§8. Study of High Power Sub Terahertz Pulse Gyrotron for Application to Collective Thomson Scattering Diagnostics in LHD

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i) Introduction

Use in collective Thomson scattering (CTS) diagnostics of fusion plasmas is mostly fit for gyrotrons on their distinctive ability of high power at high frequencies. At present, gyrotrons around 100 GHz developed for electron heating are used in CTS diagnostics [1], [2]. EM waves within this frequency band suffer from severe refraction and/or absorption in a plasma. Moreover, strong electron cyclotron emission is a large noise source. Use of a gyrotron in a sub-THz frequency range will resolve these problems.

We have been developing high power sub-THz gyrotrons. Firstly, second harmonic (SH) oscillation was used. We have succeeded in high power single mode oscillation [3] and realized a maximum power approaching 100 kW at 389 GHz [4]. However, mode competition with fundamental harmonic (FH) modes has prevented achievement of much higher power [5].

Then, we have started a task of development of an FH mode sub-THz gyrotron under the NIFS collaboration study scheme and succeeded in oscillation approaching 250 kW with a prototype gyrotron [6], [7]. Then, an actual gyrotron for use in CTS diagnostics in LHD was fabricated based on the same design concept of that of the prototype gyrotron.

ii) Design of an actual gyrotron

The sub-THz gyrotron for CTS will be operated in a pulse mode. Therefore, a moderately over-moded cavity is used to satisfy simultaneously avoidance of mode competition and a low Ohmic loss on the cavity surface. The frequency of the actual gyrotron is set at 303 GHz that is slightly higher than the fourth harmonic of the on-axis electron cyclotron frequency of LHD of standard operation to reduce an ECE noise. The oscillation mode is the $TE_{22,2}$ mode belonging to the same whispering gallery mode family as the $TE_{14,2}$ mode of the prototype gyrotron. The mode number has increased to meet a pulse width and a duty ratio up to 10 ms and 10%, respectively.

Figure 1 plots the dependencies of the oscillation power and the efficiency on the beam current I_B. The beam voltage V_k is 65 kV. An oscillation power higher than 300 kW is expected at I_B of 15 A with the pitch factor α of 1.2. Further higher power approaching 500 kW can be expected at I_B of 20 A with a practical value of α = 1.3. The oscillation efficiency is substantially higher than 30%. The average Ohmic loss density is lower than 1.4 kW/cm^2 for 300 kW and 10% duty ratio oscillation. The electron gun was newly designed and optimized for the $TE_{22,2}$ mode by using the same design principle as reported in Ref. [8]. An electron beam of high quality with the expected α values and sufficiently small velocity spreads can be generated up to I_B = 20 A.

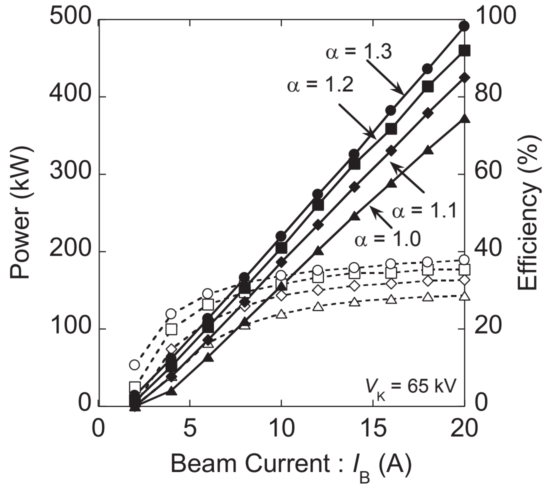

Fig. 1 Oscillation power and efficiency of the design calculation are plotted with closed circles and open circles respectively as functions of the beam current. The different symbols correspond to different values of the pitch α from 1.0 to 1.3.

The actual gyrotron has been fabricated. A picture of the gyrotron is shown in Fig. 2. This gyrotron will be mounted on a liquid He-free 12 T superconducting magnet. The diameter of the room temperature bore is 100 mm. An internal mode converter is installed into a rather narrow room. The electron gun design is also compatible with the mode-convertor. The vacuum window is made from a single crystal sapphire disk of c-axis cut.

Fig. 2 Picture of the fabricated actual gyrotron.

We will start oscillation test very soon in FS 2015.

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