



TES microcalorimeter spectrometers for x-ray science

Main author:

ULLOM J. N.

Co-authors:

Abbamonte P., University of Illinois Urbana-Champaign

Alpert B. K., NIST

Becker D., NIST

Bennett D. A., NIST

Denison E., NIST

Doriese W. B., NIST

Fang Y., University of Illinois Urbana-Champaign

Fischer D., Brookhaven National Laboratory

Fitzgerald C. P., NIST

Fowler J. W., NIST

Gard J., University of Colorado Boulder

Hays-Wehle J. P., NIST

Hilton G. C., NIST

Jaye C., Brookhaven National Laboratory

Joe Y. I., NIST

Mates J. A. B., University of Colorado Boulder

McChesney J., Advanced Photon Source, Argonne National Laboratory

Morgan K. M., NIST

O'Neil G. C., NIST

Reintsema C. D., NIST

Schmidt D. R., NIST

Simones F., Advanced Photon Source, Argonne National Laboratory

Swetz D. S., NIST

Tatsuno H., NIST

Uhlig J., Lund University, Department of Chemical Physics

Ullom J. N., NIST

Vale L. R., NIST

In recent years, NIST and several collaborating institutes have developed and deployed the first TES-based microcalorimeter spectrometers for x-ray science. These spectrometers contain up to 240 TESs (see figure right) and larger instruments are planned. This development process has led us into several different areas of photon science. In this talk, we provide an overview of measurements where TES spectrometers are already active and areas where they will play a role in the future. One example is x-ray absorption spectroscopy (XAS). This powerful technique provides element-specific local structural information including extremely precise measurements of interatomic distances. XAS also provides information on electronic configurations, emphasizing unfilled orbitals. We describe fluorescence-detected XAS measurements performed at the National Synchrotron Light Source and transmission-mode XAS measurements performed in a laboratory apparatus at NIST. In particular, we demonstrate the successful determination of iron oxidation states using transmission-mode XAS. Another example is x-ray emission spectroscopy (XES) in which the shape of fluoresced x-ray lines reveals detail beyond the identity of the fluoresced element. XES primarily provides information on occupied electronic orbitals. For example, it can be used to determine the spin-state of the 3d level in iron, a measurement that enables the study of spin cross-over behavior. We have demonstrated XES at both sub-keV and several-keV energies, including showing that TESs can distinguish between high-spin (HS) and low-spin (LS) iron compounds (see figure left). XES is closely related to so-called x-ray chemical shifts that are potentially invaluable signatures of chemical speciation for industrial and forensic analyses. Soon, the detection of chemical shifts by TESs will be routine in a variety of experimental settings. Using a spectrometer at the Advanced Photon Source, we have also begun to study elastic x-ray scattering, an application where the energy resolution of TESs provides useful suppression of the fluorescence background. This technique provides access to information about spatially varying electronic structure. Finally, we describe the use of TES spectrometers for absolute energy metrology. Our recent laboratory measurements of fluoresced lanthanide x-rays show that TESs can be used to update tabulations of x-ray reference data.

The development of TES spectrometers has required advances in sensors, multiplexed readout, bulk cryogenics, and software. System performance depends on all these components and can be limited by any of them. In addition to discussing the areas of x-ray science mentioned above, we briefly mention some current technological challenges whose solutions will further improve spectrometer performance and the science returned by these exciting instruments.

