A Novel Thermal Detector for Far-Infrared and THZ imaging Arrays

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This paper reports on novel MEMS based thermal detector architecture, which could allow the construction of very large focal plane arrays of bolometers for far-infrared and THz imaging. The principal challenge in developing large format cryogenic bolometer arrays is related to the multiplexing and readout of cryogenic detectors. The readout architectures that are being developed and deployed are mostly based on Superconducting Quantum Interference Devices (SQUIDs), which are highly sensitive but also relatively complex devices and have shortcomings with respect to the robustness of SQUIDs for operation in nonideal condition.

The detector architecture presented here is based on the transition-edge sensor (TES), which is integrated on the surface of a freestanding micro electro mechanical (MEM) switch (Fig. 1). The key idea in this architecture is in thermal switching and in transformation of TES output to voltage pulses for faster detection and simpler multiplexing and readout of detectors.

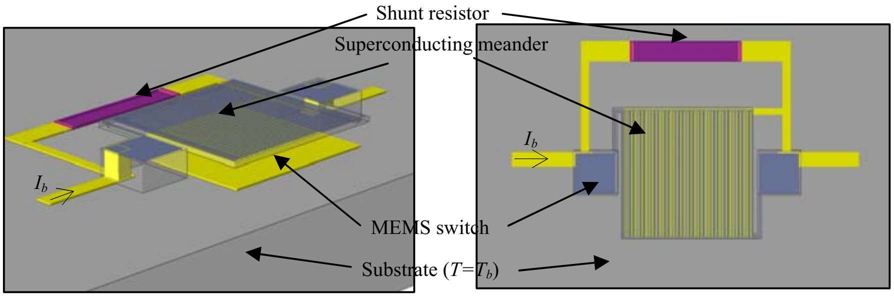

Fig.1 Schematic drawing of the novel thermal detector architecture. Transition-edge sensor, consisting of superconducting thin film meander, is integrated on top of the MEMS switch.

The TES on top of the MEMS switch is current biased slightly below its critical current. A shunt resistor is in parallel with the meander on the substrate. In the up-state of the MEMS switch, the TES is thermally well-isolated from the substrate at bath temperature of T_b. Incident optical power absorbed to the film increases the temperature of the TES with time. The critical current of the superconducting meander get decreased with increasing temperature and when reaching the value of the bias current I_b, the meander quenches and becomes dissipative causing voltage to build up across the meander and shunt resistor. This voltage is used for triggering the MEMS switch and when reaching the pull-in voltage of the switch, the switch closes and the thermal conductance between the TES and the substrate get increased causing a fast cool-down of the film. As the film cools near to the bath temperature, it returns back to the superconducting state and the voltage disappears releasing the MEMS switch and the new thermal integration cycle begins again. The frequency of the voltage pulses generated in the detector is proportional to the incident optical power and the array of detectors can be read out through common readout line by amplitude multiplexing of the pulses facilitated by the choice of shunt resistance values. Figure 2 shows simulated voltage and displacement responses of the detector at $T_b = 4K$ for incident optical power of 4 pW.

(a)

$$f_0(P_{opt}) = \frac{P_{opt}}{T_c C_{th}\left(1 - T_b/T_c - (I_b/I_{c0})^{2/3}\right)}$$

P_{opt} = incident optical power
C_{th} = the thermal capacitance of the detector
T_c = critical temperature of TES
T_b = bath temperature of the detector
I_{c0} = critical current density of thin film meander
I_b = bias current

(b)

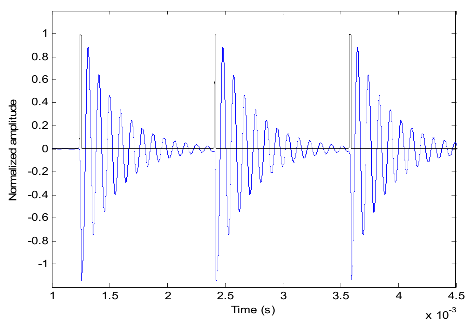

Fig. 2 The switching frequency of the detector with certain assumptions (a) and the simulated normalized voltage (solid line) and displacement (dodded line) of the MEMS based thermal detector (b).

In this paper, we will introduce the detector architecture and show the detector operation principle with analytical methods and with time domain simulations. Also, a noise model for the detector will be derived.