An 8×8 CPW MKIDs Developed at 0.35THz

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Abstract**—Microwave Kinetic Inductance Detectors (MKIDs) are rather promising for THz direct detector arrays of large size, particularly with simple frequency-division multiplexing. Purple Mountain Observatory is developing a terahertz superconducting imaging array (TeSIA) for the DATE5 telescope to be constructed at Dome A, Antarctica. Here we report on the development of a prototype array for the TeSIA project, namely an 8×8 CPW MKIDs array at 0.35THz. The array consists of 64-pixel superconducting resonators in the frequency range of 4-5.575 GHz with an interval of 0.025 GHz and 64-pixel twin-slot antennas at 0.35 THz for coupling THz radiation to the detector array. Based on our design, we fabricate the MKIDs array using TiN superconducting film with Tc about 4.5 K. And the performance is characterized at different temperatures. Detailed results and analysis will be presented.**

Keywords—MKIDs; TiN; Superconducting resonator; CPW; TeSIA

I. INTRODUCTION

China is planning to construct an observatory at Dome A, Antarctica, which has been found to be the best site (with low perceptible water vapor and low atmospheric boundary layer) on the earth for THz and Optical/IR astronomy. One of the telescopes to be built there is a 5-m THz telescope (DATE5 [1]) targeting at 350um and 200um atmospheric windows. One science case for the DATE5 is to observe extreme starburst galaxies at different redshifts to better understand the nature and evolution of these enigmatic and important objects. Therefore, we are going to develop an imaging camera with 1024-pixel. We are currently developing a detector array demonstrator to meet such a requirement in the future [2].

The detector array demonstrator has 8×8 pixels and will work at 0.35 THz, which is chosen to demonstrate the performance of the detector array on a small sub-millimeter telescope (POST, with a diameter of 30cm) situated at Delingha, China. As is well known, microwave kinetic inductance detectors (MKIDs [3]) use frequency domain multiplexing that allows thousands of pixels to be read out over a single microwave transmission line followed by a cryogenically cooled low noise amplifier. Furthermore, a large number of MKIDs can be integrated like a filter bank to realize on-chip spectrometers such as DESHIMA and SuperSpec [4, 5]. Hence we choose MKIDs to develop our detector array demonstrator. The MKIDs make use of TiN superconducting films with a critical temperature of approximately 4.5 K, which can be operated at temperatures of ~0.3K [6]. Furthermore, TiN MKIDs can reach a noise equivalent power (NEP) below 1x10-19 W/Hz0.5, which is a sufficiently high sensitivity for ground-based astronomical observations [6]. The 8×8 TiN MKIDs will be integrated with a micro-lens array of 8×8 0.95-mm hyper-spherical Si lens with a separation of 2 mm between individual lens. The readout for this MKIDs detector array demonstrator is similar to others, but adopting a commercial arbitrary wave-function generator to generate 64-tone input signal. The 0.3K refrigerator for the demonstrator is a He3 two-stage sorption cooler (CRHe7 [7]) based on a liquid helium cryostat, which offers over 10 hours continuous cooling with a total heat load of up to 20 µW. In this paper, we mainly introduce the design, fabrication, and characterization of the 8×8 TiN MKIDs.

II. MKIDs Development

We adopted the coplanar-waveguide (CPW) type resonator to design our 8×8 TiN MKIDs array because it has a relatively simple architecture of only one thin-film layer on the substrate. This kind of resonator has a quarter-wavelength transmission line with one end capacitively coupled to a feed line and the other matched to a planar antenna (twin-slot antenna, for example) [8].

The 8×8 MKIDs array was fabricated in the cleanroom of RIKEN Center for Advanced Photonics (Japan). As introduced before, we chose TiN superconducting films for this MKIDs detector array [9, 10]. MKIDs based on TiN superconducting films have a few advantages including a) T_c can be controlled between ~0-5 K by the components of Ti and N_2 [6]; b) quasi-particle lifetime is around 10-200 μs [6]; c) low loss in the superconducting state [6]. Firstly, a 100-nm thick TiN film was deposited on a high resistivity Si wafer in a DC magnetron sputtering system. Secondly, the CPW lines were defined in contact lithography by a mask aligner. Thirdly, the etching course was done in an ICP machine. The fabricated MKIDs have a T_c approximately equal to 4.5 K. Hence they can be operated in a 0.3 K low temperature environment.

