§1. Operational Status of the 77 GHz Gyrotrons in the LHD

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The enhancement of the output power per gyrotron has been planned in order to enlarge the plasma operational regime in the Large Helical Device (LHD). Final aim is 5 MW injection to plasmas using 8 sets of 1 MW ECRH system. The replacement of the existing gyrotrons with new 77 GHz tubes of the design value 1 MW/ 5 s is in progress. [1] These high power gyrotrons can be effective tools for controlling the local plasma parameters due to the high power density. Two 77 GHz high-power gyrotrons were installed by the end of 2008. The gyrotrons are operated with a CPD collector and a gun with triode configuration for better controllability. Six sweeping coils are set around the collector and a triangular current of 1.9 Hz is applied to the coils to distribute the heat load. We have been continuing the conditioning and have attained 1.0 MW/ 5 s for the two 77 GHz gyrotrons up to now. We successfully achieved the improvement of the output power and the efficiency for the #2-77 GHz gyrotron by the stepwise applying of the anode voltage to reduce the collector voltage drop at the oscillation start-up phase. In 2009 one of the existing-168 GHz gyrotrons has been replaced with third 77 GHz gyrotron, which has the capability of 1.5 MW/ 2 sec, 300 kW/ CW in the design value.

Figure 1 shows the time evolution of (a) the applied voltage for the collector V_C, for the body V_B and for the anode V_A, (b) the beam current I_C, the collector sweep current I_{sweep}, the body current I_B and the anode current I_A and (c) the output power after the MOU in the operation of 1.55 MW/1.5 s for the third 77 GHz gyrotron. In this operation, the applied voltages of the collector, the body and the anode were fixed at V_C = 65 kV, V_B = 80 kV (the potential depression was 15 kV) and V_A = 45 kV. As can be seen from the figure, the beam current decreased by 7.5 A during the oscillation due to the temperature decrease of the cathode due to the extraction of the beam current and the output power tended to decrease. The output efficiency was 36.0 % in the operation. The maximum output power we confirmed was 1.6 MW/ 0.5 s with the efficiency of 36.6 %. The achieved operations for the 77 GHz gyrotrons in several cases are summarized in Table I.

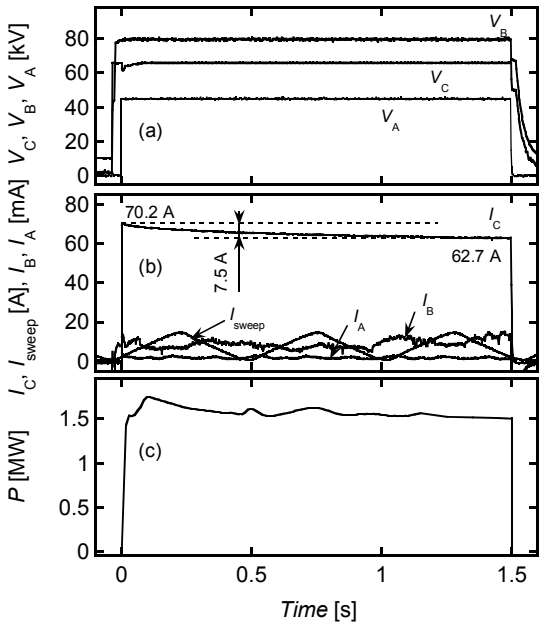

Fig. 1. Time evolution of (a) V_C, V_B and V_A, (b) I_C, I_{sweep}, I_B and I_A and (c) the output power after the MOU in the operation of 1.55 MW/1.5 s for the third 77 GHz gyrotron..

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

TABLE I. Summary of the achieved operations for the 77 GHz gyrotrons

No.	Design	Pulse operation	CW operation
#1	1 MW/ 5 s 0.3 MW/ CW	1.10 MW/ 1.2 s (36.4 %) 1.01 MW/ 5.0 s (33.0 %)	0.29 MW/ 60 s (29.2 %) 0.13 MW/ 935 s (21.7 %)
#2	1.2 MW/ 5 s 0.3 MW/ CW	1.10 MW/ 1.2 s (29.6 %) 1.02 MW/ 5.0 s (30.3 %)	0.2 MW/ 370 s (19.8 %) 0.12 MW/ 1800 s (11.3 %)
	Two step V_A rise	1.31 MW/ 0.1 s (38.2 %) 1.30 MW/ 1.0 s (34.0 %)	-
#3	1.5 MW/ 2 s 1.2 MW/ 10 s 0.3 MW/ CW	1.6 MW/ 0.5 s (36.6 %) 1.53 MW/ 1.6 s (36.0 %) 0.91 MW/ 1.8 s (40.9 %)	0.33 MW/ 420 s (40.1 %) 0.30 MW/ 900 s (36.1 %) 0.22 MW/ 4500 s (32.4 %)