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Transition-Edge Sensor Microcalorimeter Development for Particle Physics at IHEP

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The transition-edge sensor (TES) is a type of thermal equilibrium superconducting detectors that offers excellent energy resolution, a wide dynamic range, and high quantum efficiency. We are developing TES microcalorimeters for Neutrino-less double beta decay (0νββ) experiments and high energy astrophysics missions.

In regular nuclear double beta decay (2νββ), two electrons are emitted along with two antineutrinos. In contrast, 0νββ emits only electrons, without accompanying neutrinos or antineutrinos. This process necessitates that the neutrino to be a Majorana particle, meaning the neutrino is its own antiparticle. To date, this decay has not been experimentally observed and the Majorana particle theory remains hypothetical. Confirmation of 0νββ would directly support the Majorana theory, which extends beyond the Standard Model. Such measurements demand extremely low noise, achievable with low-Tc TESs. We fabricate our TESs with AlMn alloy, the transition temperature of which can be finely tuned through annealing temperature and duration. We have successfully produced devices with superconducting transition temperatures with a span from 10 mK to 600 mK. We are now integrating the TES with a lithium molybdate crystal, and will characterize its spectral performance in the near future.

TESs can also be used for space X-ray/γ-ray applications to study sciences including the dynamics of matter around black holes and neutron stars, galaxy evolution, and physical phenomena under extreme gravitational and magnetic conditions, etc. We plan to build a dedicated space telescope to measure the 511 keV gamma-ray emission from the Galactic Center with an energy resolution of E/ΔE > 1000, using a large Laue focusing mirror to provide sufficient sensitivity. Compared with the existing 511 keV space projects, this project is expected to have sensitivity improvement of about one or two orders of magnitude. This measurement can help finding the origin of positron and its distribution in the center of the Milk Way. We have designed a stacked TES detector comprising six layers of arrays, each with 256 TES pixels. The total detection area is approximately 10 cm2, and the quantum efficiency at 511 keV is 93% with the six-layer stack configuration. In the coming year, we will commence the fabrication of these gamma-ray TES detectors.

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