For the fabricated 8×8 TiN MKIDs array, as shown in Fig. 1, we mainly measured its Q factors and the dependence of Q factors upon the bath temperature and the input power for the multiplexing readout. The measurements were done simply by a scalar network analyzer to the 8×8 TiN MKIDs array and a following 0.1~12 GHz cryogenically cooled low-noise amplifier, which has an equivalent noise temperature of 5 K and gain of approximately 35 dB.

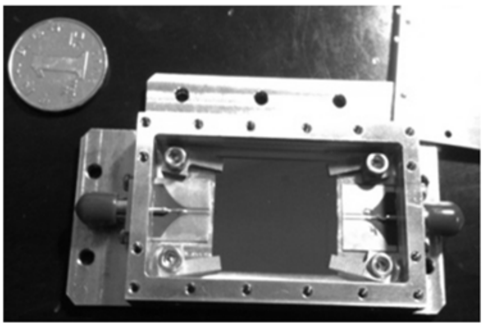

Fig. 1. Measured MKID 8×8 TiN MKIDs array, with its input and output of a CPW-to-microstrip transition (both in 50 Ω).

The transmission characteristic of the 8×8 TiN MKIDs array was firstly measured at a temperature of approximately 600 mK in the frequency range from 5.2-7.7 GHz. The result is exhibited in Fig. 2. By checking the resonance dips individually, we found that they all survived. The inset in Fig. 2 shows the result zoomed in for a 100-MHz frequency interval.

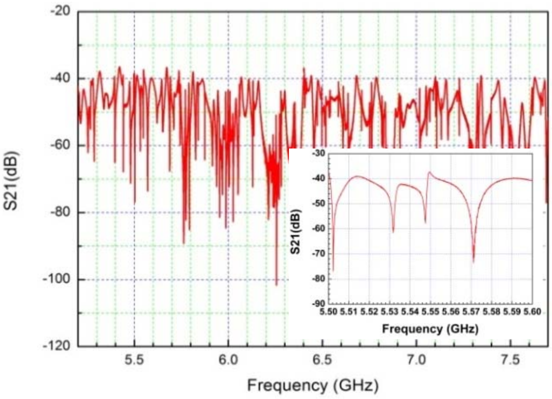

Fig. 2. Measured transmission characteristic of the 8×8 TiN MKIDs array at a temperature of approximately 600 mK in the frequency range from 5.2-7.7 GHz. The inset shows the part zoomed in for a 100-MHz interval, with four resonance dips seen clearly.

We then studied the transmission characteristic of the 8×8 TiN MKIDs array with increasing the bath temperature (600 mK to 950 mK). The measured results are shown in Fig. 3 for the frequency range of 5.5~5.6 GHz. Obviously, the four resonances demonstrate the same behavior, namely the higher the temperature, the lower the resonance frequency and the shallower the resonance dip. We also plotted the dependence of the resonance frequency upon temperature, as shown in the inset in Fig. 3.

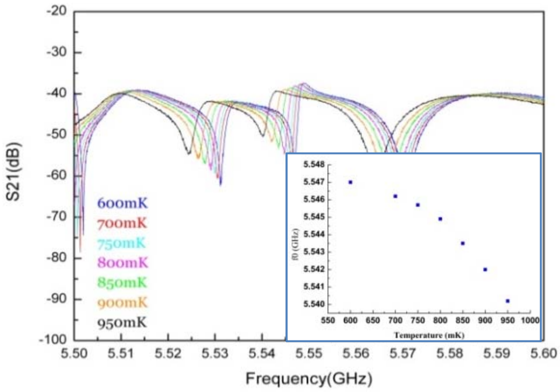

Fig. 3. Measured transmission characteristic of the 8×8 TiN MKIDs array as a function of the bath temperature, shown in the frequency interval of 5.5~5.6 GHz. The inset presents the dependence of then resonance frequency upon temperature.

III. CONCLUSION

We have designed and fabricated an 8×8 TiN MKIDs array. Its transmission characteristic has been measured with respect to the bath temperature and input power. The temperature dependence follows that predicted by the Mattis-Bardeen theory, while the resonance frequency and the quality factor are both insensitive to the input power when it is below -40 dBm.

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