Frequency-Tunable Gyrotron with Broad Bandwidth at Terahertz Regime

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A reflective-type gyrotron is a promising source for frequency-sensitive applications. The frequency tunability is attributed to the internal feedback between the forward-moving electron beam and the backward propagating wave. The generated backward wave is reflected at the cutoff section close to the gun end. We proposed a tapered structure operated at TE_{02} mode and centered at 203 GHz with the high-quality beam generated from a non-adiabatic electron source. Simulations carried out by our particle tracing, self-consistent code, and verified with the 3D commercial Computer Simulation Technology (CST) particle in cell solver, suggest a decent tuning bandwidth. Experimental data, surprisingly, shows an even broader bandwidth of 36 GHz by overlapping the adjacent waveguide modes, especially for the TE_{22} mode. The continuous frequency tunability over a wide bandwidth demonstrates that the proposed reflective gyrotron is an excellent terahertz wave source for many applications.

The step-tunable gyrotrons (Fig. 1, left) can generate the radiation with discrete frequencies over tens or even hundreds of GHz by employing a high-Q cavity similar to the gyromonotron. By adjusting the magnetic field, the oscillation frequency could be switched from one transverse mode to another, but the frequency tunability of each transverse mode is limited. Although the step-tunable gyrotrons have restricted frequency tunability in a transverse mode, they could directly export the high-power radiation without using a mode converter. In comparison, the gyro-BWO (Fig. 1, middle) with continuous frequency tunability demands a single-mode converter with high-converting efficiency at the upstream of the interaction cavity to extract the backward wave, which is very difficult to fabricate in the terahertz region. The continuous-tunable bandwidth in a few GHz ranges is achievable by employing the high-order axial modes (HOAMs, l = 1, 2, 3…) of a transverse mode inside a cavity with a low-Q factor.

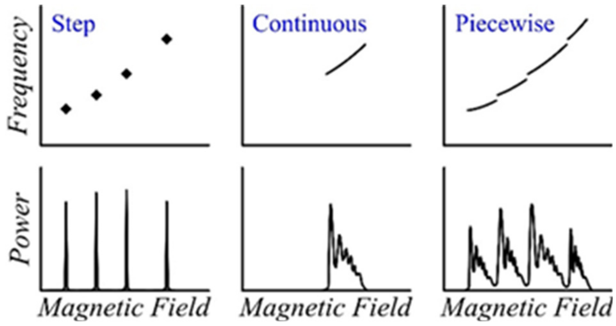

Fig. 1. Schematic oscillation frequencies and power spectra for the step-tunable gyrotron, the continuous-tunable gyro-BWO, and the piecewise-tunable reflective gyro-BWO.

Here we study a hybrid version, called the reflective gyro-BWO (Fig. 1, right), in which the upstream mode converter is omitted, and the oscillation frequency can be piecewise-tunable between transverse modes. Fig. 1 illustrates the oscillation frequencies and the power spectra of the step-tunable gyrotron, the continuous-tunable gyro-BWO, and the piecewise-tunable reflective gyro-BWO. The reflective gyro-BWO shows a continuous-tunable bandwidth in a transverse mode similar to the gyro-BWO and has the oscillation frequencies smoothly tunable over each transverse modes as compared to the step-tunable gyrotron.

References

[1] T. H. Chang, T. Idehara, I. Ogawa, L. Agusu, S. Kobayashi, J. Appl. Phys., **105**, 063304 (2009).
[2] C. H. Tsai, T. H. Chang, Y. Yamaguchi, and T. Idehara, IEEE Trans. on Electron Devices, **67**, pp. 341–346 (2020).
[3] C. H. Tsai, T. H. Chang, Y. Tatematsu, Y. Yamaguchi, M. Fukunari, T. Saito, and T. Idehara, IEEE Trans. on Electron Devices **68**, pp. 324-329 (2021).