Report on Cryogenic Micro-Calorimeter Detectors in High-Precision X-Ray Spectroscopy Experiments at GSI/FAIR

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In recent years, cryogenic micro-calorimeter based detectors have proven to become an indispensable tool for high-precision X-ray spectroscopy experiments involving highly charged heavy ions. Due to their unique working principles of converting the incident particle's energy into a proportional rise in temperature in the sensor, they combine several advantages over conventional energy resolving photon detectors. For example, metallic magnetic calorimeters (MMC) – like the maXs-series detectors developed in cooperation with the KIP in Heidelberg – use the temperature dependant change of the sensor's magnetization in a magnetic field in combination with a SQUID-based read-out to convert the absorbed energy into a measurable signal. This yields an intrinsic energy resolution of up to $E/\Delta E \approx 6000$ [1], comparable to crystal spectrometers. At the same time MMCs cover a broad spectral range of several orders of magnitude, comparable to semiconductor based detector systems. Additionally, they posses an excellent linearity with deviations understood from first principles (see for example [2]) as well as a rise time down to $\tau_0 \approx 100\,\mathrm{ns}$ [3], making them particularly well-suited for high precision experiments in fundamental physics.
However, achieving this outstanding performance requires the shift from a traditional analog to a fully digital signal processing scheme. The high sensitivity of the detectors leads to comparably strong susceptibility to fluctuations of operation parameters like external magnetic fields or the substrate temperature. In order to mitigate these effects, a detailed understanding of the detector is essential. Therefore, during the last years, several measurements using multiple MMC detectors have been performed at different experiment facilities of the GSI Helmholtz-Centre for Heavy Ion Research in Darmstadt, Germany (see for example [4, 5, 6]). A comprehensive software framework for MMC signal analysis was developed and benchmarked using the insights gained, preparing MMCs for the deployment as spectrometer detectors for future high precision measurement campaigns. We will report on key results of these experiments and discuss the feasibility of utilizing micro-calorimeter based detectors in fundamental physics research.

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