Technology Focus: Electronic Components

Microwave Kinetic Inductance Detector With Selective Polarization Coupling

Low-noise detector and readout functionality are combined into one device.

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A conventional low-noise detector requires a technique to both absorb incident power and convert it to an electrical signal at cryogenic temperatures. This innovation combines low-noise detector and readout functionality into one device while maintaining high absorption, controlled polarization sensitivity, and broadband detection capability. The resulting far-infrared detectors can be read out with a simple approach, which is compact and minimizes thermal loading.

The proposed microwave kinetic inductance detector (MKID) consists of three basic elements. The first is the absorptive section in which the incident power is coupled to a superconducting resonator at far-infrared frequency above its superconducting critical frequency (where superconductor becomes normal conductor). This absorber's shape effectively absorbs signals in the desired polarization state and is resonant at the radio frequency (RF) used for readout of the device. Control over the metal film used in the absorber allows realization of structures with either a 50% broadband or 100% resonance absorptance over a 30% fractional bandwidth.

The second element is a microwave resonator — which is realized from the thin metal films used to make the absorber as transmission lines — whose resonance frequency changes due to a variation in its kinetic inductance. The resonator's kinetic inductance is a function of the power absorbed by the device. A low-loss dielectric (mono-crystalline silicon) is used in a parallel-plate transmission line structure to realize the desired superconducting resonators. There is negligible coupling among the adjacent elements used to define the polarization sensitivity of each detector. The final component of the device is a microwave transmission line, which is coupled to the resonator, and allows detection of changes in resonance frequency for each detector in the focal plane array.

The spiral shape of the detector's absorber allows incident power with two polarizations to couple to the detector equally. A stepped impedance resonator was used that allows the incident power absorbed in the detecting membrane area to be uniformly distributed in the detector's transmission line at the RF readout frequency. This maximizes the sensitivity of the detector. The signal is read out via a frequency multiplexing technique that requires a minimum number of interface transmission lines for readout. This reduces the packaging complexity and coupling to the device's thermal environment.

This work was done by Edward Wollack, Kongpop U-yen, Thomas Stevenson, Ari Brown, Samuel Moseley, and Wen-Ting Hsieh of Goddard Space Flight Center. Further information is contained in a TSP (see page 1). GSC-16342-1

Flexible Microstrip Circuits for Superconducting Electronics

Improved wiring geometry should further reduce the size of the wiring while also reducing the crosstalk among wire pairs.

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Flexible circuits with superconducting wiring atop polyimide thin films are being studied to connect large numbers of wires between stages in cryogenic apparatus with low heat load. The feasibility of a full microstrip process, consisting of two layers of superconducting material separated by a thin dielectric layer on 5 mil (≈0.13 mm) Kapton sheets, where manageable residual stress remains in the polyimide film after processing, has been demonstrated. The goal is a 2-mil (≈0.051-mm) process using spin-on polyimide to take advantage of the smoother polyimide surface for achieving high-quality metal films. Integration of microstrip wiring with this polyimide film may require high-temperature bakes to relax the stress in the polyimide film between metallization steps.

Focal planes of cryogenic detectors typically have detectors at the lowest temperature stage with bias and readout located at higher temperature stages to reduce the cooling power requirement on the refrigerator stage that achieves the base temperature for the detectors. Large numbers of wires between cryogenic stages are often necessary and need to be designed to maintain a manageable heat load to each stage. A microstripline wiring configuration is also desired to suppress thermal crosstalk into the detectors due to amplifier switching and bias changes. With the size of focal planes increasing into the range of thousands of biased elements, and a further need for compactness of the focal plane architecture, a technology is needed that can accommodate thousands of superconducting wires between cryogenic components.

Flexible niobium wiring has been demonstrated on Kapton pieces where the impedance of the line was set by the distance between the Nb wires and the dielectric properties of the Kapton. This work proposes to fabricate microstrip Nb wiring consisting of a narrow Nb trace atop a wider trace separated by a thin dielectric layer. This wiring geometry, in comparison to the coplanar designs, should further reduce the size of the wiring while also reducing the crosstalk among wire pairs. Further, the use of a thin polyimide layer will enable lower heat loads between stages for a similar length of flexible wiring.

It was shown that 5-mil (≈0.13-mm) sheets could be readily mounted smoothly onto the substrate. The substrates were taken through all process steps, including Nb deposition and etch, oxide deposition, and aluminum deposition and etch. In all cases, the heat-release tape held the Kapton onto the substrate, indicating that the processes could be run serially to complete a full microstrip process. A Kapton film with a patterned Nb layer on it was released, and showed that the film was superconducting at a temperature close to the expected critical temperature of Nb. Polyimide layers that were free of roughness and pitting were generated through a spin-on process that used successive spins and bakes, with gradual heat lip and cooldown cycles, to build up the film to a full thickness of 2 mils (»0.051 mm). The full thickness film is baked at elevated temperatures to relieve residual stress in the film.

This work was done by James Chervenak of Goddard Space Flight Center, and Jennette Mateo of SB Microsystems. Further information is contained in a TSP (see page 1).GSC-16718-1