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


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. 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 \( I_{\text{sweep}} \), 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.  

Figure 1. Time evolution of (a) \( V_C \), \( V_B \) and \( V_A \), (b) \( I_C \), \( I_{\text{sweep}} \), \( I_B \) 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.


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

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