Terahertz Imaging with a Two-dimensional Array Detector Based on Superconducting Tunnel Junctions

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***Abstract*—We demonstrated terahertz imaging using a two-dimensional array detector with 5×5 elements based on superconducting tunnel junctions. Real-time 25-pixel imaging at 0.65 THz was successfully performed. The array detector also allowed the shortening of the total acquisition time for larger images, made up of pixel blocks.**

I. Introduction

Terahertz (THz) imaging devices with high sensitivity, broadband characteristics, and large format arrays are required for various applications in fields such as industry, medicine, biology, agriculture, and astronomy. However, detector arrays for THz imaging are still under development.

Superconductor bolometers, generally called transition edge sensors, are well developed as high sensitivity cryogenic detectors of THz waves. However, bolometers are sensitive to temperature fluctuation, mechanical vibration, and electrical interference. Superconducting tunnel junction (STJ) detectors provide an excellent alternative. The detection mechanism is based on photon-assisted tunneling process, giving the theoretical responsivity of the quantum-limited value e/hν below the superconductor gap [1].

In previous reports, we have proposed and developed an STJ direct detector for THz waves, and demonstrated nondestructive imaging of visually opaque materials using one-pixel [2] and linear array detectors [3]. Prototype detectors were designed to have the maximum sensitivity at 0.65 THz, so as to fit an essential atmospheric transmission window for the astronomical observation site in Atacama Desert [4].

II. Terahertz Imaging

We demonstrated THz imaging using an STJ two-dimensional array [5]. As a THz wave source, we used a backward-wave oscillator (BWO) for its high output power and frequency tunability in the range of 0.5-0.7 THz [6]. Figure 1 shows the BWO imaging system with the STJ array. The sample is moved in a plane perpendicular to the beam axis using an XY linear motor stage. The beam passing through the sample is refocused onto the STJ array in a cryostat. Current signals from the array are read out in parallel using a multi-pixel readout system based on trans-impedance amplifiers, and then fed to a series of lock-in amplifiers synchronized with an optical chopper placed in front of the source.

Figure 2 shows a THz image of a metallic test pattern using the 25-pixel array operated at 0.3 K. The total acquisition time was one minute using the 25-pixel array detector. The detector has a capability of scan speed up to 25 times faster than a one-pixel detector. A larger format array of STJ detectors is expected to further shorten the total acquisition time.

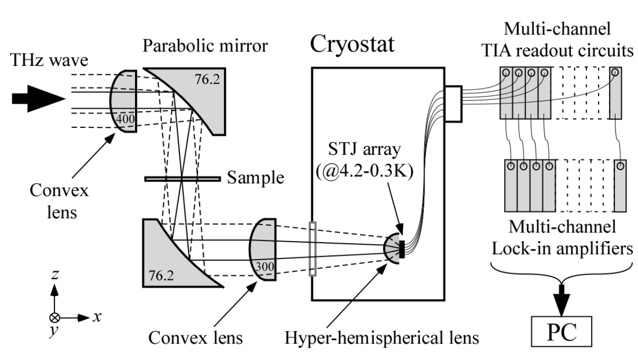

Figure 1. Schematic of the BWO imaging system with the STJ array. The numbers on the optical elements indicate their effective focal lengths in millimeters.

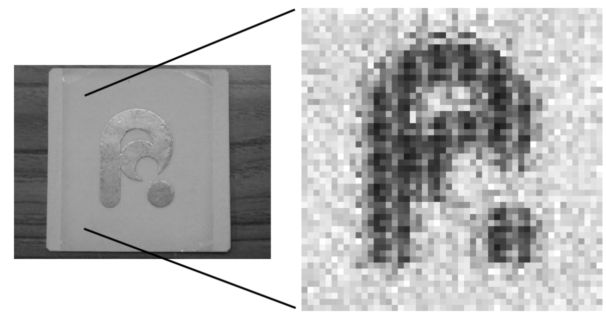

Figure 2. Left: A test pattern (RIKEN logo made of aluminum foil on paper). Right: A 50x50 pixel THz image, made up of 10x10 blocks, each taken with the 25-pixel array detector (one image pixel is 0.8x0.8 mm).

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