Realizing the Potential of TES Microcalorimeters for X-ray and Gamma Ray Science at Light Sources

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The transition-edge sensor (TES) microcalorimeter uses the sharply temperature-dependent resistance of the superconducting transition to measure the energy of x-ray and gamma ray photons. A single TES is a broadband, energy-dispersive area detector capable of eV-scale energy resolution with good quantum efficiency. With an array of hundreds or thousands of sensors, a TES-based spectrometer can have orders of magnitude higher throughput than wave-length dispersive instruments. I will introduce the basic principles of TES operation, and discuss how they are exploited to optimize TES performance for a wide range of photon energies, from soft X-rays to gamma rays. Because the TES thermometer and the material that absorbs incoming radiation can be separate structures, we can use high-Z materials like tin and bismuth to stop photons with high efficiency up to 200 keV with $R > 1000$. For soft x-rays, using a thin film absorber with lower total heat capacity enables energy resolution of < 1 eV FWHM for $E < 1$ keV. This flexibility allows us to customize the TES array to the scientific goals of a particular light source.

Additionally, recent advances in TES design and high-bandwidth readout that have enabled faster sensors ($\tau < 100$ us) and larger arrays (>1000 pixels). By engineering the thermal time constant of the TES, the photon response time can be reduced to tens of microseconds, allowing a single sensor to count thousands of photons per second. Over the next three years, a 1000-pixel soft x-ray TES spectrometer will be built for first light at the LCLS-II. With the success of microwave readout techniques, 10,000-pixel instruments are expected to arrive on the timescale of five years, and work is underway to expand to 10^5-pixel or larger arrays. This rapid expansion of capability will enable novel measurements both in the lab and at the world's most powerful light sources.