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

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i) Introduction

Development of a gyrotron suitable to a power source of collective Thomson scattering (CTS) diagnostics is a challenging task. At the moment, fusion grade gyrotrons with frequencies from tens of GHz to 140 GHz are considered for a power source of CTS and experiments with these gyrotrons have started [1, 2]. However, electromagnetic waves with these frequencies suffer from a strong plasma dispersion effect. High level background electron cyclotron emission is also a large noise source. Use of a sub-terahertz gyrotron will resolve these problems.

Development of a high power sub terahertz pulse gyrotron is under way with collaboration between FIR-FU and NIFS for application to CTS from a high density plasma in LHD [3]. As the first step, a second harmonic gyrotron of demountable type was fabricated and tested. Experiments have proved single mode oscillation of second harmonic modes and oscillation power 50 kW at 350 GHz with the TE6,5 mode and 40 kW at 390 GHz with the TE8,5 mode [4]. These values are the world records as second harmonic oscillation in the frequency range around 400 GHz.

ii) Fabrication of a sealed off gyrotron

Although we have succeeded in high power single mode sub-terahertz oscillation at second harmonic, some problems should be resolved for further higher power and stable oscillation. These are accuracy of gyrotron assembly, good vacuum condition in the gyrotron tube, fine tuning of the electron beam radius in the cavity, operation at high voltage to keep good electron beam quality, etc. Then, we have fabricated a sealed-off gyrotron for precise assembly and good vacuum condition. The shape of insulating ceramics of the electron gun has been also changed to suppress discharge on the surface of the atmosphere side. The electro dynamical design of the electron gun is the same as that of the demountable type gyrotron. This electron gun generates a laminar electron beam with a good quality for the electron beam setting of 70 kV, 10 A. The same oscillation modes as those of the demountable type gyrotron were chosen. The cavity dimensions of 2.99 mm in radius and 12 mm in length of the straight section are also the same values. Then, we can examine the effects of sealing off.

Figure 1 shows the photograph of the sealed-off gyrotron mounted on an 8 T superconducting magnet. This magnet is of liquid helium free type. The diameter of the room temperature bore is 100 mm. The length of the gyrotron is about 1250 mm. The vacuum window is made of a single crystal sapphire disc. The c axis is perpendicular to the disc surface. The gyrotron was sealed-off after baking at 400 ºC.

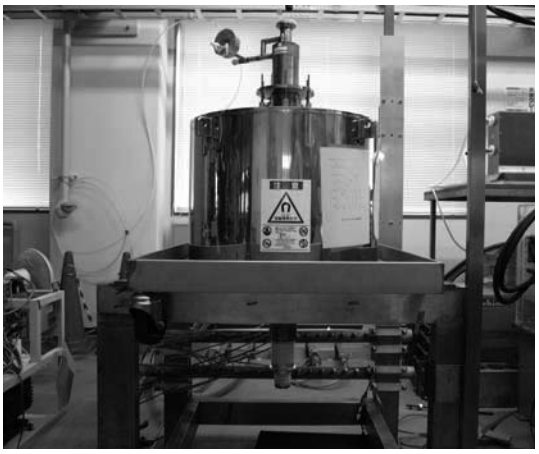

Fig. 1. Sealed-off gyrotron mounted on the 8 T superconducting magnet. This picture was taken before setup of the gun coils.

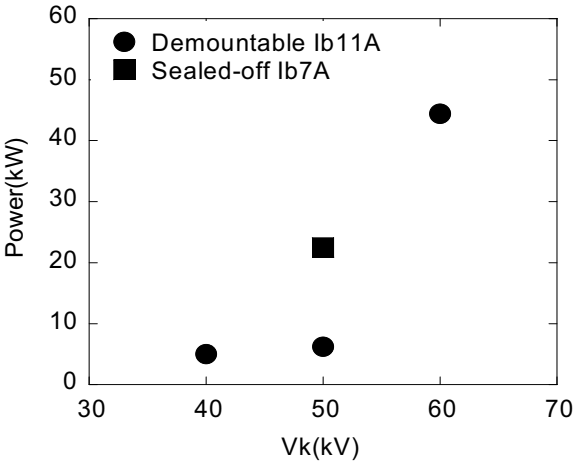

Fig. 2. Output power measured with a water load as functions of the beam voltage.

The experiment is now in the process of aging. Up to now, second harmonic oscillations with around 350 GHz and 390 GHz have been identified. As shown in Fig. 2, the oscillation efficiency at the beam voltage of 50 kV is much higher than that of the demountable type gyrotron. The beam voltage and the beam current will be increased from now on.

[1] Bindslev, H. et al., Phys. Rev. Lett. **97** (2006) 205005.
[2] Kubo, S. et al., Plasma and Fusion Res. **5** (2010) S1038.
[3] Saito, T. et al., IRMMW and THz 2009, R4D05.
[4] Notake, T. et al., Phys. Rev. Lett. **103**, (2009) 225002.