§23. 1.8 MW/ 1 s Operation of a 77 GHz Gyrotron with Flexible Anode Voltage Control

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Since 2006, the installation of 77 GHz gyrotrons with each output power of over 1 MW has progressed in the Large Helical Device (LHD).[1)] In the present state, three 77 GHz gyrotrons are operational for plasma experiments.

The anode voltage (V_A) of the 77 GHz gyrotrons can be flexibly controlled using the preset waveform and the improvement of the electric efficiency was successfully achieved by applying stepwise V_A. Figure 1 shows the time evolution of (a) the applied voltage for collector V_C, for body V_B and for anode V_A, (b) the beam current I_C, the anode current I_A and the body current I_B and (c) the MOU output power for the latest-installed 77 GHz gyrotron. In this operation, enough low V_A not to start oscillation was applied for 100 ms. After that, V_A was increased to ~40 kV and the output power of 1.8 MW was stationary obtained for 1 s.

The charge neutralization of the gyrotron electron beam due to the ionization of the residual gas in the tube is a key for the improvement of the electric efficiency by the stepwise V_A applying. Figure 2 shows the dependence of the MOU output power on (a) V_B, (b) T_1 and (c) I_C, where T_1 denotes the duration of the first step of the stepwise V_A. The electric efficiency η is also plotted in fig. 2 (c). The circles and triangles in fig. 2 (a) and (c) represent the results of the operations with the stepwise V_A and the regular V_A (rectangular waveform), respectively. T_1 was fixed at 100 ms for the case of the stepwise V_A in fig. 2 (a) and (c). In fig. 2 (b), the gyrotron operation parameters were kept unchanged except for T_1. The oscillation duration T_p was set at 10 ms for all these operations in fig. 2 (a)-(c). As can be seen from fig. 2 (a), the operation with the regular V_A required 5~6 kV higher V_B to generate the similar output power with the stepwise V_A case. This means

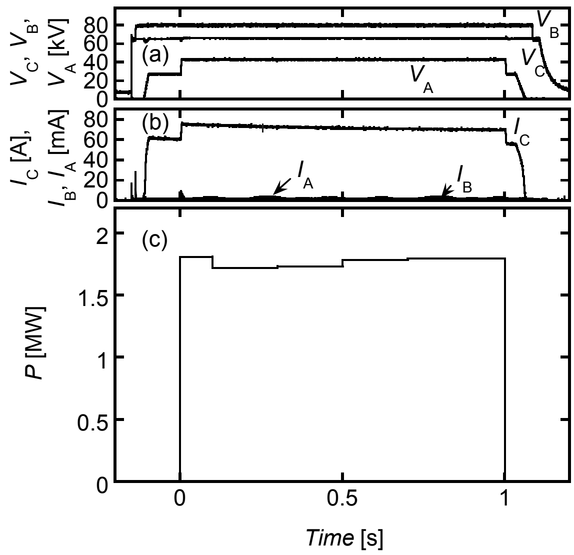

Fig. 1. The time evolution of (a) the applied voltage for collector V_C, for body V_B, for anode V_A, (b) the beam current I_C, the anode current I_A, the body current I_B and (c) the output power in the oscillation of 1.8 MW/ 1 s

that the drop of the beam accelerating voltage occurred for the regular V_A case due to the space charge effect of the electron beam. Figure 2 (b) shows that the output power increased with the increase of the first step duration and was saturated for the longer duration than 50 ms. This indicates that the drop of the accelerating voltage recovered through the charge neutralization process in the T_1 phase and the space charge was fully neutralized for ~50 ms in the operation. These results suggest that the gyrotron operational parameters are able to be optimized for the fully accelerated electron beam by applying the stepwise V_A with the adequate T_1 duration, leading to the improvement of the output power and the electric efficiency as shown in fig. 2 (c).

1) Takahashi, H., et al.: Fusion Sci. Technol. **57**, 19 (2010).

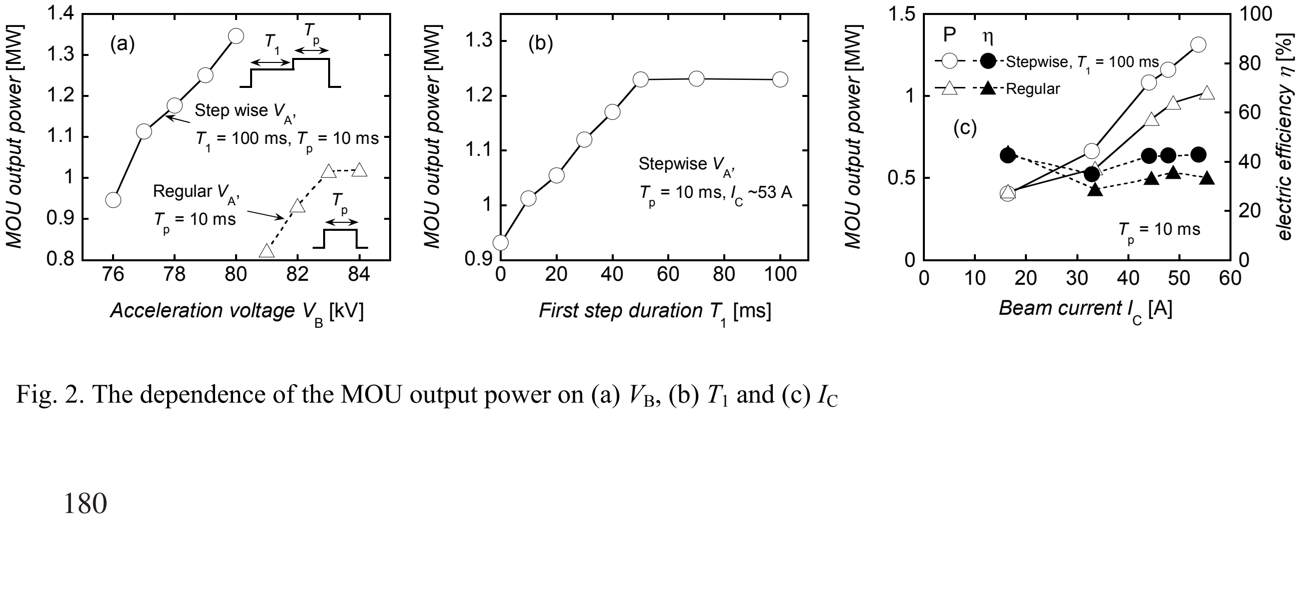

Fig. 2. The dependence of the MOU output power on (a) V_B, (b) T_1 and (c) I_C