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A POLARIZING FOURIER TRANSFORM SPECTROMETER TO CHARACTERIZE MILLIMETER-WAVELENGTH FILTERS AND MEASURE THE ATMOSPHERIC OPACITY

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We will shortly complete the testing of a cryogenic (1.8K) total-power sky monitor which will measure the temporal fluctuations of the sky brightness at millimeter wavelengths. In this article we outline the development of a polarizing Fourier Transform Spectrometer (FTS) that can characterize the spectral response of our mm-wavelength filters and entire optical system. Since the FTS will be portable, we can also measure the seasonal changes in the atmospheric transmission windows above Sierra Negra (the GTM site). These data will influence the design of submillimeter and millimeter filters for future GTM instruments.

The Total Power Sky Monitor System

Atmospheric water vapour is the principal source of molecular absorption at mid-IR to millimeter wavelengths, and hence the primary reason for the limited number of ground-based atmospheric windows available to astronomical observations in this wavelength regime. We are developing a millimeter-wavelength total-power sky monitor to measure the spatial and temporal fluctuations of the atmosphere above Sierra Negra, the site of the Gran Telescopio Milimetrico (GTM). The data from this experiment will help characterize the loading (due to the variable sky background) on the next generation of state-of-the-art superconducting Transition Edged Sensors (TES). These TES detectors will be used in the fabrication of a future large-format focal-plane continuum array-camera for the GTM.

The total-power sky monitor (Fig. 1) consists of He^4 cryostat with a composite bolometric detector (a bismuth-coated sapphire absorber with an NTD Germanium thermistor, connected via a weak thermal-link (12 micron Niobium-Titanium wires) to a heat-sink at 1.8 - 4 K) at the exit aperture of a f/2.6 Winston cone.

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Fig. 1. He^4 cryostat; cold plate assembly (feedhorn-coupled detector, JFET module); close up view of bolometer (9mm^2 absorbing substrate and NbTi leads).

A 1.1 mm band-pass filter, IR blocking filters and nitrogen-cooled vapour shields control the power incident on the bolometer. Amplification of the current-biased signal is provided by a cold (120 K) JFET pre-amplifier, and room temperature electronics. The cryostat vacuum-window is 0.6 mm thick HDPE. Exterior to the cryostat, we have a calibration unit that chops a 77 K cold-load (LN2) against the variable sky signal at 1-10 Hz.

Laboratory results are consistent with the expected R-T behavior of the bolometer (using a Haller-Beeman NTD type-B thermistor), and indicate that we have achieved a receiver NEP of 1 x 10^{-14} WHz$^{-1/2}$ at 4.2 K and 1 x 10^{-15} WHz$^{-1/2}$at 1.8 K. The measured thermal conductance (G) of the bolometer is 10^{-7} - 10^{-8} W/K.

The millimeter wavelength sky monitor will be completed and tested on the site of the GTM in summer 2004.

The Polarizing Fourier Transform Spectrometer

The total-power sky monitor (TPSM) will measure variations in the atmospheric opacity through a 1.1 mm band-pass filter. An equally important goal of our development plan is to provide an instrument that can measure both the transmission properties of

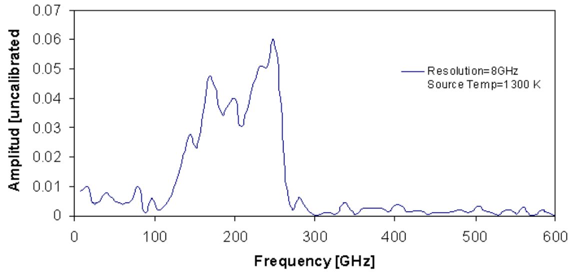

Fig. 2. The transmission profile of a 2 mm band-pass filter is obtained from the Fourier transform of its interferogram.

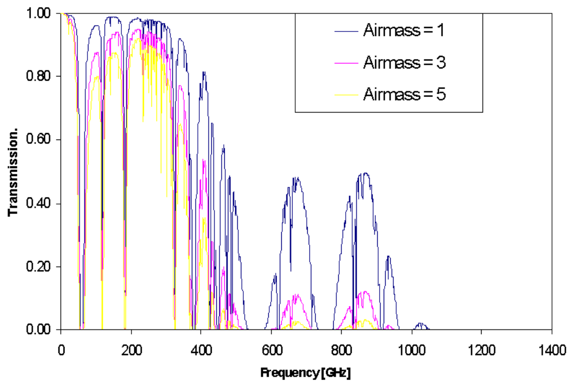

Fig. 3. The expected atmospheric transmission at submm/mm wavelengths(with 1.5 GHz resolution and assuming 1 mm PWV) above the GTM site (Sierra Negra, Puebla) computed from atmospheric models (Grossman, 1989) at different air masses.

the entire optical path (including pass-band filters) for GTM receivers (Fig. 2), and an instrument that can measure the spectral transmission profile of the sub-millimeter and millimeter atmospheric windows above Sierra Negra under different seasonal conditions (Fig. 3).

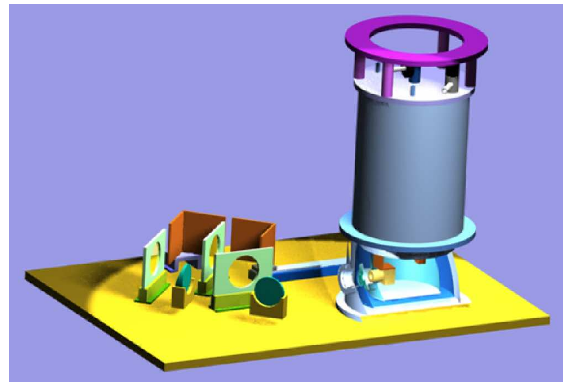

Fig. 4. 3-d model of the Fourier Transform Spectrometer.

The construction of a polarizing Fourier transform spectrometer (FTS) satisfies these goals, and utilizes the same cryostat, bolometer detector, calibration unit and other hardware in the TPSM.

The FTS is based on a Martin-Puplett interferometer, which uses a wire-grid polarizer as a beamsplitter and roof mirrors for reflectors. One advantage of this design, which is an adaptation of the Michelson interferometer, is that it is possible to provide access to two input and two output beams by tilting polarizers at 45° to the incident radiation.

On a system like this it is useful to have a reference such as a blackbody calibration source. The detection element is our 1.1 mm cryogenic system (shown in the 3-d view of the FTS - Fig. 4). The 4.2 K dewar is shown with a cut-away of the cold plate, horn and detector assembly.

The FTS is under construction and will be ready for observations at the end of 2004.

REFERENCES

Grossman, E. 1989, AT - Atmospheric Transmission Software, User's Manual, Univ. of Texas and Airhead Software Co., Austin, TX

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