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Optimization of TES bolometers with integrated tunnel junction cooling for CMB measurements

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Precise measurement of the temperature and polarization anisotropies of the cosmic microwave background (CMB) is an important field in contemporary science and has been a key motivator for the development of kilopixel arrays of polarization-sensitive superconducting detectors, such as transition edge sensors (TESs). Alongside collaborators, NIST has developed large arrays of feedhorn-coupled TES polarimeters, which have been deployed on several CMB instruments. We are now working to develop a large array of low-thermal-conductance microwave polarimeters with normal-insulator-superconductor (NIS) refrigerators integrated at each TES. Sorption-pumped 3He cryogenics are attractive for balloon-borne and satellite-based CMB experiments due to their simplicity and small size, but only provide bath temperatures of 300 mK. To achieve low noise equivalent power (NEP) at 300 mK, the released bolometers must have extreme thermal isolation, which results in very delicate membranes. The addition of an inexpensive, light, and compact on-chip refrigerator that operates continuously and without vibration will allow for the cooling of microwave polarimeter focal plane elements to temperatures near 150 mK, while allowing for improved sensor NEP, relaxed bolometer geometric constraints for improved mechanical robustness, and reduced sensor size. Building on studies to improve our understanding of the thermal conductance properties of silicon nitride, we have designed, fabricated, and tested TES bolometers with on-chip NIS refrigerators. We present the design details of these integrated NIS-cooled TESs, including the range of thermal conductance values targeted. Additionally, the fabrication process will be described and measurements from device characterization will be presented. Results from early prototypes working at 300 mK show that the NIS refrigerators provide the TESs with an effective bath temperature of 190 mK, and further temperature reductions are anticipated.

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

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