Micro-calorimetric detectors for fast molecules and fragments

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Moving dissociative recombination (DR) experiments on molecular ions and clusters and other types of ion fragmentation studies from magnetic storage rings to the new electrostatic Cryogenic Storage Ring (CSR) will allow new benchmark measurements as the reactions can start in the rotational ground state. At the same time, the electrostatic storage at significantly reduced energy will challenge the detection schemes and conventional detectors will often not be able to provide all necessary information.

We are presently developing large area magnetic calorimeters for the position and energy resolved detection of massive particles, as required for the determination of the kinetic energy release, the branching ratios and the identification of the masses of the fragments in DR reactions.

The metallic magnetic micro-calorimeters (MMC) developed by our group at KIP are operated at about 30 milli-Kelvin and use a paramagnetic sensor to monitor the temperature of a massive particle absorber. The absorption of a particle causes an increase of the detector temperature and a corresponding drop of sensor magnetization, which is detected by a low-noise high-bandwidth dc-SQUID magnetometer and serves as a measure of the deposited energy. The present detector arrays for high resolution x-ray spectroscopy consist of 250-μm sized pixels with a quantum efficiency close to 100%, an energy resolution below 3 eV for x-ray energies up to 10 keV, and excellent linearity.

The active area of our present detector prototype ‘PIZZA’ for the CSR has a diameter of 36 mm and is composed of 16 absorber segments to stop the molecular fragments. A paramagnetic temperature sensor is connected to each absorber along its arc. In this configuration the energy deposited by a molecular fragment and hence approximately its mass are proportional to the time integral of the detected temperature pulse, while its radial position can be derived from the signal risetime due to the finite diffusivity of heat inside the absorber segment.

We present the physics of MMCs, design considerations and the micro-fabrication of present prototypes. We compare the performance as recently tested with light pulses from LEDs and 6 keV x-rays to the one expected from detailed numerical simulations, and discuss the potential degradation of energy resolution due to the creation of lattice defects when the detector is used for massive particles.