§2. Oscillation Frequency and Spectra of High Power Gyrotrons for ECH Experiments

Shimozuma, T., Ito, S., Kobayashi, S., Mizuno, Y., Takita,Y., Kubo, S., Idei, H.

High oscillation efficiency of a gyrotron is one of crucial demand for over mega watt, long pulse operation. The efficiency can be affected by an electron beam quality, and degraded by spurious oscillations. We have been researching such spurious oscillation caused by some beam instabilities in the gyrotron for obtaining high power, high efficiency and steady operation.

In these researches, we installed a frequency spectrum measurement system, which consists of a high frequency spectrum analyzer (Agilent Technology E4407B) and millimeter wave range mixers (Agilent Technology: harmonic mixer 11970W 75–110 GHz and Oleson Microwave Labs: harmonic mixer M06HWD 110–170 GHz). The system covers frequency ranges of 9 kHz–26.5 GHz and 75 GHz–170 GHz, which satisfies frequencies of our gyrotrons with 82.7 GHz, 84 GHz and 168 GHz.

In the measurement, sampling signals from a gyrotron was picked up by a copper tube (ϕ6 mm o.d.) and guided to the mixer. The sweep of the spectrum analyzer was triggered by a rise timing of the gyrotron acceleration voltage. The trigger timing could be delayed by a built-in delay time generator. Fig. 1 a) shows a frequency spectrum of the 84 GHz/0.8 MW/3 sec. GYCOM gyrotron. The spectrum was obtained at 10 ms after the start of 30 ms oscillation pulse. The width of the spectrum is below 100 kHz (Resolution and Video Band Width are both 30 kHz). A single mode oscillation was observed. Time variation of the central frequency of the spectrum is plotted in Fig. 1 b). It was measured shot by shot base. The central frequency gradually decreases from 84.07 GHz to 83.87 GHz ($\Delta f \simeq 200$ MHz) during 2 sec. pulse. This is due to the thermal expansion of the interaction cavity of the gyrotron.

The frequency spectrum of a 168 GHz/0.5 MW/1 sec. Toshiba gyrotron was also measured. Fig. 2 a) shows two oscillation frequencies (f=167.62 GHz and 168.27 GHz). The higher frequency mode is the $TE_{31,8}$ main mode of this gyrotron, and high output power comes out of the gyrotron window. The lower frequency mode could be identified as the competing mode of $TE_{28,9}$. The width of the spectrum is below 500 kHz as shown in Fig. 2 b). A single mode oscillation could not be observed even in a short pulse operation of 10 ms. This phenomena leads to degradation of the oscillation efficiency.

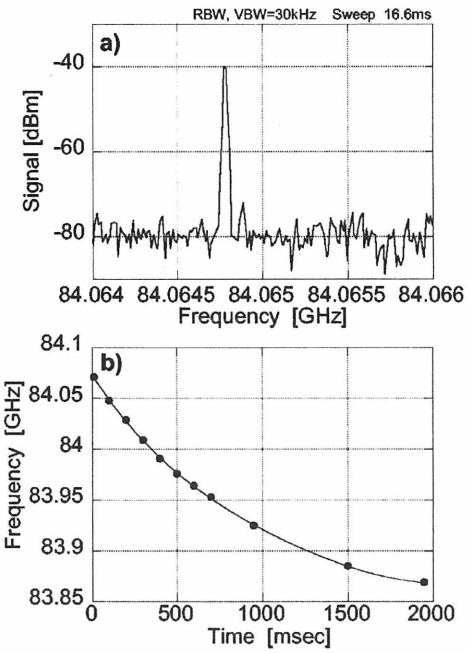

Fig. 1: a) Frequency spectrum of 84 GHz gyrotron oscillation. b) Temporal variation of the central frequency is plotted during 2 sec. pulse. The data were obtained shot by shot base.

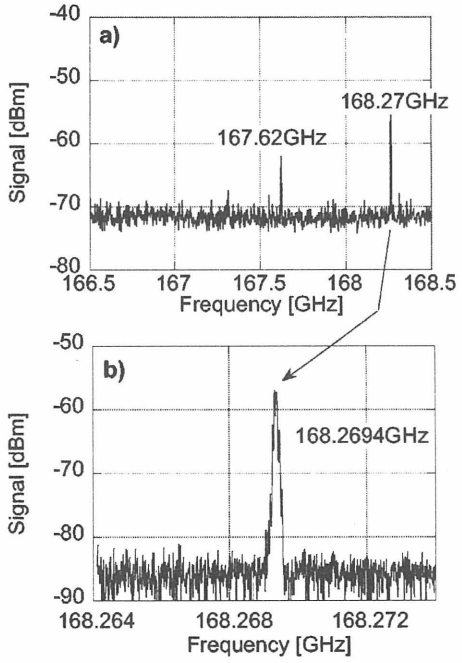

Fig. 2: a) Frequency spectrum of a 168 GHz gyrotron (2 GHz span). b) The expanded spectrum of the same shot(10 MHz span).