Kinetic Inductance Detector based focal plane arrays for the Terahertz Intensity Mapper

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Abstract— **The Terahertz Intensity Mapper (TIM) is a NASA far-infrared balloon mission, which will fly 2 arrays of ~3600 kinetic inductance detectors (KIDs). The horn-coupled low-volume aluminum lumped-element KIDs are photon noise limited at 80 fW of loading, satisfying the TIM requirements. Kilopixel arrays of these KIDs have been made with >95% yield and we will report on their latest performance evaluation.**

Keywords—kinetic inductance detector, focal plane array, terahertz, kilopixel arrray

I. Terahertz Intensty Mapper

The Terahertz Intensity Mapper (TIM) [1] is a NASA far-infrared balloon mission which aims to study the three-dimensional structure of star formation in the universe. To achieve this, TIM will perform spectroscopic observations of far-infrared fine-structure lines, in particular those of ionized carbon and nitrogen, at the peak of cosmic star formation (0.5<z<1.5). These far-infrared emission lines are relatively un-extincted by dust, enabling TIM to measure the star formation activity in dust-obscured galaxies, which account for >70% of the star formation at cosmic noon.

To perform its spectroscopic observations TIM will employ two long-slit (1° slit length) grating spectrometers that cover the 240-317 µm (SW) and 317-420 µm (LW) wavelength bands, respectively, at a spectral resolution R~ 250. Each of these spectrometer arms is serviced by a focal plane containing ~3600 pixel. In turn, each focal plane will contain four quadrants of ~900 hex-packed horn-coupled kinetic inductance detectors (KIDs).

II. Single Pixel Performance

The fully-aluminum lumped-element KIDs for TIM use a novel "chain-link" absorber design [2] that achieves >90% absorption efficiency in both polarizations across the entire SW or LW band. It achieves this despite the low sheet resistance of 30 nm thick aluminum (Rs~0.7 Ω/sq), while limiting the volume to 100 μm^3 to achieve the required sensitivity, and using a minimum feature size of 500 nm to increase fabrication yield. We have demonstrated that these KIDs are photon noise limited above 80 fW of optical loading with a white noise spectrum down to 1 Hz [3]. A detector limited NEP~1.3×10^{-18} W/$Hz^{0.5}$ is achieved at 215 mK. This easily satisfies the TIM requirements.

III. Array Development

The first quadrant arrays of 864 pixels for the LW module have now been fabricated and tested. They demonstrate over 95% of detector yield, which we attribute to the simple single-layer fabrication and a KID design focused on robustness. It also demonstrates our packaging design, which mounts the array against the hornblock using 50 µm bosses to maintain the air gap between the horns and the array. Our first measurements show the KIDs' quality factor and thermal response are consistent with those of the single pixel test devices, which builds confidence for the optical performance of the entire array. We will present our progress towards a full optical performance evaluation as well as our first results of post-processing aimed at removing resonator collisions.

References

[1] J. Vieira, et al., "The Terahertz Intensity Mapper (TIM): an Imaging Spectrometer for Galaxy Evolution Studies at High-Redshift", *Proceedings of the 30th ISSTT*, Apr. 2019.

[2] R. Nie, et al., "Absorber design and optimization of Kinetic Inductance Detectors for the Terahertz Intensity Mapper", *Journal of Low Temperature Physics*, accepted 2022

[3] R.M.J. Janssen, et al., "Single Pixel Performance of the kinetic inductance detectors for the Terahertz Intensity Mapper", *Journal of Low Temperature Physics*, submitted 2022

[4] L.-J. Liu, et al., "Design of the Kinetic Inductance Detector based focal plane assembly for the Terahertz Intensity Mapper", *Journal of Low Temperature Physics*, submitted 2022

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