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Master thesis : Multi-band IR sensor for Earth Observation

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Multi-band Infrared Sensor For Earth Observation

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Abstract

A new CubeSat is in development by students and professors of the University of Liège and the Centre Spatial de Liège. The CubeSat OUFTI-NEXT will measure the hydric stress in crop fields in order to enhance the management efficiency of the water resources for agriculture. This CubeSat incorporates a thermal imager to capture the electromagnetic radiation of the infrared band. In this project, it is analysed the performance of the different infrared detectors that can be used within the CubeSat optical instrument.

There are a few examples of CubeSat missions observing in the Mid-Wave Infrared Band or in the Long-Wave Infrared band. However, any of these missions can observe in both bands at the same time. This Master Thesis describes the feasibility of an optical instrument for a CubeSat observing in both bands with the use of a single detector. With this aim, the performance of the two main groups of infrared detectors, photodetectors and thermal detectors, is measured in terms of temperature resolution and signal-to-noise ratio in the space environment. These computations are carried on with the model of equations developed in this Master Thesis.

Keywords: CubeSat, Dual-band, Microbolometer, Photodetector, NETD, SNR.

Jesús Vilaboa Pérez
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Detector	**λ range (μm) F/number**	**Detec tivity (W^{-1})**	**NETD space (300 K x GE) (K)**	**SNR ground 300 K**	**SNR space (300 K x GE)**	**Specific detectivity, D* (m·Hz$^{1/2}$/W)**
Bird 640 Ceramic Packaging BB Wide-Band	8 to 14 F/1	$1.84\cdot10^{11}$	0.139	1289	495.1	$1.85\cdot10^{7}$
	8 to 10 F/1	$1.84\cdot10^{11}$	0.335	456.3	166.8	$1.85\cdot10^{7}$
	10 to 12 F/1	$1.84\cdot10^{11}$	0.413	447.3	197.8	$1.85\cdot10^{7}$
	3 to 5 F/1	$1.84\cdot10^{11}$	-	43.79	-	$1.85\cdot10^{7}$
	4.4 to 5.4 F/1	$1.84\cdot10^{11}$	2.2	56.36	0.21	$1.85\cdot10^{7}$
	4.4 to 5.2 F/1	$1.84\cdot10^{11}$	2.977	40.65	0.20	$1.85\cdot10^{7}$

Table 1: Performance in terms of temperature resolution and signal-to-noise ratio of the infrared detector Bird 640 Ceramic Packing BB wide band from the manufacturer SCD. The values of this table have been calculated with the model developed in this project. This detector is sensitive to the 3 μm to 14 μm of the infrared electromagnetic spectrum. It can be seen how the values of temperature resolution, NETD for the Mid-Wave Infrared Range, MWIR, are much larger than the ones for the Long-Wave Infrared Range, LWIR. The mission OUFTI-NEXT has a requirement of 0.4 K of NETD. Therefore this requisite is accomplished by this detector only in the LWIR band. However, the MWIR band will be very useful to observe objects at high temperature, for example, a fire.

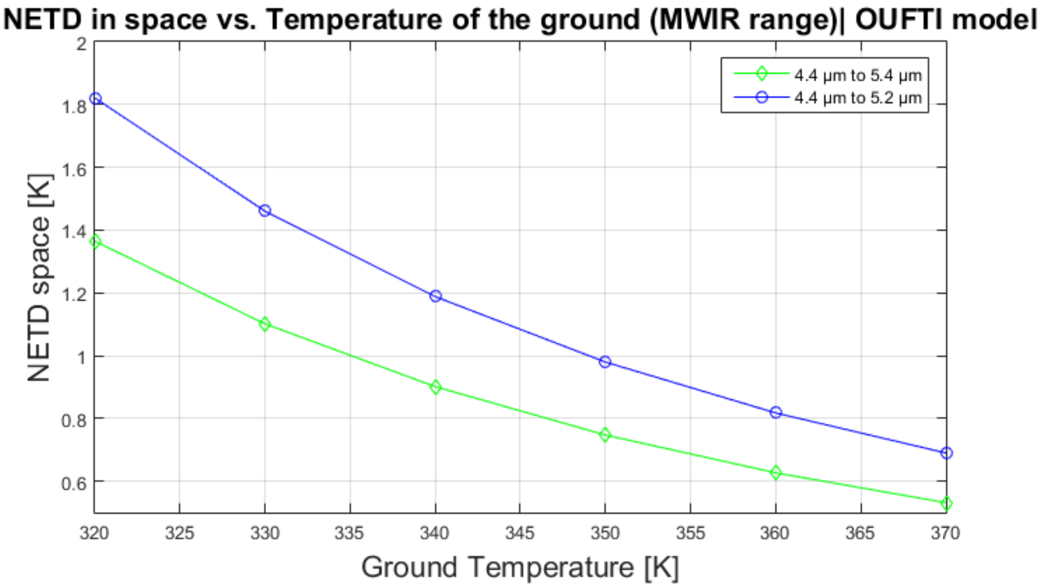

Figure 1: Temperature resolution for the wide band microbolometer Bird 640 Ceramic Packing BB used with a band-pass filter for the MWIR range, for different infrared wavelength bands.

