THz Leaky Lens Antenna integrated with Kinetic Inductance Detectors

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Abstract

This contribution presents the fabrication and measurements of the leaky lens antenna integrated with a cryogenically cooled Kinetic Inductance Detector, in order to achieve an ultra sensitive THz receivers over a bandwidth ranging from 0.15 GHz to 1.5 THz. The system has been manufactured and characterized in terms of power efficiency, and radiation pattern properties. The agreement between the expectations and the measurements is excellent already at this first attempt. These measurements demonstrate the manufacturability and repeatability at THz frequencies of the properties of the leaky lens antenna concept.

1 Introduction

Reflector systems with wideband antenna feeds and arrays receiving growing interest for applications in the THz frequency ranges such as radio astronomy and space observation [1]. For THz space observation, dielectric lens antenna arrays are typically used in focal plane array configurations, due to their easy integration. However, the typical antenna solutions used as feed of dielectric lenses are efficient only over a narrow band [2]. An improved solution is the leaky-lens antenna recently proposed in [3], which can achieve multi-octave bandwidth. This antenna consists of a leaky-wave slot

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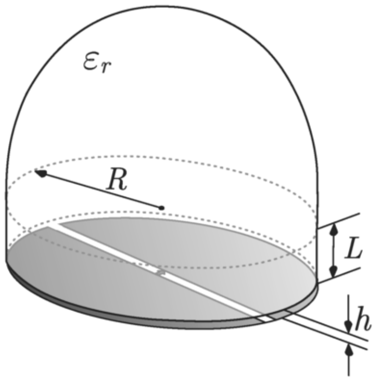


Figure 1: Dielectric lens fed by single leaky-wave slot.

kept at an electrically small distance from the dielectric lens (Fig. 1), in order to obtain directive radiation inside the dielectric and, consequently, efficient illumination of the lens. The leaky-lens was experimentally proved to be non-dispersive and highly efficient over a wide bandwidth in the microwave [4]. Standalone demonstrations of antennas, is typical in the microwave domain. They can be useful, but not conclusive, in the THz regimes due to the importance of parasitic effects that come in when the actual connection of a micro-metric antennas and receivers are eventually realized. In order to be able to characterize an antenna efficiently in the THz frequency domain it is essential to co-design it together with the receiver it is intended to operate with.

This contribution represents the first demonstration of the feasibility of the leaky lens antenna concept at THz frequencies. The antenna is integrated with a cryogenically cooled Kinetic Inductance Detector (KID) [1, 5], so that the two of them would function as an ultra-sensitive receiver over a bandwidth ranging from 0.15 GHz to 1.5 THz. KIDs had previously shown photon noise limited performance at frequencies of 350 GHz in a narrow band [6] in an architecture similar as the one presented here, with however a narrow band twin slot antenna [2]. The present system with KIDS and Leaky Lens Antenna has been manufactured and characterized in terms of, radiation pattern properties at several frequencies.

2 Manufacturing

The functioning of KID detectors as microwave resonators that function as THz power detectors is discussed in [1]. The KID resonator (central in Fig. 2) is coupled to a GHz Transmission line on one side (top portion of

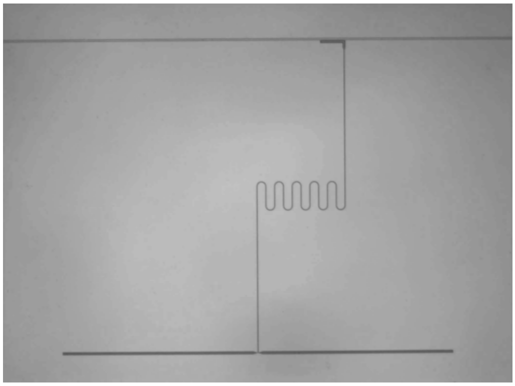


Figure 2: Micrograph from front side with front illumination. The slot is is 4 mm long.

Fig. 2 and the to the THz antenna on the other side (long slot in Fig. 2). The KID resonator is made of a 200 nm thick Tantalum film and provides a virtually frequency independent THz power sensitivity for frequencies above the gap frequency of Tantalum (320 GHz). The key difficulty in manufac-

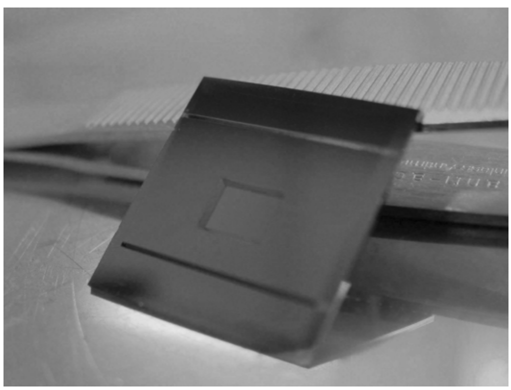


Figure 3: Sample fabrication: finished chip seen from the backside.

