§8. Development of High Power Sub-terahertz Pulse Gyrotron

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i) Abstract

Development of a high power sub terahertz pulse gyrotron has just started under collaboration between FIR-FU and NIFS for application to collective Thomson scattering from a high density plasma in the Large Helical Device. As a step to the final goal, a second harmonic gyrotron using a newly designed electron gun was fabricated aiming at 50 kW at around 400 GHz. Oscillation modes were carefully selected from the view point of mode separation. The electron optics was also considered in detail. Then, experiments have proved single mode oscillation of second harmonic modes and oscillation power of 50 kW at 350 GHz and 40 kW at 390 GHz.

ii) Background

Recently, development of high frequency gyrotrons as power sources for many applications has been intensified. Among those, development of a sub terahertz high power pulse gyrotron as a power source of collective Thomson scattering (CTS) diagnostics is a challenging task.

For a power source of CTS, fusion grade gyrotrons with frequencies from tens of GHz to 140 GHz are considered and experiments with these gyrotrons have started [1]. However, electromagnetic waves with these frequencies suffer from a strong plasma dispersion effect. Moreover, high level background electron cyclotron emission is a large noise source. Use of a sub-terahertz gyrotron will resolve these problems. We have started a challenging task of development of a high-power, sub terahertz pulse gyrotron with a frequency around 400 GH as a power source of CTS [2, 3] and succeeded in obtaining 50 kW at 350 GHz and 40 kW at 390 GHz.

iii) Results

The design of the developed gyrotron consists of three aspects. Use of a newly designed electron gun is the first aspect [4]. This electron gun generates a laminar electron beam with a good quality for 60 kV, 7 A and 70 kV, 10 A. The second aspect is selection of the oscillation modes that are well isolated from other competing modes. In particular, isolation from fundamental modes is very important for a second harmonic mode to oscillate as a single mode. We have searched many candidate modes and finally selected two modes TE6,5 and TE8,5. The electron optics is the third aspect and it is closely connected with the mode selection because the electron beam radius should coincide with that at the maximum of the coupling efficiency. The cavity dimensions thus determined are 2.99 mm in radius and 12 mm in length of the straight section.

Experiments have been carried out with this gyrotron. Figure 1 (a) shows oscillation intensities as functions of the magnetic field at the cavity with the beam voltage as a parameter. We have succeeded in gyrotron operation up 60 kV. The beam current is fixed at 5 A. Figure 1 (b) plots oscillation intensities measured through a high pass filter. The cut off frequency of this filter is 303 GHz. Then, peaks in Fig. 1 (b) stand for second harmonic oscillation. The modes shown in Fig. (b) were identified as the TE6,5 and TE8,5 modes from frequency measurement with a Fabry-Perot interferometer. Moreover, single mode oscillation was confirmed for these modes up to 60 kV and 11 A.

Oscillation power was measured with a carefully designed water load for measurement of a low average power. The maximum power so far obtained is about 50 kW for TE6,5 mode (350 GHz) and about 40 kW for TE8,5 mode (390 GHz). These powers are new records of gyrotron power obtained in this frequency range at second harmonic resonance.

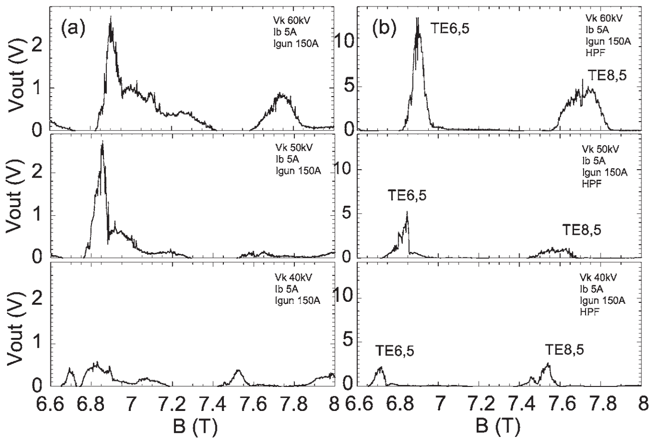

Fig. 1. Oscillation intensities are plotted as function of the magnetic field at the cavity with the beam voltage as a parameter. (a) Oscillation intensities were measured at an open end of a waveguide connected to the output window of the gyrotron. (b) A high pass filter was inserted in between the waveguide end and the detector.

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[2] T. Saito et al., "Development of a sub terahertz high power pulse gyrotron for collective Thomson scattering," IRMMW and THz 2008, W5D28.

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[4] V. N. Manuilov et al., "Electron gun for powerful short pulse gyrotron with operating magnetic field 8 T," Int. J. Infrared and Milli. Waves **27** (2008) 1103.