High-Resolution Superconducting Tunnel Junction Soft X-Ray Spectrometers

S. Friedrich
Lawrence Livermore National Laboratory, 7000 East Ave., L-270, Livermore, CA 94550, USA

Superconducting tunnel junctions (STJs) can be used as high-resolution X-ray detectors with broadband efficiency. STJs consist of two superconducting electrode films separated by a thin insulating tunnel barrier. X-rays absorbed in one of the electrodes excite excess charge carriers above the superconducting gap in proportion to their energy, and the resulting increase in tunneling current provides a measure of the X-ray energy. The small gap of order ~1 meV translates into a theoretical energy resolution below 10 keV for soft X-rays, and the charge carrier life time of order ~1 μs enables operation at rates above 10,000 counts/s per STJ pixel. We have built a high-resolution soft x-ray spectrometer with 9-channel arrays of Nb-Al-AlOx-Al-Nb STJs. The detector is cooled to ~0.1 K by a two-stage adiabatic demagnetization refrigerator while being held at the end of a 40-cm-long detector cold finger that can be inserted into an experimental chamber. The 0.6 mm x 0.6 mm array has an energy resolution of 10-15 eV FWHM for x-ray energies below 1 keV and total count rate capabilities above 100,000 counts/s. We are currently upgrading the spectrometer to 36 channels for increased sensitivity. Additional improvements are possible using larger arrays, higher-efficiency absorber films and STJs with higher spectral purity. We will discuss spectrometer performance, and demonstrate its capabilities for fluorescence-detected X-ray absorption spectroscopy in material science and biophysics.