§12. 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. We have reported over 200 kW oscillation of a prototype gyrotron [6]. In this report, we show new experimental results approaching 250 kW and the preliminary design work for an actual gyrotron.

ii) Experimental results

The prototype gyrotron is mounted on a liquid He-free 12 T super conducting magnet, the diameter of the room temperature bore of which is 100 mm. The electron gun was very carefully designed for realization of a high quality electron beam at large beam currents [7]. This gyrotron is equipped with an internal mode convertor to deliver a Gaussian beam. It is of sealed-off type for high power oscillation. The vacuum window is made from a single crystal sapphire disk of c-axis cut. The design oscillation mode and the frequency are co-rotating $TE_{14,2}$ mode and 295 GHz, respectively.

Succeeding the previous result [8], operation conditions of the gyrotron was carefully optimized and the beam current I_b was increased up to 14 A. The result is indicated in Fig. 1. It plots the window power P measured with a water load and the efficiency as functions of I_b. The value of P increases with I_b approaching 250 kW at I_b of 14 A and V_k of 65 kV. The efficiency gradually decreases with I_b but still higher than 25%.

The $TE_{14,2}$ mode is well isolated from possible competing modes and very stable single mode oscillation is obtained for wide rages of operation conditions.

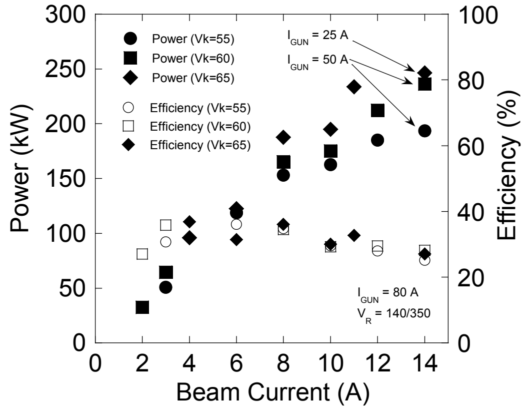

Fig. 1 Oscillation power and efficiency are plotted with closed circles and open circles respectively as functions of the beam current.

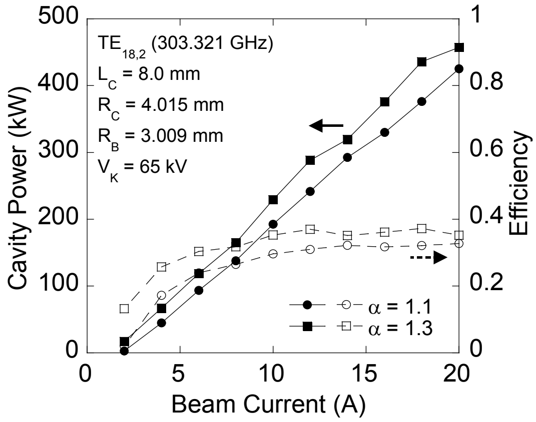

Fig. 2 Preliminary design calculation of the actual gyrotron for the case of the $TE_{18,2}$ mode..

iii) Design of an actual gyrotron

The design concept to realize single mode high power oscillation of sub-THz gyrotron has been verified with the prototype gyrotron. An actual gyrotron will be designed upon this concept and, in the fiscal year 2014, we will manufacture a gyrotron that will be really used in the CTS diagnostics on LHD. The power target is 300 kW with the pulse width up to 1 ms.

Figure 2 shows an initial design calculation for the case of $TE_{18,2}$ mode. Over 300 kW power is expected. Now, works are under way for the final decision of the oscillation mode including the design of an electron gun congruent with the oscillation mode.

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