Optical Characterization of ultra-low NEP TES bolometers with high optical efficiency in the 5--9 THz range

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We have characterized in detail the optical response of prototype detectors for the short-wave band (34-60 μm) of SAFARI, the far-infrared spectrometer for the SPICA satellite observatory. Each bolometer consists of a transition edge sensor (TES), with a transition temperature close to 100 mK, and a tantalum absorber on a thermally-isolated silicon nitride membrane. The nitride membrane sits behind a few-moded conical horn and in front of a hemispherical backshort. SAFARI requires extremely sensitive detectors (NEP≈2x10^{-19} W/Hz^{½}), with correspondingly low saturation powers (~5 fW), to take advantage of SPICA's cooled optics.

To meet the challenge of testing such sensitive detectors we constructed an ultra-low background test facility based on a cryogen-free high-capacity dilution refrigerator, paying careful attention to stray-light exclusion, shielding, and vibration isolation. For optical measurements the system contains internal cold (3-35 K) and hot (up to ~300 K) black-body calibration sources, a light pipe for external illumination, and a broad-band reference detector for characterising the spectral content of the calibration sources. Following a long programme of optimization and characterization the test bed is in routine use, measuring the broad-band and spectral response of SAFARI prototype detectors.

We have measured the optical response of an 8x8 prototype array, as well as single pixels with an NEP as low as 4-5x10^{-19} W/$Hz^{½}$, approaching the requirement of the SAFARI flight detectors. We used a spatial mode-filtering technique to measure the effects of the different circular waveguide modes admitted by the conical feedhorn. We found an optical efficiency of 60% integrated over the passband for a detector with a 200x200-μm tantalum absorber, in good agreement with simulations. The spectral response, measured with an external FTS through the light pipe is consistent with the expected transmission of the filter stack. We compare these results with simulations and discuss them in terms of the instrument performance.