Expanding superposition bandwidth with frequency-modulated terahertz radiation from superconducting Josephson plasma emitter

*Itsuhiro Kakeya[1], Ryota Kobayashi[1], Rintaro Mori[1], Keitaro Sugimoto[1], Manabu Tsujimoto[2]

[1] *Department of Electronic Science and Engineering, Kyoto University, Nishikyo, Kyoto 615-8510, Japan*

[2] *Core Electronics Technology Research Institute, National Institute of Advanced Industrial Science and Technology*

Tsukuba,Ibaraki 305-8565, Japan

Abstract

Communication using terahertz (~10^{12} Hz) electromagnetic waves is critical for developing 6th-generation wireless network infrastructures. Conflictions between stable radiation and the modulation frequency of terahertz sources impede the superposing of transmitting signals on carrier waves. The Josephson junctions included in a cuprate superconductor radiate terahertz waves[1)] with frequencies proportional to the bias voltages[2)] . Thus, the modulation of the bias voltage leads to the modulation of the Josephson plasma emission (JPE) frequency. We achieved to demonstrate sinusoidal signal at 3 GHz superimposed on sub-terahertz carrier waves in a JPE device radiating at 840–890 GHz with the maximum FM bandwidth of 40 GHz[3)].

To achieve higher transmission rate of wireless communications, expanding bandwidth of superimposed signals and increasing in radiation power resulting in increased signal-to-noise ratio are indispensable. When the superimposed signal frequency was increased up to 10 GHz, FM comb spectrum was found up to 7.5 GHz and the spectrum bandwidth given by the actual modulation amplitude applied to the JPE showed complicated superimposed frequency dependence. This is the result of complicated frequency dependence of impedance of bias-applied circuit of the JPE. We discuss the loss and the reflection of the circuit and suggest the method to expand the bandwidth of the superimposed signal. We also continue to increase radiation efficiency of JPE with implementing numerical simulations to actual device fabrications. The development of reproducing radiation properties of JPE by circuit simulations using a SPICE simulator[4)] and three-dimensional finite-difference time-domain simulations.

References

1) L. Ozyuzer, A. Koshelev, C. Kurter, N. Gopalsami, Q. Li, M. Tachiki, K. Kadowaki, T. Yamamoto, H. Minami, H. Yamaguchi and others, Science (1979) 318 [5854], 1291 (2007).
2) I. Kakeya and H. Wang, Supercond Sci Technol 29 [7], 073001 (2016).
3) M. Miyamoto, R. Kobayashi, G. Kuwano, M. Tsujimoto and I. Kakeya, Nat Photonics 18 [3], 267 (2024).
4) R. Kobayashi and I. Kakeya, Supercond Sci Technol 38 [2], 02LT01 (2025).

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