§ 16. High Power Beam Injection with Newly Designed Accelerator for LHD-NBI Beam Line #1

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The LHD experiment with NBI has started with two beam-lines since1998. So far we have accumulated many know-hows and technologies for long period operations. The accumulation has been feedback for developments of the beam lines, and the injection power and the energy increased year by year. By rising up the injection power, the experimental boundary for target plasmas can be expanded. The attainable maximum power, however, had a certain limit around a power of 3.5 MW; the beam energy is about 165 kV at the power limit. Beyond the limit, the breakdowns in beam accelerator occur frequently and it is necessary to decrease the applied voltage to cure the breakdown damage on the accelerator electrodes.

There are mainly three methods to increase NB injection power. The first is to increase the beam energy. The next is to enhance the ratio of H^- ion current to arc power input arc plasma inside ion source. The third is to improve port-through power by adjusting the focal and steering conditions of beam accelerator. In the second case the power is just proportional to the H^- current because of the limit of beam energy. On the other hand, the injection power increases as a product of the energy and beam current; the power is proportional to $E_b^{5/2}$ following the Child-Langmuir's low, where E_b is the beam energy. In the last case it is necessary to investigate the beam characteristics very accurately by using a beam detector available to measure global beam and single beamlet profiles. The power increment in this improvement is about 10 %. Considering the advantage and priority including some missions of LHD-NBI, the first improvement was selected.

Breakdowns at accelerator are considered to be caused by following two reasons; the first one is local irregularity of the accelerating electric field, and the others are emissions of gases and secondary ions form electrodes. The former is reduced by designing the electrode configuration and by removing the local damages of the electrodes. Concerning the latter, the gas and secondary-ion emissions are induced by beam exposure onto the electrodes. The exposure is carried by off-focus and widely spread beam component and the component is inevitable in beam acceleration. The highest beam power deposits on an electrode called grounded grid. Although the grid is cooled by flowing water, there is some area where cannot be sufficiently cooled. The simplest method to resolve the problem is to remove such an area. Consequently, the multi-slit grounded grid, MSGG, is replaced form multi-aperture grounded grid, MAGG. A segment of the MSGG is shown in Fig. 1.

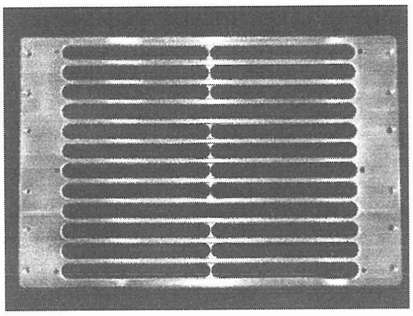

Fig. 1. A photograph of the multi-slit grounded grid

The maximum beam energy jumped up from ~165 keV to 180 keV by applying the MSGG. The energy of 180 keV is one of the mission value of LHD-NBI. According to the energy increment the maximum injection power reached 4.4 MW as shown in Fig. 2. The power is evaluated by shine through power at a calorimeter array installed on an armor located opposite side of the beam line. In beam conditioning the maximum power goes up to 4.7 MW and the power is calculated by using the injection power evaluating value. The reason why conditioning power exceeds the injection value is related the temperature control of plasma grid, and we are going to improve the injection power.

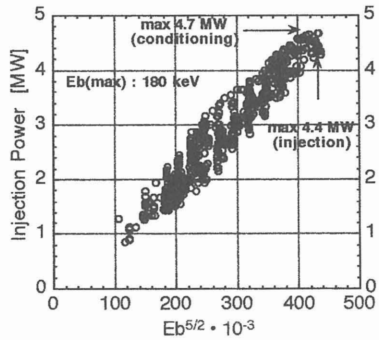

Fig. 2. Beam injection power as a function of $E_b^{5/2}$.

In Fig. 3 the beam heat loads onto the MSGG and the MAGG are shown as functions of acceleration heat, which is a product of beam energy and acceleration current. The heat on the MSGG is about a half times as much as that on the MAGG. The ratio corresponds to the ratio of the grid areas.

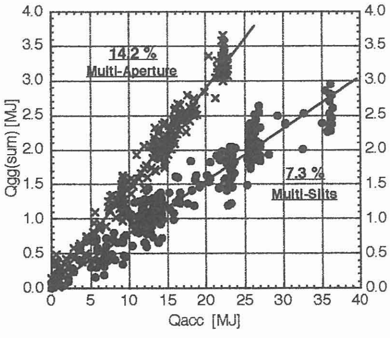

Fig. 3. Heat loads on the MSGG and MAGG to acceleration heat.