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Towards energy dispersive X-ray spectroscopy with sub-eV energy resolution: Metallic magnetic calorimeters with direct sensor readout

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Metallic magnetic calorimeters (MMCs) are energy dispersive particle detectors that use a paramagnetic temperature sensor sitting in a weak magnetic field to convert the energy deposited into an absorber by an incident particle into a magnetic flux change within a superconducting pickup loop. The latter is connected to the input coil of a current-sensing SQUID to form a superconducting flux transformer and thus to transduce the change of sensor magnetization into a magnetic flux change within the SQUID loop. Though this configuration yields an excellent detector performance, e.g. an energy resolution of 1.6 eV (FWHM) for soft X-ray photons, transformer losses degrade the energy resolution compared to the fundamental limit set by thermodynamic energy fluctuations within the detector.

To further increase the energy resolving power, we have started the development of a direct MMC readout scheme omitting the flux transformer. Here, the paramagnetic temperature sensor is placed directly on top of or within the SQUID loop to significantly enhance the signal coupling. For testing this scheme we have designed and fabricated an 8 x 8 pixel prototype array where each dc-SQUID is a parallel gradiometer formed by two meander-shaped coils and is optimized according to the RCSJ model. Though the device showed the expected coupling enhancement, SQUID Joule heating prevented the detector to reach the cryostat base temperature. The resulting degradation of the energy resolution was further impacted by reaching the slew rate limit of the non-optimized readout chain.

Within this contribution, we present the design, performance and microfabrication processes of our prototype device as well as our next-generation detector with direct sensor readout. The design of the latter device has been refined to reduce the influence of SQUID Joule heating. Additionally, the detector and readout chain were optimized to avoid slew rate issues.

Less than 5 years of experience since completion of Ph.D

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