ED1-1-INV

Ultra-light Dark Matter Search Based on RF Quantum Upconverters

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The science reach of searches for Ultralight (sub-μeV), wavelike dark matter candidates including axions and hidden photons can be greatly enhanced by quantum sensors. At Stanford/SLAC, we are developing the Radio Frequency Quantum Upconverter (RQU), a Josephson-junction-based device capable of measuring low-frequency electromagnetic signals more sensitively than the Standard Quantum Limit. In particular, these sensors will be used to search for QCD axion dark matter in the Dark Matter Radio experiment at masses from 10neV to 1 μeV. The RQU is a quantum sensor capable of implementing multiple quantum coherent measurement techniques below 300 MHz, including two-mode squeezing, sideband cooling, and backaction evasion. I will describe the implementation of an RQU with superconducting microwave circuit elements and quantum coherent measurement protocols appropriate for ultra-light dark matter detection.

Keywords: Josephson Junctions, Dark matter search, quantum sensors

ED1-2-INV

Development of fine-pitch high-resolution hybrid TES microcalorimeter arrays toward the Lynx X-ray microcalorimeter

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We are developing hybrid transition-edge sensor (TES) microcalorimeter arrays for next generation X-ray satellite missions such as the Lynx X-ray microcalorimeter. The Lynx mission is one of four flagship mission concepts currently being studied for consideration in the National Academy of Science 2020 decadal survey. The proposed Lynx design combines a subarcsecond X-ray optic with a microcalorimeter imaging spectrometer incorporating ~100,000 pixels. The baseline design of the Lynx X-ray Microcalorimeter is a hybrid array consisting of three TES sub-arrays: main array, enhanced main array, and ultra-high-resolution array. The main array will provide 3 eV energy resolution over the 0.2–7 keV energy band with 1” pixels for 5’× 5’ field of view (FOV). The enhanced main array is placed at the center of the main array and covers 1’ × 1’ FOV with 0.5” pixels, which will provide 1.5 eV energy resolution over the same energy band. The ultra-high-resolution array, which is placed beside the main array, covers 1’ × 1’ FOV with 1” pixels and will provide 0.3 eV over the 0.2–0.75 keV energy band. To match with the subarcsecond angular resolution, the pixel pitch is 50 μm for the main array and the ultra-high-resolution array and 25 μm for the enhanced main array. To reduce the number of sensors, the main array and the enhanced main array are position sensitive 5×5 multi-absorber ‘hydra' microcalorimeters. Our prototype hydra array achieved 2.5±0.9 eV full-width-half-maximum (FWHM) and 3.4±1.0 eV FWHM at 1.25 keV for the 25 μm and 50 μm pitch pixels respectively, and the prototype for the ultra-high-resolution array achieved 0.3 eV FWHM at 3 eV. We will report the requirements to the detector, the concept of our detector design, and the recent achievements we have made.

ED1-3

The developments of TES array and the detector stage towards the observation from 100 eV to 15 keV for STEM

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An energy-dispersive X-ray spectroscopy (EDS) on a scanning transmission electron microscope is a useful tool for material analysis, planetary science, and other researches. We have been developing 64-pixel TES arrays as detector for the EDS system and the detector head with 3D superconducting wirings. The energy resolution is 7 eV (FWHM, at FeK¥alpha) under a few hundred cps with 17 TES pixels^{1}. In the current system, we can detect only the low energy X-ray to 0.5 keV, to improve the sensitivity below 0.5 keV to and increase statistic are required. The sensitivity for low energy depends on background level and low detection efficiency. We increase the signal-to-noise ration by improving the energy resolution of the TES with two different type TESs. On the other hands, the s statistic was limited by the number of operating pixels, in order to improve the number of operating pixels without using the 3D superconducting wirings^{2, 3}, we adopted poly-capillary X-ray optics^{4} for increasing the solid angle from the specimen and developed a detector head with simple design. In this paper we present the details of the detector head design for 64-pixel parallel readout and of the concept design of the TES array with two types of TES in the same device for the wide energy band.

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Keywords: TES, EDS

ED1-4

Understanding the temperature sensitivity and current sensitivity in two-dimensional transition-edge sensor film

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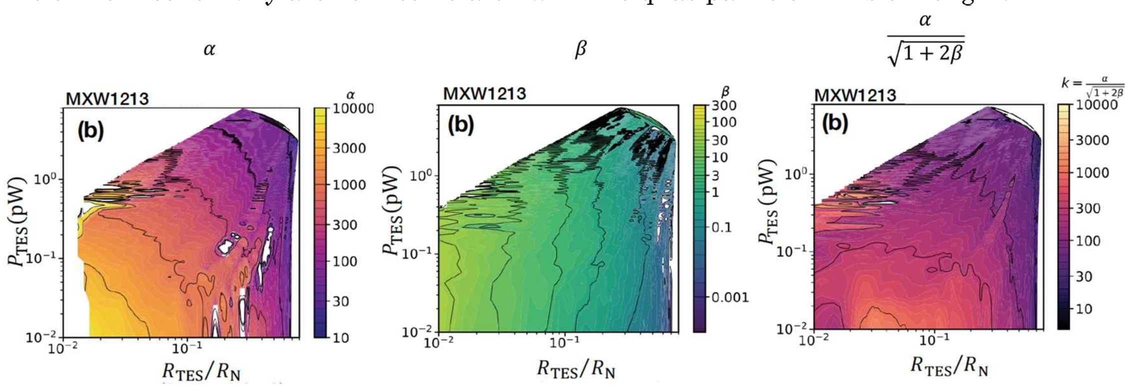
Transition-edge sensor fabricated by normal-superconducting bilayer is widely applied to X-ray spectrometers and infrared to sub-mm image sensors with the aim of potentially unprecedented high energy resolution and sensitivities. As a key component of the X-ray microcalorimeter, the transition-edge sensor has two main parameters that affect the energy resolution, temperature sensitivity and current sensitivity. Tremendous efforts have been made to fabricate transition-edge sensor with high temperature sensitivity and low current sensitivity in order to enhance the energy resolution of the detectors. However, since the resistance of the transition-edge sensor is a complex function of temperature, current and magnetic field, we were lack of systematic knowledge of the resistive surface in its superconducting transition, which has prevented us achieving an optimized operational point of the detector. We thus conducted an experiment to map the resistance, temperature sensitivity and current sensitivity of the transition-edge sensor in its complete superconducting transition, in order to understand if/how the temperature sensitivity and current sensitivity are correlated with each other and where to identify the global optimized bias point to achieve the best energy resolution. As a result, the experimental evidence suggests that the current sensitivity depends only on the resistance of the transition-edge sensor, which supports the prediction of the two-fluid model. With the concept of the phase-slip center as a resistive mechanism, we demonstrate that the figure of merit of the energy resolution as well as the current sensitivity are both correlated with the quasiparticle diffusion length.



Keywords: Transition-Edge Sensor, Energy Resolution, Current Sensitivity, Two-fluid model