Startup Scenarios in MW-Class Gyrotrons With Diode and Triode-Type Electron Guns

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***Abstract*—Start-up scenarios for gyrotrons with diode and triode-type electron guns have been analyzed numerically by the use of code MAGY. Simulations have shown that in gyrotrons with diode-type electron guns a fast voltage rise allows one to avoid excitation of parasitic modes. In gyrotrons with triode-type electron guns, excitation of parasitic modes can be avoided by proper choice of the mod-anode voltage delay time.**

I. Introduction

To handle ohmic losses in cavity walls, MW-class long pulse (CW) gyrotrons should operate at very high-order modes. In order to avoid excitation of parasitic modes, it is necessary to carefully choose the start-up scenario[1]. When gyrotrons are used for plasma applications, generation of parasitic modes during the voltage rise and fall times is very dangerous for the receiving channels of numerous diagnostic tools. In this work, some new ideas for the solution of the problem are presented. In particular, we consider fast voltage rise in gyrotrons with diode-type electron guns and start-up scenarios in gyrotrons with triode-type electron guns.

II. Results

Since gyrotrons with diode-type guns are widely used nowadays, it is well known that, as the beam voltage rises, first, a high-frequency parasitic mode is excited. Then, at higher voltage, this mode can be replaced by the desired one. Recent progress in the development of fast solid-state switches for high-voltage modulators makes it possible to significantly shorten the voltage rise time. We have analyzed the effect of voltage rise time shortening numerically with the use of code MAGY[2]. The simulations were done for the 2 MW, 165 GHz, FZK coaxial gyrotron. The voltage was rising from 50 kV to 78 kV in 2.8 microseconds. It was shown that shortening the rise time from 2,800 ns to 500 ns does not bring to significant changes in the scenario. However, the shortening to 300 ns reduces the power level of parasites to less than 1 kW. Further shortening to 100 ns reduces their level to less than 1 W. But if the voltage rise time shortens even more, the low-frequency parasite is excited instead of the desired mode.

Such behavior can be interpreted as follows. Excitation of a high-frequency parasite is avoided when the voltage rises fast enough because this mode has a rather small growth rate (small pitch-angles at low voltages). So the gyrotron passes through the region of its self-excitation too fast. Therefore its amplitude which starts to grow from the noise level does not reach significant level when the self-excitation conditions for the desired mode are fulfilled. The replacement of the desired mode by a low-frequency parasite at very short voltage rise times can be explained by the same argument. Now the gyrotron passes through the region of the self-excitation of the desired mode too fast. Therefore, when the device enters the region of excitation of the parasitic mode, the desired mode amplitude is still too low to survive.

In the case of triode-type guns, the designer has a freedom to manipulate with relation between the beam voltage and the mod-anode voltage during the voltage rise time[3] (see Fig. 1).

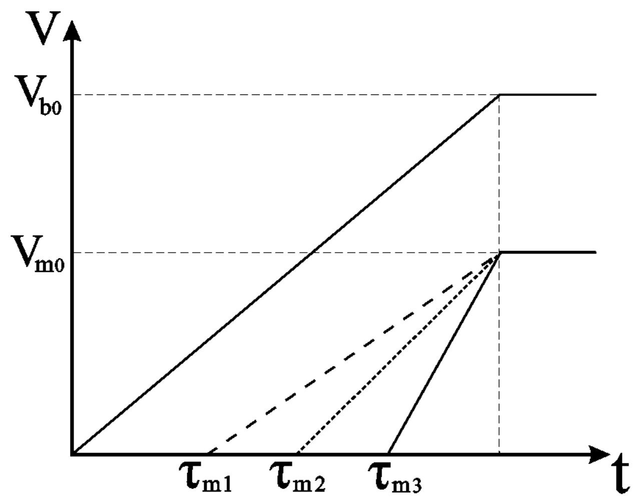

Fig. 1. Rise of the beam and mod-anode voltages in time. V_{b0} and V_{m0} are the maximum values of the voltages, τ_{mn} correspond to different delay times between the two.

We have obtained new results for the case when the delay time between the start of the beam voltage and the start of the mod-anode voltage is varied. In our simulations, we were using the parameters of the 1 MW CW, 170 GHz gyrotron developed at Japan Atomic Energy Research Institute (JAERI) for ITER and 1 MW long pulse, 110 GHz "Toto" gyrotron developed at Communications and Power Industries (CPI) for plasma heating experiments at Doublet-3D tokamak. These gyrotrons have triode-type electron guns.

