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THERMAP: a mid-infrared spectro-imager based on an uncooled micro-bolometer for the Marco Polo R mission.

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Abstract

We report on an on-going feasibility study of a mid-infrared (8-18 μm) spectro-imager for the Marco Polo R mission (THERMAP). Based on the recent development of uncooled micro-bolometer technology, we can now use these detectors for planetary missions. We present our results on using this detector to perform calibrated radiometric images, and a preliminary assessment of its performances for spectroscopic measurements of a Near Earth Asteroid (NEA).

1. Introduction

The thermal properties of small bodies in the Solar System extensively contribute to the knowledge of their global physical properties and dynamical evolution. Their determination allows us to constrain the surface properties (roughness, presence of regolith), the internal structure through the thermal inertia, and to quantify the Yarkovsky effect that controls the non-gravitational evolution of the orbit. The latter is particularly important for the prediction of the orbit of NEAs (Near Earth Asteroids), such as Apophis that could impact the Earth, hence for the design and development of future space missions to change the trajectory of those bodies. The mid-infrared properties are best determined by the space-resolved mapping and spectroscopy of the surface of the body. This requires a specific and dedicated instrument, implemented on a spacecraft for a flyby, or better a rendezvous or a sample return mission, like Marco Polo R.

We are carrying out a feasibility study of a thermal spectro-imager designed for the Marco Polo R mission. With the recent progress of uncooled micro-bolometers technology and its space qualification by the CNES, such an infrared (8-18 μm) detector is a baseline for our proposed instrument.

2. Experiment

Our experiment has been set up to perform calibrated radiometric images and preliminary performance assessment for spectroscopic measurements. The set-up includes :

- an IRXCORE640 module, based on an uncooled 640x480 micro-bolometer array from the ULIS company (France) [1], a thermal detector whose material's electrical resistance changes with its temperature, and its read out electronics, from the INO company (Québec) (Fig. 1);
- a Surnia Series germanium objective (f = 50 mm @ f# = 0.86) from the JANOS TECHNOLOGY company (USA) (Fig. 1 and 2);
- an OMEGA Engineering, Inc. black body with a 255 K to 420 K temperature range that covers a large fraction of the expected surface temperature of a NEA at 1 AU, and a maximum calibration uncertainty of +/-0.2 K (Fig. 2);
- and a set of neutral density thermal infrared filters with transmittance values of 50%, 10% and 1%, from the EDMUND OPTICS company (USA).

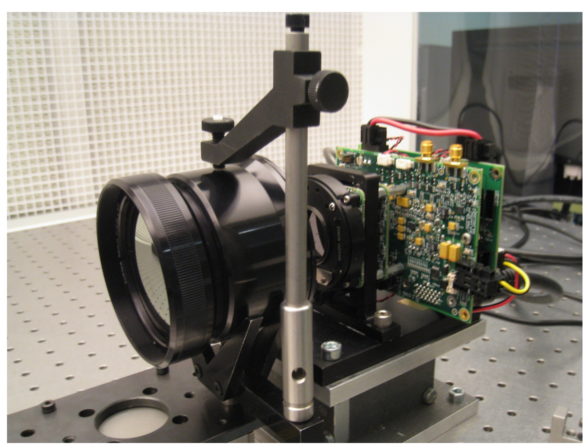


Figure 1: The Surnia Series germanium objective (left) and the IRXCORE640 module: a 640x480 micro-bolometer array (middle) and its associated electronics (right).

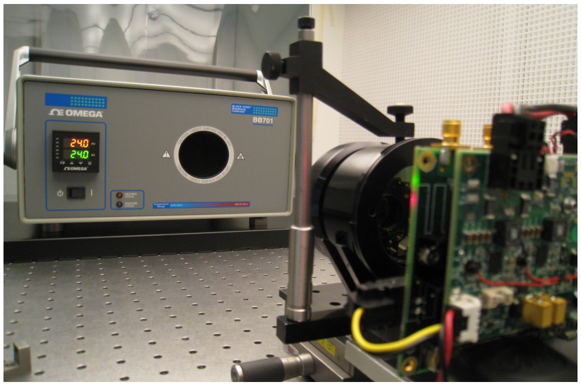


Figure 2: The OMEGA Engineering, Inc. black Body (grey box on the left), and the Surnia Series germanium objective (middle) next to our detector, the IRXCORE640 module (right).

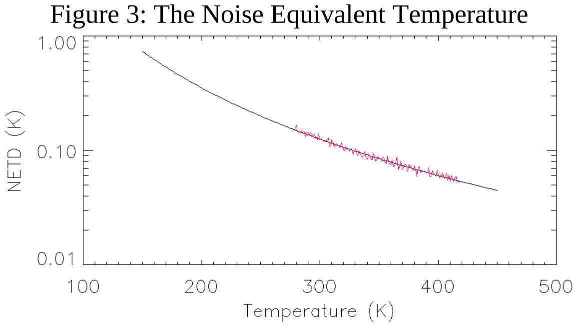
3. Results

3.1 Calibrated radiometric images

We measured the response of the detector between 258 K and 418 K. As expected from theoretical considerations, it follows very well a power law of the scene temperature. Therefore, two calibration points are sufficient to determine the absolute scene temperature with an accuracy better than 1 K.

Combining the above response with the measured noise of the whole system (detector and electronics), we derived its Noise Equivalent Temperature Difference (NETD) (Fig. 3). The NETD corresponds to the uncertainty of the measurements at a given temperature. The NETD is typically lower than 200 mK, and goes down to 70 mK at 400 K.

Figure 3: The Noise Equivalent Temperature



Difference NETD of the detector. Data are in red. The solid black line is a power law fit to the data.

3.2 Preliminary performance assessment for spectroscopic measurements

Spectroscopy is more challenging than imaging because the fluxes are much lower due to the spectral dispersion. In order to assess whether our detector is sensitive enough for spectroscopic measurements, we calculated the percentage of flux available at 10 µm and 18 µm, compared to the total flux emitted by a 300 K black body between 8 and 18 µm, depending upon the spectral resolution specified by a spectral range $\Delta\lambda$. In a first step, we simulated the low fluxes available to the detector in spectroscopic measurements by acquiring images with our flux attenuating neutral density mid-infrared filters (transmittance **:** 50%, 10%, 1%).

Preliminary results are very encouraging : we can perform spectroscopic measurements with our detector with a typical spectral resolution R>100 at 300 K. For a NEA at 1 AU with a typical surface temperature >350 K, we can expect to reach an even higher spectral resolution, sufficient to fulfill the scientific objectives of the Marco Polo R mission.

4. Conclusions

We demonstrated that it is possible to use new generation uncooled micro-bolometers arrays to realize the mid-infrared spectro-imager of the Marco Polo R mission. Calibrated radiometric images can be obtained down to at least 258 K (lower limit of our experiment), and mid-infrared spectroscopy seems possible with good spectral resolution (R>100). The THERMAP instrument, based on the above concept, will be proposed for the Marco Polo R mission and any other space missions to small bodies of the inner solar system.

Acknowledgements

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References

[1] Tissot, J. L.: IR detection with uncooled sensors, Infrared Physics & Technology, Volume 46, Issue 1-2, p. 147-153, 2004.