Progress of 300 GHz high order mode gyrotron development

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***Abstract*—A short pulse high order mode gyrotron for 300 GHz oscillation was tested. The designed oscillation mode is $TE_{32,18}$ and the gyrotron is operated with a 13T superconducting magnet. The output RF power and its frequency was measured. In the preliminary experiment, the 520 kW power was obtained at 299.85 GHz which corresponds to designed oscillation mode.**

I. INTRODUCTION

In the research and development of high power long pulse gyrotron for fusion application, 170 GHz was the maximum frequency at present, which is required for the power source of Electron Cyclotron resonance Heating and Current Drive (EC H&CD) on ITER. On the other hand, for the next generation fusion device such as DEMO, 200~300 GHz high power CW gyrotron will be required. In JAEA and Tsukuba University, as a preliminary research of the high frequency high power gyrotron, a short pulse 300 GHz gyrotron is designed, fabricated and tested. This presentation reports the recent results of detection of excited modes and measurement results of gyortron output power.

II. EXPERIMENTAL SETUP

The 300 GHz gyrotron is operated with 13 T liquid He fee super conducting magnet (SCM) which has a room temperature bore diameter of 110 mm. Figure 1 and 2 shows the configuration of gyrotron test stand where the 300 GHz gyrotron are settled in SCM. A diode type magnetron injection gun is utilized. A cavity is a conventional open cylindrical type, and its diameter is 31.6 mm. The oscillation mode to obtain the 300 GHz is $TE_{32,18}$. The output window is settled on the top of gyrotron and RF power is radiated without internal mode converter.

An RF dummy load is connected and RF power was measured by calorimetric method. The dummy load has a waveguide port for RF detection. Figure 3 shows the configuration of RF detection system. The heterodyne detection system using a 22nd harmonic mixer was connected to the port. This system was utilized for measurement of RF frequency and detection of oscillation. Measured RF signal was converted to IF signal at range of DC-2.5 GHz by the mixer. IF signal was provided to mode detection channels which is a set of a band pass filter and a detector which is corresponding to each oscillation mode. For mode detection, band pass filters were selected for 300 GHz as the main mode, 296 GHz as the low side mode, and 302 GHz as nearby mode.

The output window of the gyrotron was designed for 300 GHz. The additional SiO_2 disk was utilized to control the reflection by window at nearby mode oscillation. The thickness of the disk was 1.98 mm. When the disk is settled on the gyrotron window, the minimum reflection was obtained at 301.8 GHz and reflection at 300GHz was increased up to 20%. The gyrotron was operation at both condition with and without the SiO_2 disk to compare the effect of reflection to cavity oscillation.

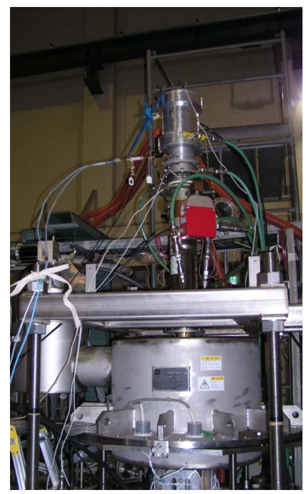

Fig.1 The 300 GHz gyrotorn and 13T liquid He free super conducting magnet settled in the test stand. RF dummy load is connected on the top of gyrotron.

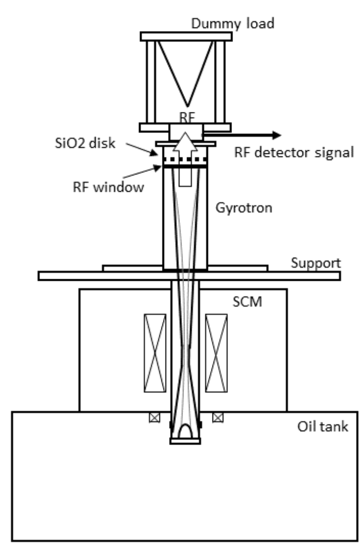

Fig.2 The schematic of the test stand configuration for 300 GHz gyrotorn experiment.