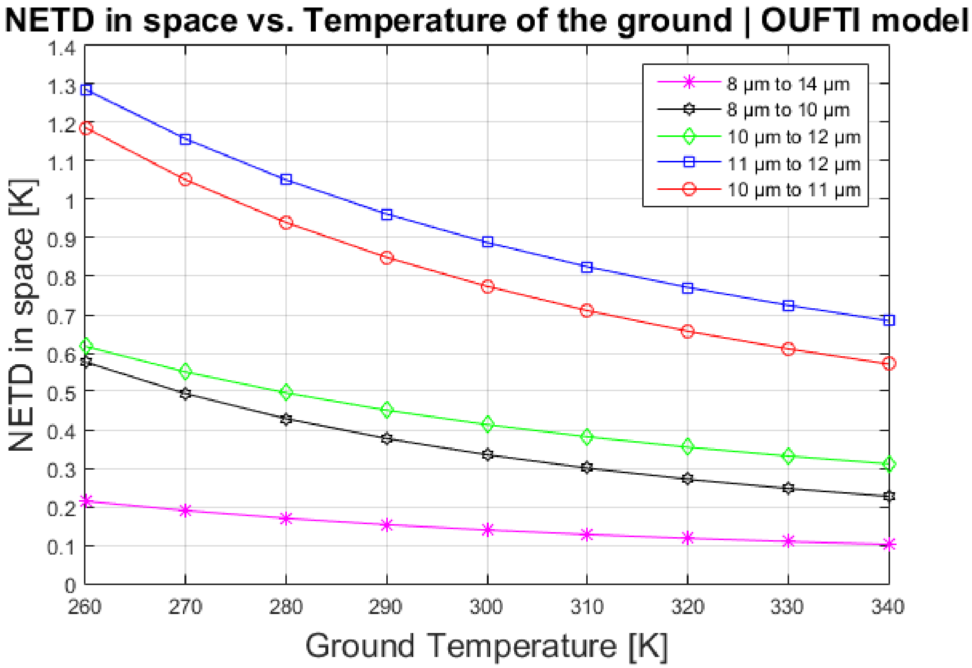

Figure 2: Temperature resolution for the wide band detector Bird 640 Ceramic Packing BB with a band-pass filter for the LWIR, for different infrared wavelength bands.

Detector	**λ range (μm) F/number**	**Detectivity [W^{-}1]**	**NETD space 291 K (K)**	**SNR ground 300 K**	**SNR space 291 K**	**Specific detectivity, D* (m·Hz$^{1/2}$/W)**
LEO-LP MW	3.7 to 4.8 F/5.5	$4.6 \cdot 10^{14}$	-	1885	-	$4.43 \cdot 10^{7}$
	4.4 to 4.8 F/5.5	$4.6 \cdot 10^{14}$	0.004	1031	405.3	$4.43 \cdot 10^{7}$
HiPIR-Engine HOT	3.4 to 4.8 F/2.2	$9.7^{*} \cdot 10^{13}$	-	1197	-	$2.47 \cdot 10^{8}$
	4.4 to 4.8 F/2.2	$9.7^{*} \cdot 10^{13}$	0.039	612.7	38.52	$2.47 \cdot 10^{8}$
HOT Hawk	3 to 5 F/2.8	$6.7 \cdot 10^{13}$	-	1801	-	$1.03 \cdot 10^{8}$
	4.4 to 5 F/2.8	$6.7 \cdot 10^{13}$	0.013	1122	67.73	$1.03 \cdot 10^{8}$
SuperHawk	3.7 to 4.95 F/2.8	$2.7 \cdot 10^{14}$	-	1553	-	$2.07 \cdot 10^{8}$
	4.4 to 4.95 F/2.8	$2.7 \cdot 10^{14}$	0.015	1002	67.88	$2.07 \cdot 10^{8}$
Pelican-D JT 640	3.6 to 4.9 F/3	$9.1 \cdot 10^{13}$	-	1534	-	$1.0 \cdot 10^{8}$
	4.4 to 4.9 F/3	$9.1 \cdot 10^{13}$	0.014	922.3	81.25	$1.0 \cdot 10^{8}$
Kinglet 640 SLC	3.6 to 4.2 F/2.5	$2.0 \cdot 10^{14}$	0.011	1193	-	$4.57 \cdot 10^{8}$
Mini Blackbird 1280	3.6 to 4.2 F/3.4	$7.7 \cdot 10^{14}$	0.006	1097	-	$3.41 \cdot 10^{8}$
HOT Neutrino SWAP C	3.4 to 5.0 F/5.5	$2.1 \cdot 10^{14}$	-	1236	-	$2.0 \cdot 10^{7}$
	4.4 to 5.0 5.5	$2.1 \cdot 10^{14}$	0.005	789.9	183.9	$2.0 \cdot 10^{7}$
IRnova Dag MW	3.7 to 5.1 F/4	$1.3 \cdot 10^{14}$	-	1588	-	$4.44 \cdot 10^{7}$
	4.4 to 5.1 F/4	$1.3 \cdot 10^{14}$	0.007	1137	113.4	$4.44 \cdot 10^{7}$

Table 2: Temperature resolutions and signal-to noise ratios, computed with the model developed in this project, for the main Mid-Wave Infrared Range detectors. The detectors finally selected according with the requisites of the mission were the HiPIR Engine HOT from the German manufacturer AIM, and the HOT Neutrino SWAP C from the American FLIR.