Towards Ultra-Low-Noise Transition Edge Sensors for Millimeter-Wave and Far-Infrared Space Telescopes

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Abstract

Upcoming submillimetre-wave and far-infrared space telescopes will require a new generation of cryogenic (50mK) ultra-low-noise Transition Edge Sensors (TESs). For example, BPol is a submillimetre-wave (3.0-0.5mm) telescope dedicated to searching for B modes in the polarisation state of the CMB, whereas SPICA is a cooled-aperture infrared (210-35μm) telescope aimed at studying star formation in distant galaxies. Furthermore, the detector technology needed for these infrared missions is closely related to the calorimeter technology needed for the Cryogenic Imaging Spectrometer on the International X-ray Observatory, IXO.

In recognition of the importance of ultra-low-noise TES technology for experimental astrophysics, the European Space Agency (ESA) has established a program[1] to study the physics, materials science, and performance of ultra-low-noise submillimetre-wave and far-infrared TES imaging arrays. The central theme relates to understanding how the NEP can be reduced from 10^{-17}WHz$^{-1/2}$ (typical of ground-based experiments) to 10^{-18}WHz$^{-1/2}$ (needed for space-borne CMB experiments), 10^{-19}WHz$^{-1/2}$ (needed for space-borne cooled-aperture infrared telescopes), and 10^{-20}WHz$^{-1/2}$ (needed for space-borne infrared interferometers). Achieving ultra-low-noise operation is not in itself a major challenge, but achieving ultra-low-noise operation while maintaining high saturation powers (1pW for CMB astronomy, and 10fW for IR astronomy), fast response times (<10ms), and high optical sampling is a considerable problem. Moreover, the pixels must be packed into large multiplexed imaging arrays, and must be useable in space.

In this paper, we review the physics and technological challenges associated with developing ultra-low-noise TESs for space applications. We review the needs of typical missions, and address the fundamental device physics that limits the performance of single pixels. We consider issues such as power handling, noise, and response time, and discuss how these relate to the form and layout of the device. We also consider how the properties of the materials that make up the device affect performance, and how these can be chosen to achieve the specifications required. Finally, we consider the problems associated with packing TESs into large polarimetric and photometric imaging arrays, and touch on issues relating to uniformity of performance.

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