High photon-number resolution transition-edge sensors with scalable kinetic-inductance-based readout

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We report on progress in developing high-resolving-power single-photon detectors (SPDs) based on transition-edge sensors (TESs) read out with scalable kinetic inductance current sensor (KICS) arrays. Our team has previously demonstrated photon-number-resolving TES SPDs with near-unity quantum efficiency at 1550 nm [1]. More recently, we have focused on improving the spectral resolution of our devices. We have found that energy loss to the substrate in the form of phonons was a dominant source of energy uncertainty in our devices. To mitigate these losses, we have started fabricating TES SPDs on 100-nm-scale thickness SiN membranes, as shown in Fig. 1 (left). These devices show an energy resolution of better than 40 meV ($R = E/\Delta E > 20$) at the single photon peak (0.8 eV) while maintaining linearity (relatively flat energy resolution) to roughly the 4-photon peak.

We are also developing cryogenic multiplexed readouts for TES SPDs that do not require the use of superconducting quantum interference devices (SQUIDs). These KICS readout devices [2] exploit the nonlinear current dependence of the kinetic inductance of a superconductor, and their resonator-based design makes them intrinsically multiplexable in the microwave frequency domain. Furthermore, these devices are self-biased using a superconducting persistent current scheme, significantly reducing bias line pickup. We have previously used these devices to read out TES SPDs with low readout noise and measured resolving powers already matching those of SQUID-based readouts [3]. We have since developed 12-pixel KICS multiplexer chips, as shown in Fig. 1 (right), and have begun using them to read out counterpart 12-pixel TES arrays.

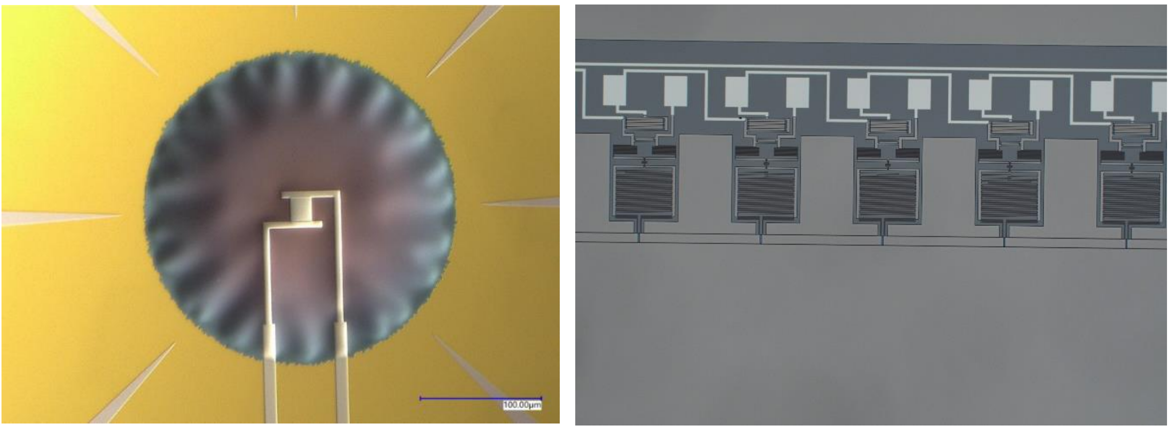

Fig. 1: *(Left) 20 nm thick W TES SPD (20 µm x 20 µm square) fabricated on a 100-nm-scale thickness SiN absorber (circular region), with Nb leads connecting the TES to the readout circuit. (Right) Micrograph of portion of 12-pixel KICS multiplexer chip with integrated TES bias circuit.*

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References

[1] A. E. Lita, A. J. Miller, and S. Nam, *Opt. Express*, **16**, 3032–3040 (2008). https://doi.org/10.1364/OE.16.003032

[2] G. C. O'Neil, S. R. Bandler, I. Fogarty Florang, et al., *IEEE Trans. Appl. Supercond.*, early access (2026) https://doi.org/10.1109/TASC.2026.3673656

[3] P. Szypryt, D. A. Bennett, I. Fogarty Florang, et al., *Commun. Eng.* **3**, 160 (2024). https://doi.org/10.1038/s44172-024-00308-y