It should be mentioned that in these simulations it is the relative value of the delay time to the beam voltage rise time that is important, not its absolute value. Therefore, in order to have not very long simulation times, we have taken the rise time of the beam voltage equal to 2 microseconds. When the delay time is small, the gyrotron operation is similar to the one with a diode-type electron gun: first, a high-frequency parasite is excited and then it is replaced by the desired mode (see Fig. 2a). When the delay timed increases from about 200 ns to 400 ns the desired mode is excited first and remains stable up to

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the nominal voltage (see Fig. 2b). For large delay times, the low-frequency parasite mode is excited and remains stable (Fig. 2c).

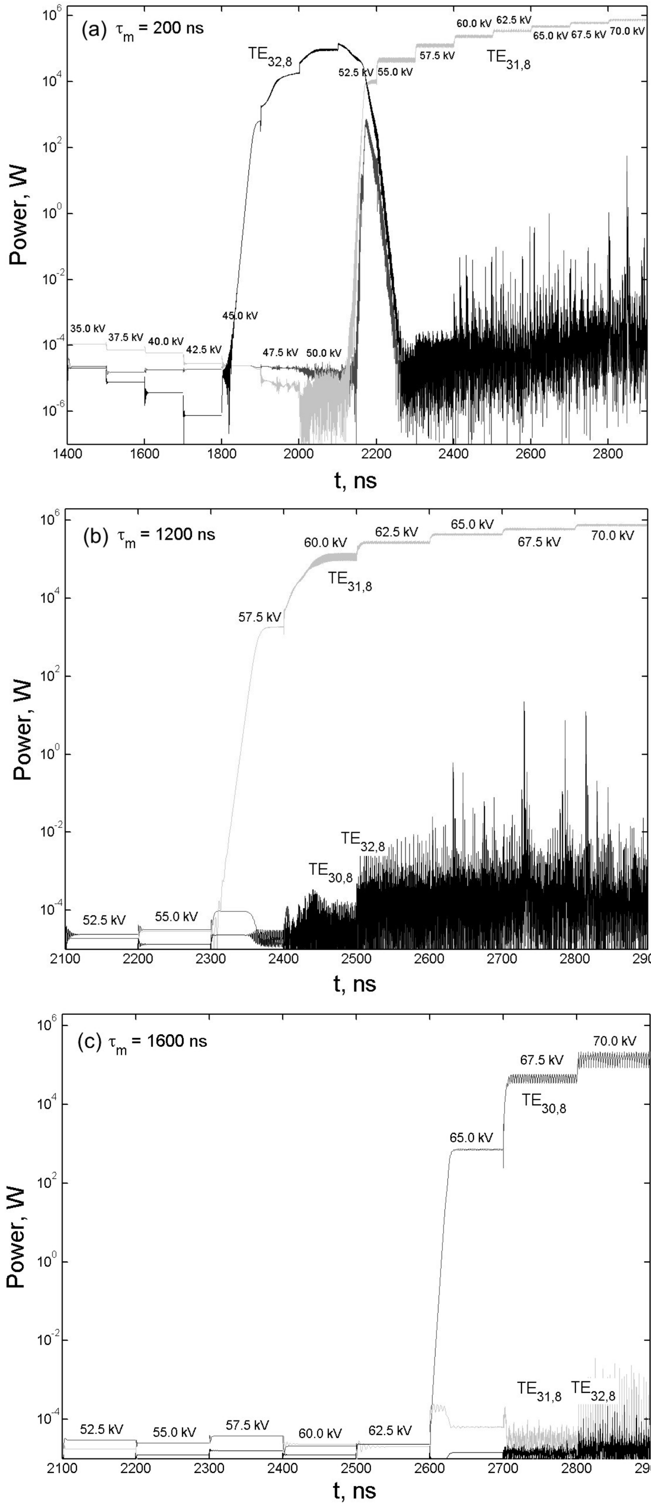

Fig. 2. Start-up scenario for the 1 MW, 170 GHz JAERI gyrotron. The mod-anode voltage delay time is equal to a) 200 ns, b) 1200 ns and c) 1600 ns.

III. SUMMARY

In gyrotrons with diode-type electron guns, a fast voltage rise (in about 1 microsecond or less) allows one to avoid excitation of parasitic modes.

In gyrotrons with triode-type electron guns, excitation of parasitic modes can be avoided when the delay time of the mod-anode voltage is in the range of 20%-60% of the beam voltage rise time. This estimate of the delay time is valid for the modes with about 2% frequency separation. For higher-order modes with smaller separation the range of delay times required for selective excitation is shorter.

ACKNOWLEDGEMENT

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