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300 GHz, 100 kW 級パルスジャイロトロンの開発
Development of a 300 GHz, 100kW Pulsed Gyrotron

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In the field of nuclear fusion research, gyrotrons play important roles in production, control, and diagnostic of burning plasmas. We have aimed at the development of a high power wave source for use in the measurement of collective Thomson scattering in Large Helical Device [1]. The performance requirements are an oscillation frequency around 300 ~ 400 GHz, an output power of more than 100 kW, and a pulse-duration of ~ 1 msec. The main components including a cavity, an internal mode-converter, and a magnetron-injection gun are precisely designed.

A cryogen-free 12 T superconducting magnet was introduced, and a cavity mode of $TE_{14,2}$ was selected at a fundamental harmonic frequency of 295 GHz. A simulation result predicts that a power of over 200 kW can be realized with an electron-beam voltage V_K of 65 kV, a current I_B of more than 10 A, and an electron velocity pitch factor α (the ratio of perpendicular to parallel velocities to the magnetic field line) of 1.2. A complicated field distribution transmitted from the cavity is converted to a Gaussian like beam by the internal mode converter. The configuration of a Vlasov-type launcher and additional mirrors was optimized under the restrictions for the available room associated with the small magnet bore diameter and the tube assembly processes.

The performance of the gyrotron is quite sensitive to the quality of the electron beam. As follows from the result of previous study [2], special attention was paid to produce a laminar electron flow with small velocity spread. An optimum structure of the electrodes was investigated with the EGUN code, and a quite small velocity spread (less than 5 %) was obtained in the cavity for α = 1.2 [3].

The operation test was preliminary carried out at a short pulse width (~ 5 μs) to find the optimum operation parameters [4]. The oscillation of the $TE_{14,2}$ mode was confirmed by the frequency measurements with a Fabry-Perot interferometer. The radiated wave distribution was evaluated by scanning a pyro-electric detector in a plane parallel to the output window (Fig. 1). The signal intensity is measured at intervals of 5 mm in both vertical and horizontal directions. A circular shaped, well focused beam is radiated. The output power was measured with a water load. Figure 2 shows the dependence of the output power and the efficiency on I_B. The desired value of 100 kW was successfully obtained at I_B = 5.5 A with a relatively high efficiency more than 30 %. The maximum power reached at 191 kW under the present operation conditions. The pulse duration of 110 kW output was extended up to 20 μs, which was restricted by the power supply.

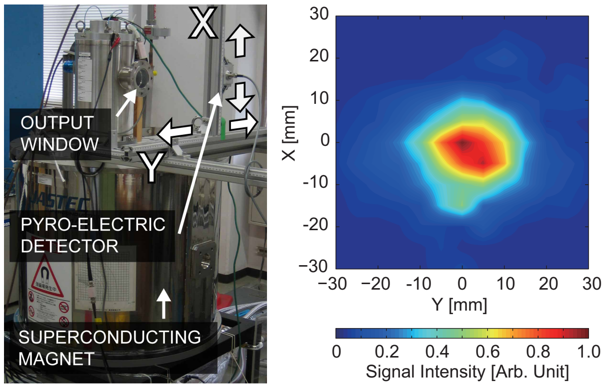

Fig. 1 Radiation pattern at 280 mm from the output window.

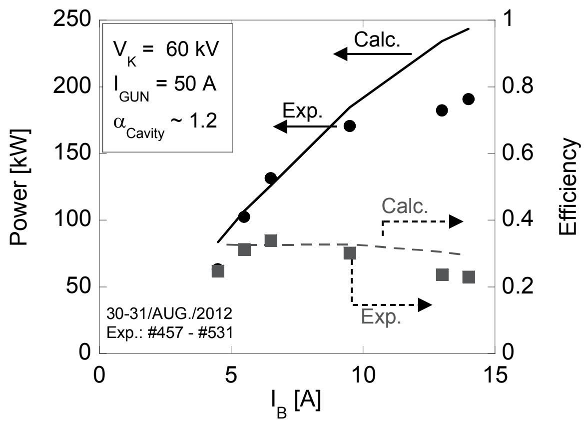

Fig. 2 Beam current I_B dependence of output power and efficiency

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[2] T. Saito et al., Phys. Plasmas **19**, 063106 (2012)
[3] Y. Yamaguchi et al., Plasma Fusion Res. **7**, 1205004 (2012)
[4] Y. Yamaguchi et al., IRMMW and THz 2012, Tue-A-3-5