RADIOMETRIC MAPPING OF EUROPA: CHALLENGES OF BUILDING A RADIATION-HARDENED, UNCOOLED, FAR-INFRARED THERMAL IMAGER.

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Introduction: Europa is the only other place, aside from Earth, where there is strong evidence that suggests a liquid water ocean underneath its icy crust. Water is a key component for biological life, propelling the interest for the Jovian moon. Thermal mapping of such an environment requires the development of a passively cooled radiometric instrument able to withstand Jupiter's high radiation environment while performing accurate measurements in the far-infrared.

Specifically, high radiation levels from Jupiter's belt set stringent requirements on radiation-hardened thermopile arrays and read-out electronics that must operate under high-energy radiation and ions. The objective of this study is to advance the current state-of-the-art Diviner (Lunar Reconnaissance Orbiter LRO [1], Fig. 1) and Mars Climate Sounder (MCS) thermal imagers to achieve higher sensitivity, 2x higher spatial resolution, with 2x greater field of view.

This work will focus on the instrument requirements, design, fabrication, and assembly of a complete thermal imager suitable for the Europa environment.

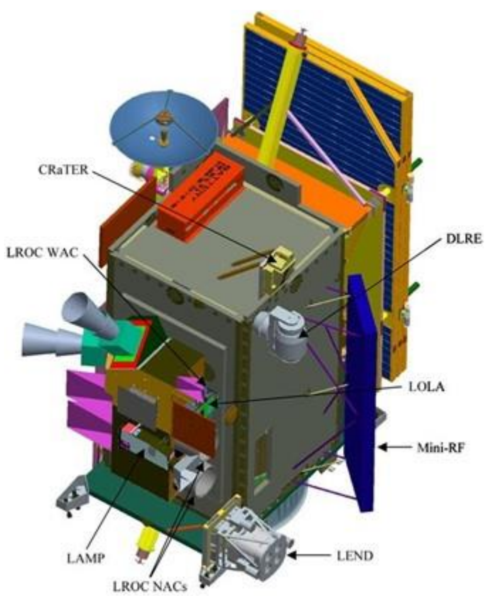

Fig 1 - Lunar Reconnaissance Orbiter (LRO) instrument build: Diviner thermal imager (DLRE) in flagship mission

Thermopile technology: Thermopiles represent an ideal thermal imaging technology [2] due to the demonstrated high reliability in flagship missions such as Pioneer 10 and 11, Voyager, Viking Orbiter, Cassini, MCS, LRO (Fig. 2).

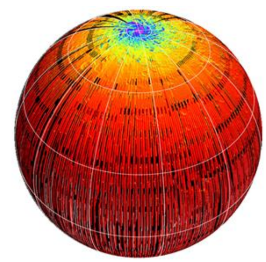

Fig 2 – Moon temperature mapping from LRO [3]

This class of thermal imagers offers a broadband spectral coverage (0.3 to >200μm), with no cryocooling system required. Thermopile pixels are inherently insensitive to instrument temperature drifts, and highly linear to incident radiation with overall detector sensitivity $D^*>10^9$ $cmHz^{1/2}/W$ @ 300K.

Signal chain - from IR radiation to digital ouput: When IR radiation impinges onto the imager, each thermopile pixel transduces the resulting pixel-to-substrate temperature difference into a voltage via Seebeck effect. Each pixel output is connected to one input channel of the readout integrated circuit and the signal is modulated at high-frequency to avoid 1/f noise then amplified.

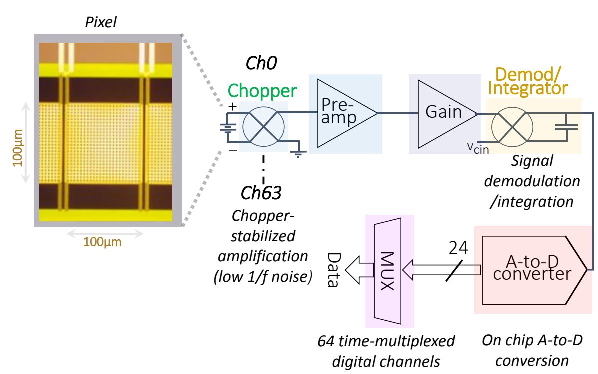

Fig 3 – Complete signal chain of the thermal imager with digital output

After amplification, the signal is demodulated back to base-band, digitized, and time-multiplexed at the output of the readout chip. Noise characterization reveals a total system noise of 77 nV/√Hz for a 120KΩ resistive load.

Radiation-Hardened by Design: In RHBD approaches, the transistor topology is changed to annular layout (Fig. 4), avoiding current leakage along the transistor edges. [4] This design strategy is necessary to ensure normal operation (e.g. amplification, noise level, frequency response) of the read-out chip under ion bombardment or high-energy radiation fluxes.

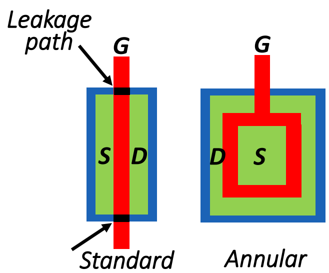

Fig 4 – Field-effect transistor: from standard to annular topology

Preliminary total-ionizing dose measurements show that all the nominal values of power supply vary less than 2% from 0 to 3Mrad (Europa requirement). Five channels are tested, showing a remarkable high stability over time during radiation exposure. [4]

References:

[1] www.nasa.gov/mission_pages/ LRO/spacecraft/
[2] M. C. Foote, M. Kenyon et al. 'Thermopile detector arrays for space science applications', International Workshop on Thermal Detectors for Space Based Planetary, Solar, and Earth Science Applications TDW 2003.
[3] D. Paige et al. 'Diviner Lunar Radiometer Observations of Cold Traps in the Moon's South Polar Region' Science, 2010, Vol. 330, p479-482.
[4] S. Gaalema et al. 'Radiation hardness by design for mixed signal infrared readout circuit applications', Proc. SPIE 7780, 2010.