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Mode Identification of High Power 77 GHz Gyrotron in LHD
LHDにおける高出力77 GHzジャイロトロンの発振モード同定

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Collective Thomson scattering (CTS) system has been developed at the Large Helical Device (LHD) using electron cyclotron resonance heating (ECRH) system with a high power 77 GHz gyrotron. The gyrotron output is modulated to subtract the back ground electron cyclotron emission (ECE) from received signals. Spurious mode power is excited during the turning on/off phase of the gyrotron power. Such spurious mode oscillation can make the CTS analysis complex or even damage the sensitive CTS receiver. Therefore, it is important to suppress or minimize spurious mode oscillation. As the first step to suppress spurious modes, we measured the oscillation frequency of 77 GHz gyrotron output and observed the spurious radiation modes. The frequency of one of the spurious modes was 74.7 GHz. The spurious mode is supposed to be $TE_{17,6}$ from cavity mode and starting current calculation.

1. Introduction

Collective Thomson scattering (CTS) diagnostic in the Large Helical Device (LHD) has been developed as a method for measuring bulk and fast ion velocity distribution functions in high density and high temperature plasmas. Recent development of high power radiation sources, like mega-watt class gyrotrons and relevant transmission/antenna system, enable to detect the scattered electromagnetic wave by small electron density fluctuations associated with the thermal ion motion in plasmas [1, 2]. The CTS diagnostic has been applied utilizing the existing electron cyclotron resonance heating (ECRH) system with high power mega-watt gyrotrons at the frequency of 77 GHz [3, 4].

2. Spurious radiation of 77 GHz gyrotron

The power of the CTS probe beam is modulated to subtract the background electron cyclotron emission (ECE). Fig. 1 shows (a) an example of the RF signal of 77 GHz gyrotron and (b) one of the CTS signals. CTS signals were obtained by a high sensitive heterodyne radiometer. The details of the CTS receiver are described in the reference [5]. During the turning on/off phase of the modulation, the spurious mode radiations are superimposed on the measured signal which is the sum of CTS

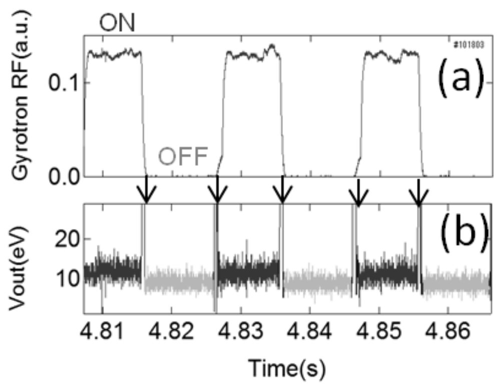

Fig. 1. Time evolution of (a) the RF signal of 77 GHz gyrotron, (b) CTS signals obtained in a high sensitivity heterodyne radiometer system [5]. Arrows indicate the spikes due to a spurious mode oscillation in Fig. 1 (b).

component and background ECE. For the precise estimation of the CTS spectrum, such spikes due to the spurious mode and background ECE have to be correctly subtracted from the received signal. Additionally, the spurious radiation signals even small in power can make saturation or overload of one or several IF amplifiers. Therefore, it is important for precise CTS measurement to develop a gyrotron operation method to suppress or minimize such spurious mode oscillation without degrading the main mode power.

3. Frequency measurement of the 77 GHz gyrotron and identification of the spurious radiation mode

As the first step for suppressing the excitation of the spurious mode, we measured the temporal evolutions of the frequency of the oscillations in the output of 77 GHz gyrotron by using a heterodyne receiver with 40 channel filter banks and a fast sampling oscilloscope. The receiver has a narrow band notch filter in the range of 76.95±0.2 GHz, to suppress the stray radiation at the main frequency for CTS diagnostic. The anode voltage relative to the cathode is optimized to give a stable and efficient gyrotron oscillation under given beam current and magnetic field condition. The time evolution of the anode voltage at the starting up phase and half modulation period is shown in Fig. 2 (a). Optimum anode voltage, 45 kV, is settled at 3 ms after the starting up. It is modulated between 45 kV and 35 kV after that with 50 Hz. The radiation frequency was measured at the anode voltage phases of (A) rising, (B) stable and (C) falling. The spurious mode frequency was observed at about 74.7 GHz when the anode voltage transits from 24 kV to 45 kV and 45 kV to 35 kV. Fig. 2 (b) shows the spectrogram during the anode voltage rising phase (indicated by a hatched region (A) in Fig. 2 (a)). Relatively strong oscillation at 74.7 GHz appeared during the anode voltage range between 27 kV to 40 kV. The main output $TE_{18,6}$ mode at 77.0 GHz was observed when the anode voltage settled at 45 kV. The spurious mode frequency is close to the calculated one of the $TE_{17,6}$ mode for a given cavity. Furthermore, The starting current calculation code [6] shows that the $TE_{17,6}$ mode is relatively easy to start oscillation as compared with the other modes under the measured condition. Therefore, the spurious mode is considered to be $TE_{17,6}$. This mode is considered to oscillate during the transition phase of the anode voltage and the electron beam current of the gyrotron. The main and powerful $TE_{18,6}$ mode starts to oscillate after the anode voltage settled at 45 kV by mode competition with $TE_{17,6}$.

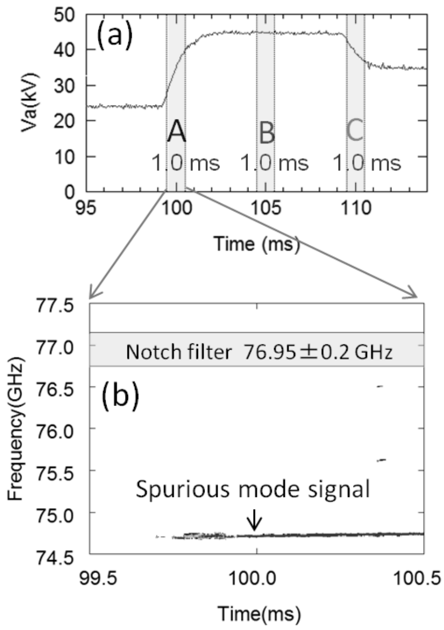

Fig. 2. Time evolution of (a) the anode voltage and (b) spectrogram of the output power frequency of 77 GHz gyrotron during the anode voltage range between 27 kV to 40 kV.

4. Conclusion

We measured the frequency evolution of 77 GHz gyrotron output power for a modulated pulse. As the result, the spurious mode frequency was about 74.7 GHz at the transition of the anode voltage. We consider that the observed spurious radiation is the $TE_{17,6}$ from the calculation of the resonance condition of the cavity and the starting current of the gyrotron. We will search the way to suppress or reduce the spurious radiation of $TE_{17,6}$ mode by optimizing the magnetic field strength and/or other gyrotron operation parameters experimentally with the help of mode competition calculation code [6].

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