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Structural optimization and implementation of superconducting terahertz source based on the anisotropic dielectric model

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Josephson Plasma Emitter (JPE) is a continuous terahertz source utilizing the intrinsic Josephson junctions in the high-Tc cuprate superconductor $Bi_2Sr_2CaCu_2O_{8+\delta}$ (Bi2212). One of its advantages among terahertz sources is controllability in the emission frequency by adjusting the applied voltage [1]. However, its maximum emission intensity of 610 μW has shown no progress since 2013 [2], mainly due to the lack of a design strategy based on numerical calculations. The anisotropic dielectric model of JPE [3] describes the linear response of Bi2212 when a small high-frequency electric field is applied, treating Bi2212 as a dielectric, thereby enabling the modeling of JPE on general electromagnetic field simulators. Using this model to simulate existing experimental setups (Fig. 1) [4], the radiation characteristics of the JPE device have been approximately reproduced, however, the adaptability of structural optimization using this model has yet to be confirmed.

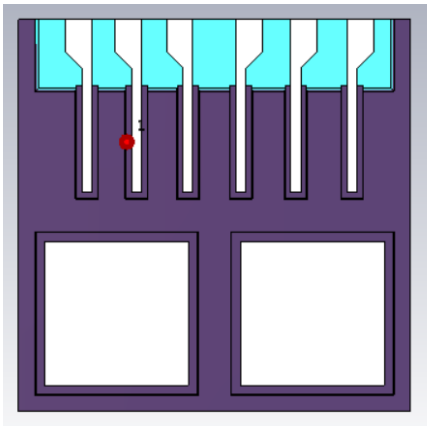

Fig. 1: A JPE modeled on an electromagnetic field simulator.

In this presentation, we introduce the results of the numerical optimization of JPE structures and the implementation of devices based on the optimal design. First, through numerical simulations, we propose structures that maximize the emission intensity by varying the height and depth while keeping the mesa (source) volume constant (Fig. 2). Next, we implement the optimal shape obtained from the calculations and measure the current-voltage-radiation characteristics of the fabricated device. Finally, we suggest a unique device design methodology delivered by a close comparison between the simulations and the measurements. This approach presents a steady step towards achieving a JPE with an emission intensity exceeding 1 mW.

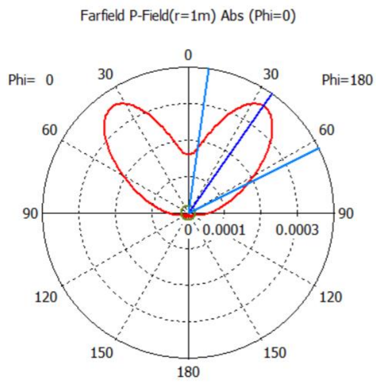

Fig. 2: A cross-sectional view of the radiation pattern expected from the structurally optimized device, operating at a frequency of 495 GHz. The cross-section is taken perpendicular to the longitudinal direction of the mesa.

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