A High-T_c Superconducting T-Ray "Flashlight" Operating in Liquid Nitrogen

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March 9, 2015 (STH28, HP92). Sources of terahertz (THz) radiation (between the far infrared and microwave frequencies) are in high demand for various applications. Stacks of intrinsic Josephson junctions in the high-transition-temperature (T_c), superconductor $Bi_2Sr_2CaCu_2O_{8+\delta}$ (BSCCO) have been found to be promising sources emitting continuous and coherent radiation [1-5]. Previously the BSCCO sources required to be cooled by liquid helium or other cooling systems due to the low working temperatures. However, there are considerable technical problems with these cooling systems, such as the large equipment volume, electromagnetic noise, and mechanical vibrations. To eliminate the need for mechanical cryocooling, we developed a compact and portable THz source based on the BSCCO intrinsic Josephson-junction stack, which can be operated in liquid nitrogen. A photo of the source setup is shown in figure 1(a). Results of work are presented in [6,7].

There have been at least two key factors making it possible to operate the device in liquid nitrogen. The BSCCO single crystals are optimally doped with $T_c \sim 88$ K, and a sandwich structure is employed to better remove heat due to self-heating out of the intrinsic Josephson junction stack [6]. A schematic cross-section view of the THz source is shown in figure 1(b). The system consists of a copper container and a stainless-steel tube acting as a waveguide. Pieces of black polyethylene films were mounted onto the output port of the waveguide to filter some of the infrared background. The inner view of the upper wall of the copper container is sketched in Figure 1(c). The BSCCO emitter is fixed on a hemispherical sapphire lens at the bottom end of the cylindrical waveguide. The THz waves are focused by the lens and then transmitted outward through the waveguide tube with polished inner walls. We also placed a 1 kΩ heating resistor near the lens to adjust the ambient temperature and, consequently, to expand the tunable frequency bandwidth [7].

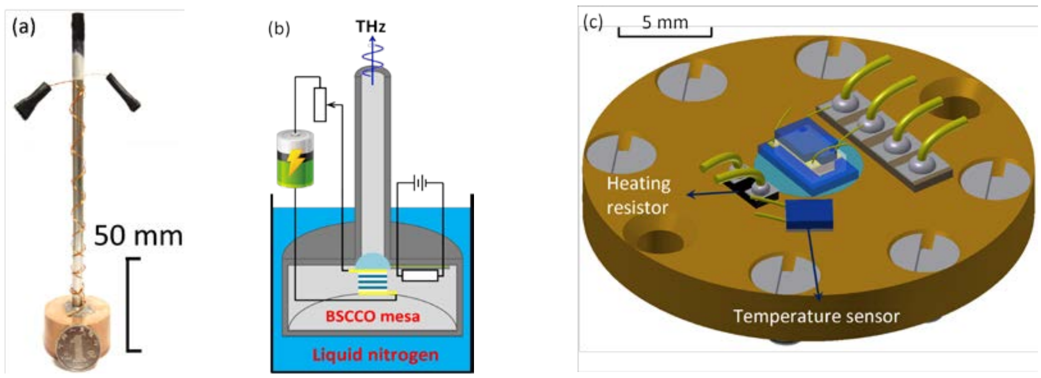

Fig. 1. (a) A photograph and (b) a schematic view of the THz source. The inner top part of the container is sketched upside down in (c).

The active junctions in the stack, numbering from 909 to 954, contribute to the emission. The maximum emission power is 1.17 μW, measured by direct bolometric detection, and the total tunable frequency range is as broad as 100 GHz with maximum emission power at 0.311 THz. Due to the low operation voltage and current, we can drive this THz source with one commercial 1.5-V battery.

This economical and convenient device could facilitate airport security, nondestructive evaluation, and remote detection of trace gases, among other applications. Further improvements in performance are possible and should enhance usefulness in applications.

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