September 26, 2014 (STH27, HP91). In recent years, high temperature superconductor (HTC) Bi$_2$Sr$_2$CaCu$_2$O$_8$ (BSCCO) devices have become indispensable for generating electromagnetic coherent terahertz (THz) radiation. Great efforts have been paid to optimize the power, frequency and tunability of terahertz emission since it was first observed in 2007 [1-4]. To get higher frequencies, it is essential to solve the problem of the self-heating, which is caused by the relatively high input DC power and the poor c-axis thermal conductivity of BSCCO [2, 3, 5]. For a conventional mesa structure, the stack of intrinsic Josephson junctions (IJJs) stands on a thick pedestal of the BSCCO single crystal, through which the heat diffuses from the mesa to the substrate. In our previous work, we developed a gold-BSCCO-gold structure (GBG) to improve the cooling condition as shown in Fig. 1 (left). It has been reported that the GBG can emit THz emission with a directly detected power as high as ~25 μW [6].

In our recent experiments, we started from fabricating a GBG structure with a BSCCO stack embedded between two gold layers. When mounted onto a single substrate the stack emitted in the frequency range of 0.43-0.82 THz. We then glued a second, thermally anchored substrate onto the sample surface with Polyimide (see Fig. 1 (right)), forming a sandwich structure (SWS) with the BSCCO stack embedded between two substrates. The transport and emission experiments were carried out again like for the pristine GBG and emission of up to 1.05 THz from the SWS stack at $T_b = 20$ K was observed, being considerably higher than that of GBG [7].

![Fig. 1. Schematic views of (left) a GBG and (right) a SWS structure. The BSCCO stack with the dimension of 230×50×1.5 μm$^3$ was fabricated by photolithography and ion milling technology, involving ~1000 junctions.](image-url)
The IVCs of GBG and SWS in the high-bias regime both exhibit negative differential resistance on the outmost branch in the voltage state. However, the highest voltage of the SWS reaches ~ 2.5 V, 25% larger than that of the GBG. One can see that at a fixed temperature, the frequency can be continuously tuned by the junction voltage \( V_0 \), according to the Josephson relation \( f_e = \frac{2eV_0}{h} \), and thus the SWS yields a broader frequency range.

Fig. 2 shows the temperature-dependent frequency at high and low current bias. Both structures exhibit the similar tendency below \( T_b \sim 88 \) K, namely, the emission frequencies gradually increase with decreasing \( T_b \). The GBG was found to radiate for bath temperatures below 65 K, while the emission of SWS can be detected over a broader temperature range below 80 K. Particularly, the emission frequencies of the SWS cover a considerably larger range than the GBG at a fixed \( T_b = 20 \) K, e.g., 0.76-1.05 THz for SWS and 0.62-0.82 THz for GBG. For the entire temperature range the SWS exhibits a much broader emission frequency range (0.34-1.05 THz) than the GBG (0.43-0.82 THz). We emphasize that the corresponding spectrum of the highest emission frequency is up to 1.05 THz, being the highest frequency within the THz radiation spectrum emitted by intrinsic BSCCO JJs until present.

Fig. 2. Emission frequency vs. the bath temperature. The inset shows the spectrum of THz emission at \( T_b = 20 \) K and \( I = 3.037 \) mA.

Acknowledgements

We gratefully acknowledge financial support by the National Natural Science Foundation of China (Grant 11234006), the Deutsche Forschungsgemeinschaft (Project KL930/12-1), the Grants-in-Aid for scientific research from JSPS (25289108), and RFBR grants 13-02-00493-a and 14-02-91335.

References