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

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i) Introduction

Development of vacuum electronic high-power sources in the terahertz band for application to various fields has intensified.[1, 2] A high power sub-terahertz gyrotron is required for application to collective Thomson scattering (CTS) diagnostics. Now, existing fusion grade gyrotrons with frequencies around 100 GHz are used in CTS.[3, 4] However, applicable parameter range is rather limited.

FIR-FU is developing a high power sub-terahertz pulse gyrotron under collaboration with NIFS for measurement of CTS signal from a high density plasma in LHD.[5] As the first step, a second harmonic gyrotron of demountable type was fabricated. Experiments with this gyrotron have proved single mode oscillation of second harmonic modes and oscillation power of 50 kW at 350 GHz and about 40 kW at 390 GHz.[6] These values were the world records as second harmonic oscillation in the frequency range around 400 GHz. The second step experiment aiming at a further higher power has then started in FY 2009 with a newly fabricated sealed-off type gyrotron. A new power record of 62 kW at 388 GHz was obtained in FY 2010.[7]

ii) Experiment for further higher power.

The sealed-off type gyrotron also works at the second harmonic frequencies. Operation of the gyrotron is in pulse mode. The pulse length is several microsecond and the repetition rate is less than 10 Hz. The $TE_{1,8}$ and $TE_{17,2}$ modes have been selected as oscillation modes because these modes are well isolated from the competing fundamental $TE_{4,3}$ mode than the $TE_{8,5}$ mode used in the first step gyrotron. A record power of 62 kW was obtained with the $TE_{1,8}$ mode. However, try for further higher power with this mode failed because of power saturation with the beam current. One probable reason is deterioration of the electron beam quality at large beam currents.

Another likely reason of the power saturation is the rather low beam field coupling coefficient C_{BF} of the $TE_{1,8}$ mode at the beam radius R_b = 1.8 mm. The bottom trace of Fig. 1 represents C_{BF} of the $TE_{1,8}$ mode as functions of R_b. The $TE_{17,2}$ mode has a larger value of C_{BF} at R_b = 2.1 mm as shown in the upper trace of Fig. 1. This condition can be realized by modification of the electron gun. Then a new electron gun was designed, fabricated, and mounted on the gyrotron.

Oscillation tests with the new electron gun achieved a higher power record of 83 kW with V_k = 60 kV and I_b = 10 A. The measured oscillation frequency was 388.9 GHz. It is almost equal to the resonance frequency f_c of the $TE_{17,2}$ mode. Single mode oscillation was confirmed by careful check of the transmission signal through a Fabry-Perot interferometer. The total oscillation efficiency was 14%. Figure 2 plots these new power records for second harmonic gyrotron oscillation in the sub-terahertz region.[8, 9] Previous power records[6, 10] are also shown in this figure. Thus, we have succeeded in attaining single-mode oscillation of second harmonic modes at power levels approaching to 100 kW.

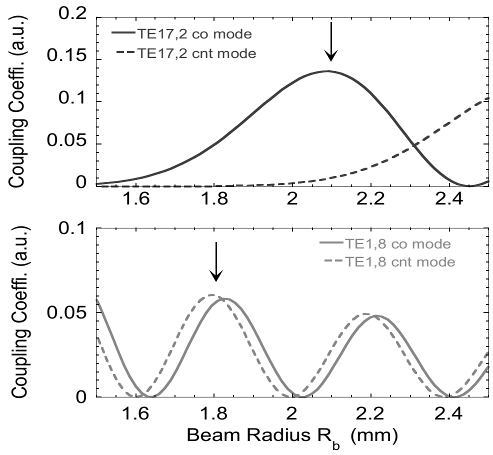

Fig. 1. Radial distribution of coupling coefficient of $TE_{17,2}$ and $TE_{1,8}$ modes. The solid line and dashed line stand for the co and counter rotating modes, respectively.

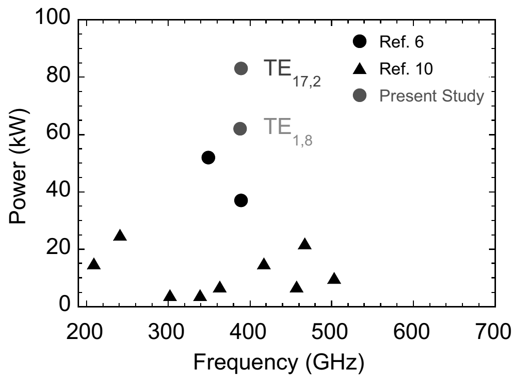

Fig. 2. Power records versus frequency.

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