§2. Development and Application of High Performance THz Gyrotron

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I. Objectives

In the development of high frequency gyrotrons of THz range, University of Fukui has realized gyrotron oscillation over a wide frequency range of hundreds of GHz by proper selection of the oscillation mode and the magnetic field strength, and the world record of the highest gyrotron frequency of 889 GHz. Very recently gyrotron oscillation at a frequency exceeding 1 THz has been achieved. Application of THz gyrotrons is expected to various fields, such as plasma diagnostics, ESR spectroscopy, highly sensitive NMR, communication, medical diagnostics and treatment, etc. Therefore, development of THz gyrotrons is strongly required.

NIFS has high level technologies such as analysis of gyrotron oscillation, high quality power transmission, etc. The main objective of this study is further improvement of development of high frequency THz gyrotrons by combining these knowledge and technology with achievements in Fukui. We have also aimed at development of a peniotron as a power source in the THz range.

II. Method and procedure

Collaborative study on the analysis of the radiation pattern of a 0.3 THz CW gyrotron in Fukui was done in 2006 and the oscillation characteristics of this gyrotron were well understood. At the same time, a possibility of application of a sub terahertz gyrotron to collective Thomson scattering (CTS) in LHD was pointed out. All members of this study recognized its importance. This trial would widen the application field of THz gyrotrons and contribute to fusion study. In addition, there was a plan to develop a sub terahertz pulse gyrotron in Fukui. Then, we have started a collaborative study for development of a sub terahertz gyrotron for CTS in LHD based on this plan. We refer to this gyrotron as the first step gyrotron.

III. Results

Figure 1 provides an example of data of the first step gyrotron[1]. It plots measured frequency as a function of the magnetic field strength at the cavity. Several fundamental oscillation modes considered to be TE_{23}, TE_{03}, TE_{52} have been observed. For application to CTS in LHD, frequency in the range of 400 GHz, where electron cyclotron emission

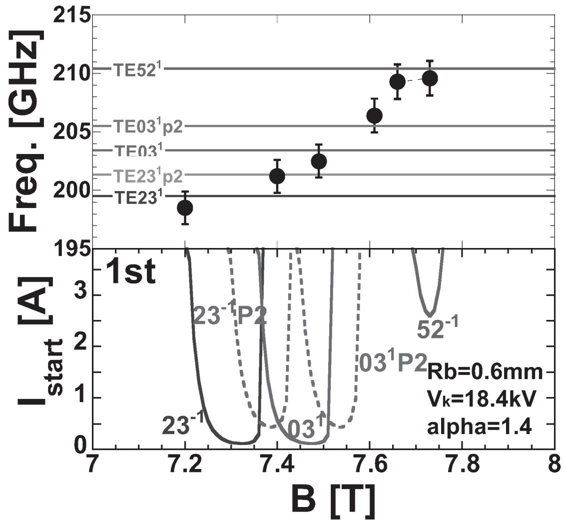

Fig.1 The upper panel plots the measured frequency as a function of the magnetic field strength at the cavity. The horizontal lines labeled by mode number indicate the resonance frequencies of each mode. The lower panel shows the starting current of each mode.

(ECE) noise would be strongly reduced, is preferable. This frequency range can be realized at the second harmonic oscillation. It should be single mode oscillation. Up to now, we have observed several oscillation modes at second harmonic in the 400 GHz range. These modes were confirmed to be single mode oscillation. This supports the present plan to develop a 400 GHz range gyrotron of second harmonic for CTS in LHD.

Along with development of gyrotron, a numerical code was developed for analysis of the CTS process. Frequency spectra of the electromagnetic wave scattered from an LHD plasma were calculated for a scattering configuration that can be realized in LHD. Optimum gyrotron frequency to reduce the ECE noise was also studied by using a numerical code of radiation transfer. Use of a gyrotron around 400 GHz is promising. Ray tracing calculation has shown that the incident and scattered wave in the range of 400 GHz propagate with a negligible bending as long as the electron density is not extremely high.

In summary, development of a sub terahertz high power pulse gyrotron has started under collaboration between NIFS and University of Fukui. In the experiment of the first step gyrotron, single mode second harmonic oscillation has been observed in the range of 400 GHz. This frequency range is preferable for CTS in LHD. Development of the second step gyrotron will start in the fiscal year 2008. A new electron gun is to be used and a higher power is expected.

1) T. Saito, T.Hayashi, Y. Tatematsu, T. Notake et al., “Development of a sub terahertz high power pulse gyrotron” Conf. Digest of 32nd IRMMW & 15th THz (2007) pp.164-165.