings and this characteristics at mid-IR wavelengths. A conceptual optical design exploiting polarization gratings is presented. Combined with the synergy between the possible future far-IR polarimeter, Hale, this instrument would provide the SOFIA community with unique and exciting science capabilities, leaving an exclusive scientific legacy.

Polarization Gratings

A novel polarizing beamsplitter using birefringent gratings (Oh & Escuti, 2007, Escuti et al. 2006) is being pioneered at NCSU’s nearly ideal experimental gratings, the m=0 beam is unpolarized, but contains typically <0.5% of the incident flux. The m=±1 orders are highly perpendicular to the m=0 beam, making the PG component a potentially ideal alternative to other analyzers. We show a simple implementation of a PG in the figure at top right. Our provisional MIR polarimeter design makes use of a PG in the lower left and right, where the level of birefringence is lower. With a relatively minor change in the construction of the PG (e.g. carbon nanotube doping) we expect to significantly improve the PG throughput, and this is shown in the thick line (lower right).

Future work will continue optimization work on the transmission of the PGs, and refining our preliminary measurements, which are likely pessimistic as the absorption bands are likely significantly more narrow than our show above. At the conceptual level of this design study, we have shown that SMIRPh can indeed be based around PG technology and in the next section we produce an optical design based on PGs.

Primary Design Inputs

1. Two spectral bands are required, spanning 5-25µm and 25-40µm, hereafter the blue and red arms respectively
2. If possible, simultaneous observations in the red and blue arm with a minimal transition in wavelength space between the arms
3. The optics must be diffraction limited at all wavelengths >15µm, the shortest wavelength at which SOFIA is expected to deliver diffraction-limited observations
4. The plate scale is set to Nyquist sample the shortest wavelength at which SOFIA is expected to deliver diffraction-limited observations
5. Instrument must be a dual-beam polarimeter to maximize efficiency and minimize spurious polarization due to variable sky transmission, emission and image quality
6. Instrumental polarization must be low (<1%)
7. Imaging and spectro-polarimetry must be available, with [total flux] imaging available as a goal
8. Spectroscopic resolution optimized to disperse entire wavelength window onto one array
9. The system should be an all-reflection design, as far as possible, to minimize chromatic aberrations
10. Optics must be readily able to be fabricated
11. The instrument must conform to the SOFIA space envelope

Design Performance

The conceptual design is shown in the figures (left), where we implement two arms per polarimetric plane in addition to the two color channels. The instrument must be able to operate at the nighttime environment of SOFIA, the space envelope and drive to have the images in the orthogonally polarized beams indistinguishable from each other. The diffraction limited performance of the design shown right as an image of the slit and seven wavelengths in the red arm.

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