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

Saito, T., Yamaguchi, Y., Tatematsu, Y., Kasa, J., Kotera, M., Idehara, T. (Univ. Fukui, FIR FU), Nishiura, M. (Univ. Tokyo, Frontier Sciences), Ikuno, S. (Tokyo Univ. Technology), Fujita, Y. (Nagoya Univ., Graduate School Eng.), Shimozuma, T., Kubo, S., Tanaka, K., Yoshimura, Y., Kobayashi, S., Ito, S., Tsujimura, T., Nakamura, H.

i) Introduction

Gyrotrons with frequencies around 100 GHz for electron heating are currently used in CTS diagnostics[1,2]. However, the probe waves suffer from severe refraction and/or absorption in plasmas. Moreover, strong electron cyclotron emission becomes a large noise source. Sub-THz waves are almost free from those problems. Therefore, a high power sub-THz gyrotron is required in CTS diagnostics in LHD. The probe wave power should be higher than 100 kW to realize a sufficient signal to noise ratio[3].

Firstly developed second harmonic gyrotron demonstrated single mode oscillation approaching 100 kW at 389 GHz[4]. However, a competing fundamental harmonic mode prevented to enhance the power[5]. We have then developed a fundamental harmonic prototype gyrotron and verified the design concept for stable single mode oscillation[6]. By using the same design concept, a gyrotron for practical use in CTS diagnostics in LHD has been designed and fabricated. This paper reports the results of oscillation test.

ii) Results of Oscillation Test

The sub-THz gyrotron for CTS is operated in a pulse mode. The frequency is 303 GHz. A moderately over-moded cavity is used to satisfy simultaneously avoidance of mode competition and a low Ohmic loss on the cavity surface. 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 extend the pulse width and the duty ratio up to 10%.

The dependence of the oscillation power and the efficiency on the beam current I_B was calculated and an oscillation power higher than 300 kW was expected for the beam voltage V_k of 65 kV and the beam current I_B of 15 A with the pitch factor of 1.2. A new electron gun was used with the design to generate a high quality electron beam[7]. This gyrotron is mounted on a liquid He-free 12 T superconducting magnet. An internal mode converter is installed.

Figure 1 plots the results of high power oscillation test in addition to the reported results[8,9]. In particular, the highest power > 320 kW was newly attained. The efficiency is higher than 30% except the low beam current. Further higher power approaching 400 kW is expected with increasing I_B after conditioning.

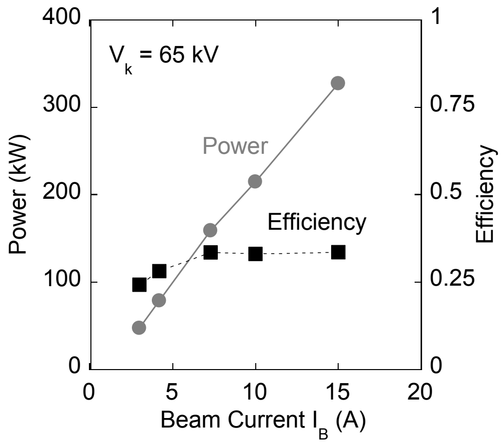

Fig. 1 Output power measured with a water load and efficiency as functions of the beam current. The beam voltage is 65 kV. Other parameters such as the modulation anode voltage are optimized for each beam current. The pulse width was set at 4 μs.

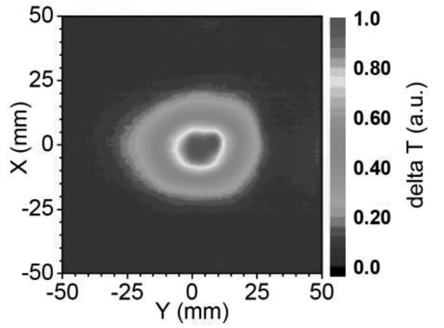

Fig. 2 Radiation pattern measured at a distance of 80 cm from the vacuum window flange. This pattern was obtained as temperature increase on a vinyl chloride plate measured with an infrared camera.

Figure 2 shows the radiation pattern measured at a distance of 80 cm from the vacuum window flange. A high quality beam is delivered from the vacuum window.

Competing modes were searched over a wide frequency band and no possible competing mode was observed throughout the pulse width including the turn on and the turn off phases. The frequency spectrum is very narrow and stable during the pulse width. The pulse width was extended up to 50 μs for 200 kW level oscillation.

The oscillation test results have proved that this gyrotron can be practically used in CTS diagnostics in LHD.

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