Structure optimization of RTD THz oscillator integrated with rectangular-cavity resonator for high output power

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Oscillators using resonant tunneling diodes (RTDs) are major candidates for THz wave sources, because of their operation at room temperature and compactness. Although we achieved a high-power oscillation of around 0.7 mW by an arrayed RTD oscillator [1], the output power of a single RTD oscillator is relatively small, in the order of 10 μW around 1 THz. For higher output power, novel RTD THz oscillators with cavity resonators and bow-tie antennas were proposed [2], and simulated output power of ~2 mW was shown at around 1 THz by the impedance matching [3]. In this work, we theoretically show that the output power further increases with cavity length by keeping the impedance matching.

The device structure is shown in Fig. 1. The oscillator is composed of a line-shaped RTD mesa, a rectangular cavity resonator, and a bow-tie antenna. The RTD has a negative differential conductance (NDC) in the current-voltage characteristics, which is utilized for the THz oscillation. The rectangular cavity is expected to reduce the conduction loss and inductance, and the large-area RTD with high capacitance and high NDC can be used even at high frequency in this oscillator, which results in high output power. The oscillation frequency is basically determined by the LC resonance of inductance of cavity resonator and RTD capacitance. A part of generated THz signal passes through the MIM capacitor at the right-hand side in the lower part of Fig. 1, and is radiated into the substrate by the bow-tie antenna. We analyzed the admittance of cavity resonator and antenna using 3D electromagnetic simulation including the conduction loss, and established an equivalent circuit model for this structure [2]. The radiated output power can be estimated by calculating power consumption at the antenna conductance.

The impedance matching is required between RTD and its load to extract the maximum output power from RTD. The load impedance can be changed by the MIM capacitor connected in parallel with the bow-tie antenna, and the impedance matching condition will be satisfied. The calculated output power is shown in Fig. 2 as a function of MIM capacitor and cavity length. The output power is maximized at a given cavity length by an optimum MIM capacitor, and the maximum output power increases with increasing cavity length. A high output power of ~5 mW is possible at the cavity length of ~90μm.

References:

[1] K. Kasagi, S. Suzuki, and M. Asada, J. Appl. Phys. **125**, 151601 (2019).

[2] K. Kobayashi, S. Suzuki, F. Han, H. Tanaka, H. Fujikata, and M. Asada, J. Appl. Phys.**59**, 050907 (2020).

[3] F. Han, K. Kobayashi, H. Tanaka, S. Suzuki, and M. Asada, JSAP Spring Meeting, 12a-B414-9 (2020).

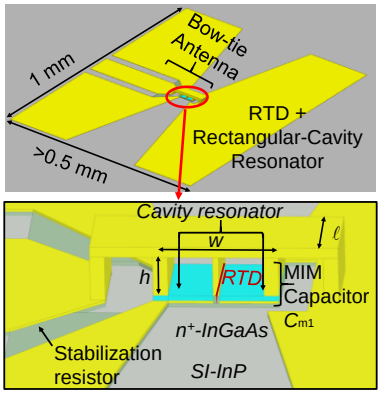

Fig. 1 Schematic structure of RTD oscillator with rectangular cavity resonator.

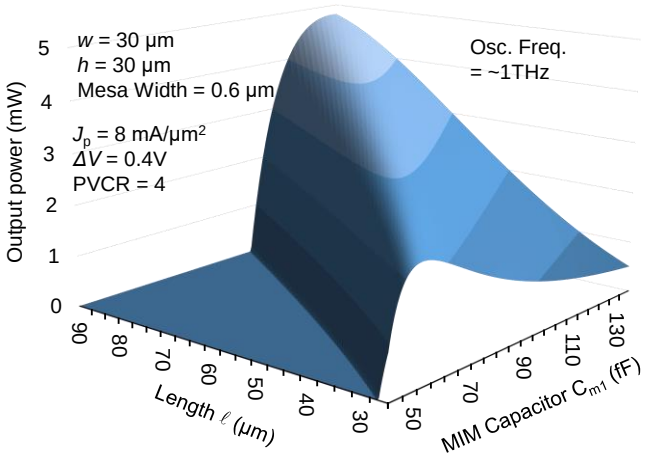

Fig. 2 Dependence of estimated output power on MIM capacitor and cavity length.