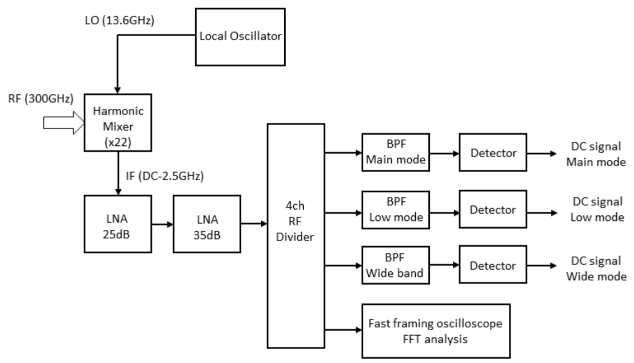

Fig.3 The configuration of RF detection system utilized for RF frequency measurement and oscillation mode detection. Three channels were utilized for three modes detection Narrow band filters were utilized in two of them for detection of main and low mode and wide band filter was utilized to detect nearby mode with comparison of main mode signal

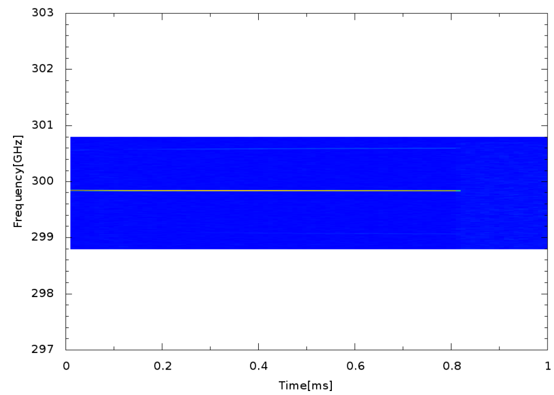

Fig.4 RF frequency spectrum for 1 ms pulse. The measured frequency was 299.85 GHz which corresponds to $TE_{32,18}$ mode.

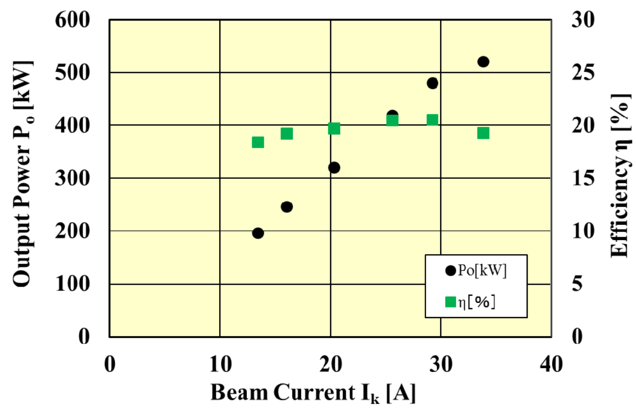

Fig.5 The dependence of RF power and oscillation efficiency on beam current at main mode operation with SiO2 disk on the output window. Voltage was constant at 80 kV.

III. Experimental Results

The RF frequency of gyrotron output was measured to determine oscillation mode in the cavity. Figure 4 is the time trace of frequency spectrum of 1 ms RF pulse from the 300 GHz gyrotron. The measured RF frequency at main mode oscillation was 299.85 GHz which identifies the designed operation mode and it was stable during the pulse. The operation condition was 80 kV and the beam current is 23 A.

Then operation map was obtained by changing main and gun magnet field. The oscillation condition of the main mode was very limited and nearby mode of which frequency was 301.8 GHz was excited at wide parameter range. The rotation direction of the nearby mode was opposite from designed mode and the mode is assumed the counter mode of the main mode. Since the counter mode is easily excited at close operation parameter, the optimization of main mode operation parameter was not sufficient and the oscillation efficiency of the main mode was lower than 20%.

The SiO_2 disk was settled to compare the oscillation mode. The operation mode map was acquired under higher reflection rate. As a result, oscillation of 299.85 GHz was obtained at wide range of magnetic field. Then the operation parameter of main mode was measured for this condition. Figure 5 shows the power and efficiency dependence on beam current for 299.85 GHz main mode oscillation. The 520 kW of RF power was obtained at 33.8 A. The oscillation efficiency was 19.3 %. The maximum efficiency was 20.6% which was obtained at 29.2A operation.

IV. Summary

The 300 GHz high power gyrotron was examined. The RF frequency was measured and oscillation mode was determined. The parameter maps of oscillation mode were obtained for different reflection of gyrotron window. As a result, the main mode oscillation was obtained at wide parameter range with high reflection condition. As a result, 500 kW of RF power was obtained at 19 % of oscillation efficiency at main mode.