Making every photon count: high resolution, high efficiency superconducting microcalorimeter detectors for beamline applications

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X-ray spectroscopy is a powerful probe of the electronic, structural, and chemical properties of numerous materials. Traditionally, detectors for x-ray spectroscopy have fallen into one of two categories. Energy-dispersive detectors (such as silicon-drift detectors) provide high collecting efficiency but only modest resolving power. Wavelength-dispersive detectors (gratings, Bragg crystals, and various layered materials) provide exquisite resolution but very limited collecting efficiency. Recently, microcalorimeter detector arrays operating near 0.1 K offer the best properties of both: high resolving power and high collecting efficiency. Microcalorimeter detectors are thus ideal for spectroscopy in photon-starved experiments such as measurements of dynamic behavior and in applications that need to distinguish large background fluxes from smaller signals such as in resonant soft x-ray spectroscopy (RSXS). I describe microcalorimeter development for synchrotron beamline applications at the National Institute of Standards and Technology (NIST) based on superconducting transition-edge-sensor (TES) detector arrays. These energy-resolving detectors have near unity collection efficiency and broadband spectral coverage, while providing energy resolution comparable to that of gratings or crystals.

In this presentation, I will discuss soft x-ray emission and absorption measurements from the superconducting TES detector installed at beamline U7A at the National Synchrotron Light Source. I will also discuss a new 240-pixel TES detector we recently deployed to beamline 29ID at the Advanced Photon Source. Operating in the soft x-ray band between 250—2,500 eV, this TES detector has a demonstrated resolution of 1.0 eV in the challenging environment of a synchrotron beamline while providing three orders of magnitude better signal in the same collecting time than scattering spectrometers at peer facilities. This performance is sufficient to eliminate the fluorescence background problem in resonant scattering measurements, allowing us to probe materials with disordered electronic structure such as the appearance of charged-stripe phases and their relationship to the emergence of superconductivity in high-temperature superconductors.