§1. The Development of 77 GHz-1 MW ECRH Systems for the LHD

Takahashi, H., Shimozuma, T., Kubo, S., Ito, S., Yoshimura, Y., Igami, H., Kobayashi, S., Mizuno, Y., Takita, Y., Mutoh, T.,
Kariya, T., Minami, R., Imai, T. (Univ. Tsukuba),
Mitsunaka, Y. (Toshiba Electron Tubes and Devices)

The enhancement of the output power per gyrotron has been planned in order to enlarge the plasma operational regime in the LHD. The replacement of the existing gyrotrons with the 1 MW tubes is in progress.[1] Final aim is 5 MW injection to plasmas using 8 sets of 1 MW ECRH system. 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. The output window is a chemical-vapor-deposition (CVD) diamond disc with high thermal conductivity and low dielectric losses. It allows operation at higher output power with longer pulses.

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 (c) the output power P in the oscillation of 1 MW/ 5 s. In this operation, the applied voltages of the body and collector were fixed at V_B = 80 kV and V_C = 65 kV (the potential depression is 15 kV). As can be confirmed from the figure, the beam current decreased by 8.7 A during the oscillation due to the temperature decrease of the cathode by the emission cooling. If we set the value of the main coil field optimally for I_C at the beginning of the oscillation, then the oscillation stops suddenly during the operation due to the decrease of the beam current. Thus we had to set the main field strength for the decreased value of I_C at the end phase of the oscillation in order to avoid this problem. This is one of the factors causing the degradation of the output efficiency.

Table I shows the summary of the operational achievement up to now. For the short pulse operation, we have attained 1.01 MW/ 3.3 s for #1 gyrotron and 1.02 MW/ 5.0 s for #2 one. Now we continue the conditioning aiming at higher power operation in parallel with expansion of pulse length with lower power level for the CW operation.

In 2009 one of the existing-168 GHz gyrotrons will be replaced with third 77 GHz gyrotron, which has the capability of 1.5 MW/ several sec, 300 kW/ CW in the design value. Therefore 4 MW injection of total ECRH power to plasma can be expected after completing the conditioning.

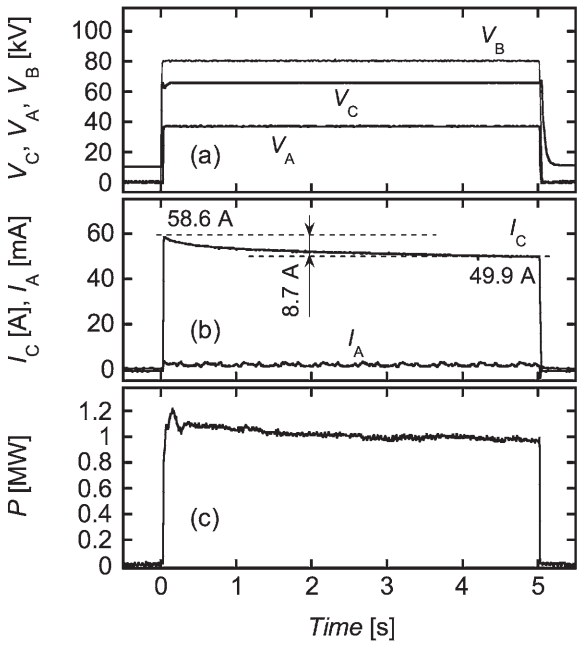

Fig. 1. The time evolution of (a) the applied voltage for collector V_C, for body V_B and for anode V_A, (b) the beam current I_C, the anode current I_A and (c) the output power P in the oscillation of 1 MW/ 5 s. The beam current decreased by 8.7 A during the oscillation.

Table I. Achieved operational regime of 77 GHz gyrotrons.

77 GHz gyrotron No.	#1	#2
Design value	1.0 MW/ 5 s, 0.3 MW/ CW	1.2 MW/ 5 s, 0.3 MW/ CW
Achieved operation		
Short pulse (≦ 5 s)		
Power/ Pulse width	1.01 MW/ 3.3 s	1.02 MW/ 5.0 s
Collector Voltage	60 kV	65 kV
Beam current	52.5 A	51.9 A
Electric efficiency	32.1 %	30.3 %
Long pulse (> 5 s)		
Power/ Pulse width	0.29 MW/ 60 s	0.24 MW/ 220 s
Collector Voltage	62 kV	60 kV
Beam current	16.0 A	17.5 A
Electric efficiency	29.2 %	22.9 %

1) H. Takahashi *et al.*, Fusion Sci. Technol., to be published