Superconducting microcalorimeters for x-ray spectroscopy

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Databases of x-ray fundamental parameters for x-ray analysis include fluorescence line positions and relative intensities, as well as line shape information including line widths and asymmetries. Although these parameters are often considered well-established, this is not uniformly true. The fluorescence line positions of some elements have few new published results in the last 40 to 60 years. Data on the lower-energy lines, such as the M lines of the heavier elements, are incomplete. Fundamental parameters measurements can be challenging because of the time required, and the difficulty in achieving reliable absolute energy calibration. The US National Institutes of Standards and Technology (NIST) has begun a new program to improve the situation.

At the heart of this new program are arrays of superconducting microcalorimeters, Transition-Edge Sensors (TESs). A TES is an energy-resolving detector, which operates at cryogenic temperatures at the superconducting transition temperature. Energy resolutions of 1 eV at 1500 eV and 2 eV at 5900 eV have been demonstrated, and arrays of hundreds of TESs currently operate with 3 to 4 eV resolution at 5900 eV. Unlike a wavelength-dispersive spectrometer, the TES can cover a very broad energy range all at once. This ability offers the potential for rapid characterization of multiple emission lines. Current devices work well from 1 to 12 keV, though future designs should be able to operate at higher or lower energies.

We present results from metrological-quality data taken with an array of 100 TESs to study the positions and shapes of the L-line emission from six lanthanide elements and four higher-Z elements. Employing the well-characterized 3d transition metals as our calibration reference standards, we find that the TESs can be calibrated to absolute accuracy of approximately 0.1 eV for use in estimating unknown line energies, a level of accuracy already better in some cases than existing published uncertainties. We also discuss the future potential for calorimeter-based approaches to improve on the determination of x-ray fundamental parameters.