Micromachined Silicon Integrating Cavities for Far-Infrared Bolometer Arrays

M. Audley[1], G. de Lange[1], G. Keizer[1], C. Bracken[2]

[1]SRON Netherlands Institute for Space Research, Groningen, The Netherlands
[2]National University of Ireland, Maynooth, Co. Kildare, Ireland

Abstract

Cryogenic radiation detectors using superconducting Transition Edge Sensors (TES)are widely used in astronomical observatories from the millimetre-wave region through hard X-rays[1]. They will provide the sensitivity needed by the next generation of space-based infrared observatories, such as the Japanese Space Agency's satellite observatory SPICA which will use a large (3.5-m diameter) primary mirror cooled to <6 K to enable high angular-resolution, sky-background limited observations of the cold dusty Universe in the mid- and far-infrared [2]. This mission promises to revolutionize our knowledge of the origin and evolution of galaxies, stars and planetary systems. The prime instrument on SPICA is SAFARI [3], a far-infrared imaging spectrometer that will provide wide-field spectroscopic maps in the far infrared, giving us the ability to study the dynamics and chemistry of a wide range of objects. SAFARI covers the wavelength range 34-210 μm (1.4-8.8 THz) using arrays of TES bolometers.

A prototype detector for SAFARI's short-wave band (34-60 μm) is shown in Figure 1. This detector is fed by a few-moded feedhorn and sits in front of a metal backshort. In order to reach the target sensitivity (NEP~0.2 aW/rtHz) the nitride legs supporting the island containing the TES and absorbing film must be made much longer than the prototype's to minimize the thermal conductance. This leads to low filling factors. We have investigated an alternative optical coupling scheme that could be used for future instruments that could achieve filling factors with ultra-sensitive TES bolometers. The detector sits in an integrating cavity formed from two silicon wafers. The cavity is formed by two pyramidal pits created by anisotropic etching of single-crystal silicon and is fed by a square waveguide created in the upper wafer by deep reactive ion etching (see Figure 2). By stacking arrays of such cavities we could achieve denser packing of the TES bolometers in the focal plane.

We have used COMSOL Multiphysics® software to model these integrating cavities using a transition boundary condition to simulate the absorber. We present the results of our simulations (see Figure 3) and show how we used COMSOL Multiphysics to optimise the geometry. We show that we can achieve a high optical efficiency over a wide band of 1.5-9 THz.

Reference

1. Kent Irwin and Gene Hilton, "Transition-edge sensors", in Cryogenic Particle Detection, C. Enss, Ed., Springer, 81-97 (2005).

2. Bruce Swinyard et al. "The space infrared telescope for cosmology and astrophysics: SPICA A joint mission between JAXA and ESA", Experimental Astronomy, 23, 193–219 (2008).

3. Brian Jackson et al. "The SPICA-SAFARI Detector System: TES Detector Arrays With Frequency-Division Multiplexed SQUID Readout", IEEE Transactions on Terahertz Science and Technology, 2, 1-10 (2011).

Figures used in the abstract

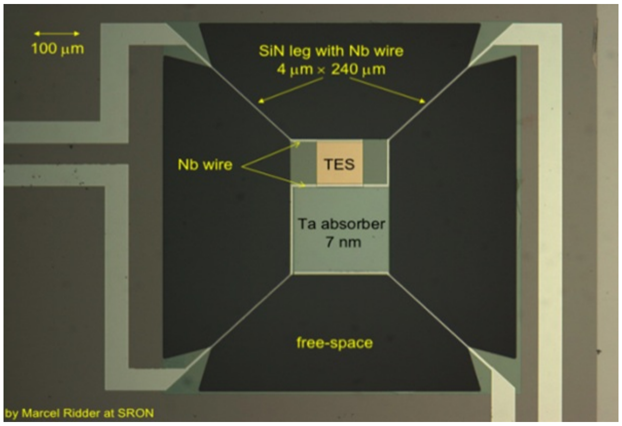

Figure 1: Prototype TES bolometer for SAFARI's SW band. The TES has a transition temperature of 100 mK and an NEP of 2 aW/rtHz.

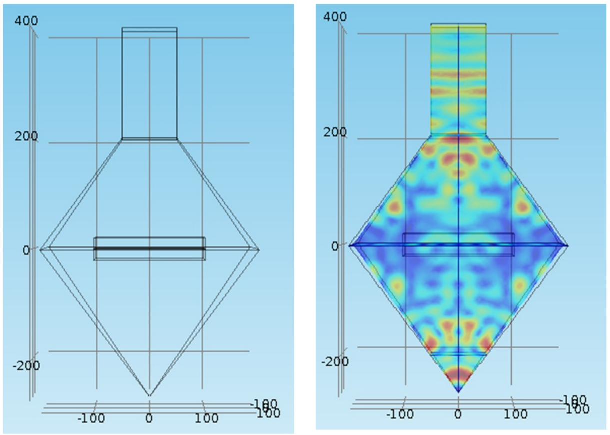

Figure 2: Left: Simple micromachined silicon pyramidal cavity. Right: Electric field in cavity when excited by the fundamental TE01 waveguide mode at 5.3 THz. Dimensions are in microns.

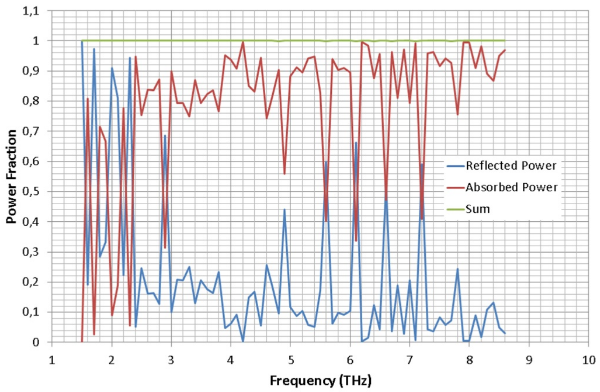

Figure 3: Fraction of power reflected and absorbed and their sum at different frequencies for the simple pyramidal cavity shown in Figure 2.