turing the antenna was the necessity to print it on a thin 3·m membrane. In the present experiment, we used a SiN membrane deposited on both sides of a Si wafer using PECVD. Using standard lithographic techniques and KOH wet etching of the Si we fabricated a membrane without Si support of 5×5 mm, on the rest of the chip the 525 μm thick Si was left in place below the SiN. Fig. 3 shows the finished chip and in the center the membrane can be observed as a small depression in the thicker wafer. A small ($h = 35, \mu$m) spacing between the slot antenna and the dielectric lens was achieved by laser etching a 30 μm deep suppression in another high resistivity silicon wafer of 350 μm thick (the 'back-short'). After clamping the chip in its holder and connecting the feed line via wire bonds to the coax feeds, we glued the spacer chip on top of the detector chip with cyanoacrylate glue, which is present only at the sides of the spacer chip, not behind the antenna feed. On top of the back-short chip we then mounted the Si lens, aligned to the center of the feed, creating the structure shown in Fig. 4.

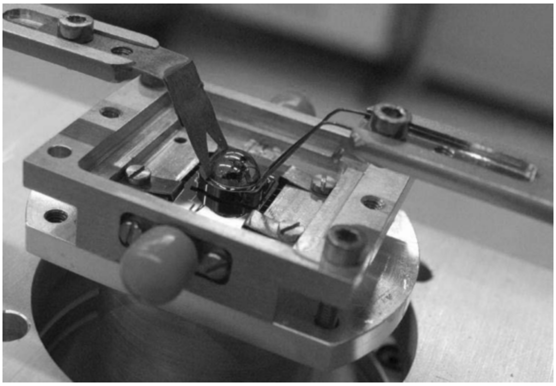
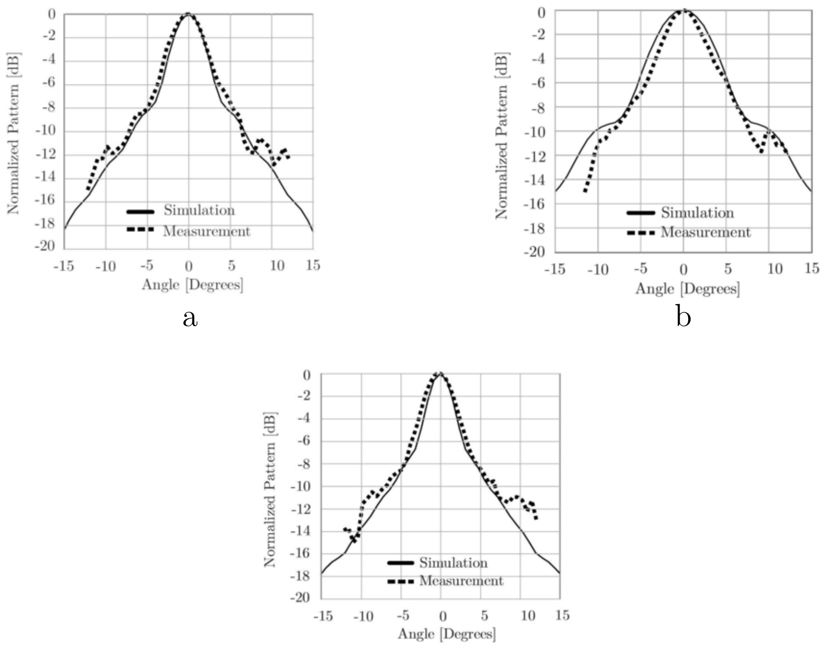


Figure 4: Chip inside the sample holder and position of the lens before gluing.

3 Measurements

The entire system was then located in inside a liquid He cryostat and thermally anchored to the cold stage of a He3 cooler, cooling the detector to 300 mK. In the experiment the lens is facing a window, equipped with IR blockers at 77 K and 4 K and a low pass filter with a cut-off at 1.2 THz at 4 K. A hot load (2000 K), with a few millimeter aperture and equipped with changeable band pass filters was used as THz source and moved at a distance of approximately 20 cm from the lens. Three different filters were located between the source and the receiver: 1) 350 GHz pass band, 2) 650 GHz pass band 3) 850 GHz pass band. These filters provide direct information on frequency performance of the receiver. Without any filter the receiver detects within the 1.2 THz bandwidth given by the filter on the cryostat window. $E-$plane radiation patterns derived from the responsivity of the KIDs as the source was moving in front of the cryostat window are shown for the three investigated frequencies (350 GHz, 650 GHz and 850 GHz) in Fig. 5 (a), (b) and (c), respectively, where they are compared with the pertinent simulation results, obtained using an in house developed tool.



a b

c

Figure 5: Comparison betwene the measuremnts and caculations for $E-$plane radiation patterns at three different frequencies: (a) 350 GHz, (b) 650 GHz and (c) 850 GHz.

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