



High Energy Resolution X-Ray Spectrometry with Thermal Microcalorimeters

New X-ray spectrometers based on the thermal detection technique are bringing the resolution of energy dispersive spectrometers (EDS) to a level comparable with that of wavelength dispersive spectrometers (WDS) using Bragg crystals. Compared with commercial EDS using Si(Li) detectors, which are limited to energy resolutions of ~120 eV for X-rays of a few keVs, thermal microcalorimeters are capable of energy resolutions well below 10 eV.

Since the mid 1980's several groups have been working on developing thermal detectors. These measure the energy deposited by a single particle by measuring the temperature rise of a suitable absorbing body. At thermal equilibrium the temperature rise ΔT is given by $\Delta T = E/C$, where E is the energy deposited in the body

and C is its heat capacity. To be sensitive to small energies, thermal detectors must be operated at low temperatures, below 0.1 K, where both heat capacity and thermodynamical noise are small ($C \propto T^3$ in dielectric and diamagnetic crystals).

Thermometers may be either silicon implanted or neutron transmutation doped (NTD) germanium chips.

The research in Milan aims to determine the electronic anti-neutrino rest mass through the precise measurement of the ^{187}Re β -decay spectrum using absorbers made from compounds containing rhenium. Absorbers made from other material can be used for other applications. Tin is attractive for X-ray spectroscopy because its high atomic number, Z, provides efficient absorption of soft X-rays for a small absorbers thickness (25 μm gives > 80% absorption up to ~10 keV), and its heat capacity becomes sufficiently

One of our three Oxford Instruments TL dilution refrigerators is currently being used for research into thermal microcalorimeters. These are very tiny detectors (≤ 1 mg) made by attaching miniaturised semiconductor thermometers to small absorbers (Fig 1). The 17 μm Al wires provide both the mechanical support and the electro-thermal connection.

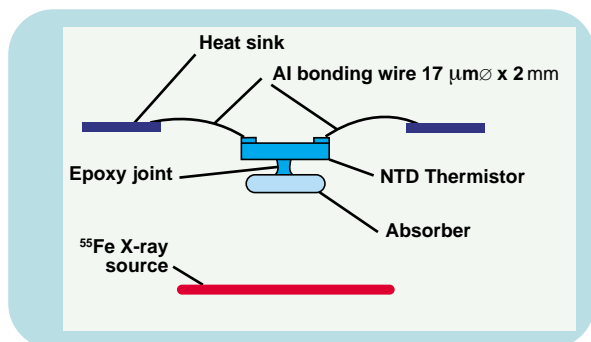


Fig. 1: Sketch of a thermal microcalorimeter

small well below its superconducting transition ($T_c = 3.7$ K). Using microcalorimeters made from tin absorbers (250 μm x 250 μm x 25 μm) glued to NTD germanium thermometers (300 μm x 100 μm x 20 μm) we have achieved energy resolutions below 10 eV. Two identical detectors showed an energy resolution of ~5 eV on the X-rays emitted by an ^{55}Fe source. To determine the instrumental response at this level requires a precise knowledge of the intrinsic spectral shape. This is shown in Fig. 2 with the doublet structure of the manganese K_α line fully resolved.

These detectors are slow and can only tolerate counting rates of ~100 Hz. Speed can be increased by operating the devices at a higher temperature, but only at the expense of the energy resolution. Using smaller absorbers can improve the energy resolution and a larger area coverage can be obtained with 2-dimensional arrays, which can also be used for X-ray imaging.

With careful design these X-ray detectors have many other potential applications ranging from space-born astrophysics to material fluorescence analysis.

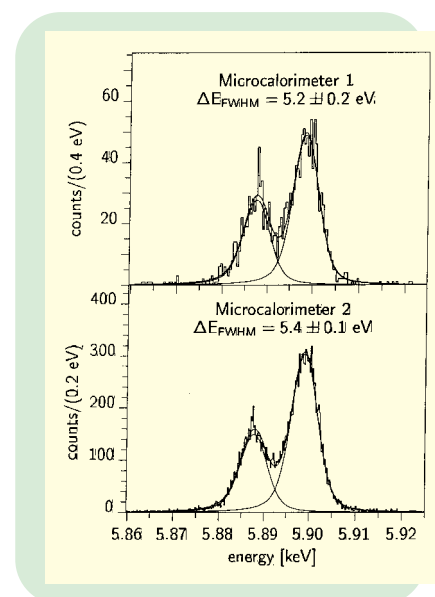


Fig. 2:

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