Development of a High-Power Broadband Coherent THz Gyrotron Oscillator

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With frequency ranging between millimeter wave and infrared wave, THz wave is currently opening up new frontiers across many areas of science, including imaging, wireless communication, biomedical. The gyrotron operating on the principle of the relativistic electron cyclotron maser is capable of generating superior high-power THz radiation, with peak power several orders higher than the competing photonics THz sources. This paper presents the development progress of a high-power 0.33 THz gyrotron oscillator. This pulse gyrotron is predicted to generate broadband coherent radiation with peak power of 2.5 kW and frequency tunable bandwidth exceeding 10GHz in each pulse by employing a novel pre-bunched interaction circuit.

The gyrotron is with high-power capability comparable to the high-energy accelerator light source, but still maintains the advantage of industrial and scientific environment installation. One of the impressive THz biomedical applications is applying the THz gyrotron power to drive the dynamic-nuclear-polarization (DNP) enhanced NMR, which greatly increases the high-field NMR sensitivity and brings revolutionary analysis tools to the biomedical and material research (Q. Z. Ni, et al., Accounts of Chemical Research, 46(9), 2013, pp. 1933–1941). One of the problems hindering gyrotron application is the narrow-band operation, even single frequency, by employing an open cavity circuit. In order to extend the coherent bandwidth of the THz gyrotron, this paper presents a THz gyrotron designed to operate in the backward-wave region, other than the conventional gyromonotron region, and a compact pulse magnet is employed to generate a time-variable magnetic field to tune the beam-wave synchronization. The pre-bunched circuit is for the first time implemented in the THz gyrotron to improve the interaction efficiency and bandwidth.

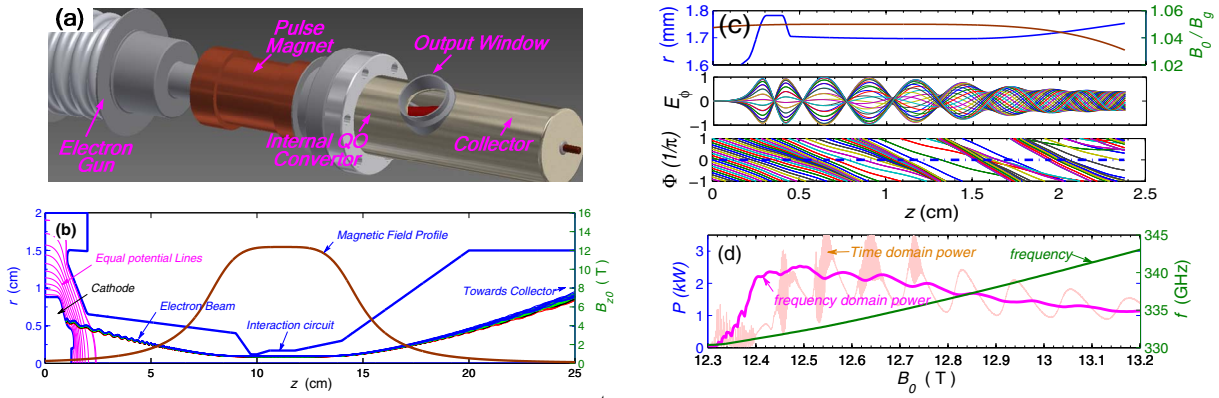

Fig. 1 (a) Mechanical design of the 0.33THz 1st harmonic TE_{62} mode gyrotron oscillator, (b) the electron-optical system with voltage 20kV and current 500mA, (c) the circuit and magnetic profiles, cold axial mode, and beam-wave phase-space bunching, and (d) the power and the tunable bandwidth.

The design of the 0.33THz 1st harmonic TE_{62} mode gyrotron is shown in Fig. 1(a). A pulse magnetic coil and Quasi-Optical mode convertor are going to be employed. And double-disc sapphire window will be installed to meet the requirement of broad bandwidth. The magnet injection gun shown in Fig. 1(b) is optimized to achieve α =1.3~1.5 in range of the magnetic field B_0=12.2~13 T. The pre-bunched interaction circuit system is demonstrated in Fig. 1(c). The performance shown in Fig. 1(d) indicates a peak power about 2.5kW (efficiency about 25%). Between the bands of 330GHz ~343 GHz, the output power is estimated to be higher than 1kW. Experimental test will be carried out next year. This THz gyrotron is with the advantage of compact and broadband tuning, and would become promising for THz remote detection/imaging and biomedical applications. This work was supported in part by the National Natural Science Foundation of China under Contract 11275206, 61471007, and the Seeding Grant for Medicine and Information Sciences of Peking University (2014-MI-01).