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Thermal Conductance Engineering for High-Speed TES Microcalorimeters

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Spectrometers based on superconducting transition-edge sensor (TES) microcalorimeter arrays have recently emerged as leading instruments in experiments which require high spectral resolution across large ranges in energy as well as large collecting area. Unfortunately, current-generation TES arrays utilize relatively slow pixels with response times on the order of 1 millisecond or longer, limiting the TES array count rate and therefore effectiveness of the spectrometer. Furthermore, new applications require significantly faster pulse-response. X-ray spectroscopy experiments at next-generation synchrotron light sources need to successfully capture very large fluxes of photons, while detectors at free electron laser facilities need pulse response fast enough to match repetition rates of the source. Additionally, experiments such as HOLMES and NuMECS seek to measure the mass of the neutrino via electron capture of 163Ho. The success of these neutrino experiments hinges on the ability to distinguish near-simultaneous lower energy decay events from single higher energy events. These pile-up events distort the spectral shape at the endpoint, which is sensitive to the mass of the neutrino. Here, the temporal response of the detector sets the detectability mass limit in these experiments.

To address these needs, we are designing high-speed TES detectors, with speeds designed to match the increased bandwidth provided by emerging microwave SQUID multiplexing techniques. In this talk, I will show results from TES detectors with novel geometric enhancements designed to increase the thermal conductance on pixels suspended on silicon nitride membranes. These enhancements include extending the radiating perimeter and creating a direct metal conduction link to the TES bath. Additionally, we are exploring devices placed directly on the silicon substrate where speed is controlled by the geometry of micromachined silicon legs. I will show that the thermal conductivity can be precisely engineered to values spanning over an order of magnitude to achieve fast thermal relaxation times tailored to the relevant applications. Using these pixel prototypes, we have demonstrated decay time constants better than 100 microseconds, while still maintaining spectral resolution of 1.9 eV FWHM at 1.5 keV. I will also discuss the trade-offs inherent with increases in the pixel speed, such as increases in device current leading to decreases in energy resolution, and potential pixel modifications to improve performance.