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Sub-mm-Wave Superconducting On-Chip Filter Bank for Astronomy

A. Pascual Laguna[1,2], K. Karatsu[1,2], D. J. Thoen[2,3], V. Murugesan[1], A. Endo[2,3], J. J. A. Baselmans[1,2]
[1] Netherlands Institute for Space Research, SRON, Utrecht, The Netherlands
[2] Faculty of Electrical Engineering, Mathematics and Computer Science, Delft University of Technology, Delft, The Netherlands
[3] Kavli Institute of Nanoscience, Faculty of Applied Sciences, Delft University of Technology, Delft, The Netherlands

Abstract**—A superconducting on-chip microstrip filter bank spectrometer prototype for Far-Infrared (FIR) Astronomy is presented. The measurements showcase its capabilities towards moderate spectral resolution ($f/\Delta f \sim 500$) broadband FIR spectroscopy. In this sub-mm-wave filter bank, each spectral channel consists of an "I-shaped" microstrip THz bandpass filter that couples the radiation to a Microwave Kinetic Inductance Detector (MKID) for a background limited detection and a scalable frequency-multiplexed microwave readout.**

I. Spectrometers for Far-Infrared Astronomy

THE Cosmic Background is as bright in the infrared as in the optical regime. However, it is the infrared spectrum that can probe star-forming galaxies, which would otherwise be invisible in the optical regime due to their dusty nature [1]. In order to characterize these galaxies, a broadband infrared spectral signature with moderate spectral resolution ($f/\Delta f \sim 500$) is required. State of the art broadband Far-Infrared (FIR) spectrometers tackle this endeavor by sensing with incoherent detectors the light dispersed by either diffraction gratings [2-4] or filter banks [5-8]. On-chip filter bank solutions have a clear advantage towards future multi-object spectrometers in terms of scalability.

II. Microstrip filter bank spectrometer

Our prototype on-chip filter bank spectrometer is based on DESHIMA 1.0 [8], with a layout as depicted in Fig. 1. In this configuration the incoming sub-mm-wave radiation is efficiently coupled to the chip circuitry via a double-slot lens antenna. The radiation is then carried from the antenna to the filter bank via a virtually lossless superconducting transmission line. A microstrip filter bank then sorts the incoming radiation into the different spectral channels, each of which consists of an "I-shaped" THz bandpass filter coupling radiation around frequency f with a resolution $f/\Delta f$ from the through-line to a Microwave Kinetic Detector (MKID). After the filter bank there is a lossy transmission line that absorbs any remaining power to avoid standing waves.

III. Measurements of a sparse filter bank prototype

As a preliminary performance assessment of our proposed microstrip filter bank concept, we have designed and built a prototype chip with a sparse sampling of the 300-400 GHz sub-mm-wave spectrum with a resolution of $f/\Delta f \sim 500$. From the measurements we can derive an internal quality factor, associated to the amorphous nature of the PECVD a-Si used, in the order of $Q_i \sim 1500$. As depicted in Fig. 2, the measured loaded quality factor of each filter is around $\overline{Q_l} \sim 550$, which is close to the targeted spectral resolution of these filters.

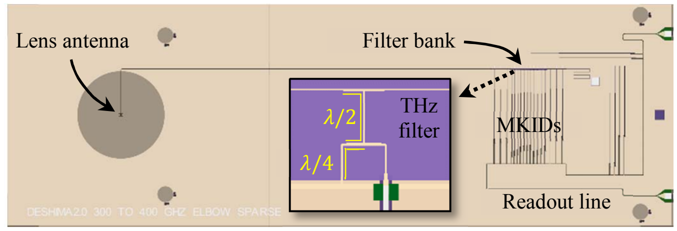

Fig. 1. Prototype chip of a sparsely sampled spectrometer in the band 300-400 GHz. In the inset one can observe one example of an "I-shaped" THz bandpass filter coupling power from the through-line to an MKID behind it.

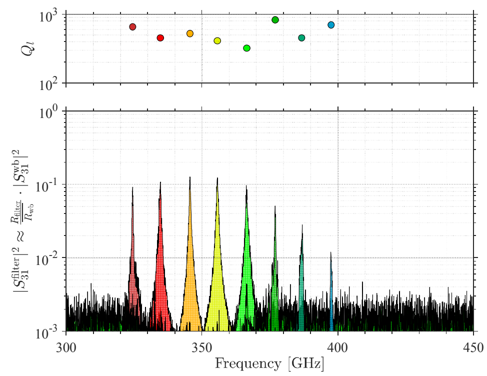

Fig. 2. Measured spectrum of the chip in Fig.1 and the loaded quality factors averaging $\overline{Q_l} \approx 550$. Each channel's spectrum $\left(|S_{31}^{\text{filter}}|^2\right)$ is estimated from the ratio of phase response of the MKID behind each filter (R_{filter}) and the average phase response of the MKIDs behind the wideband couplers at the beginning of the filter bank ($\overline{R_{\text{wb}}}$), whose coupling strength $\left(|S_{31}^{\text{wb}}|^2\right)$ is used as a reference.

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