§44. Design Study of Long-Pulse NBI for the Plasma Boundary Dynamics Experimental Device

Takeiri, Y., Nagaoka, K., Osakabe, M.,
Zushi, H. (Kyushu Univ.)

The plasma boundary dynamics experimental device (QUEST), which is being designed in Kyushu University, is a spherical tokamak (ST) with a low aspect ratio. The objectives of the QUEST are to realize long-pulse and/or steady-state plasmas and to investigate their plasma properties including the related engineering aspects. In order to sustain high-density plasmas in steady state, the plasma heating and current drive by NBI are required. The conceptual design for a steady-state NBI system, which is suitable to the CREST plasmas, was carried out.

The reference design is a 40keV-1MW NBI system. To realize the steady-state injection, a steady-state ion source is required. For that, cooling ability for the grids of the ion source should be enhanced by attaching cooling channels in the vicinity of the beam apertures. However, the transparency of the fully cooled grids is degraded due to the cooling channels. Therefore, the dimensions of a steady-state ion source become larger compared with those of a short-pulse one producing the same beam current.

Fig. 1. Photograph of the plasma grid of the test positive-ion source. The lower half area is used for the beam extraction.

The fully cooled grid is thicker due to the cooling channels, and, then, the diameter of the beam aperture should be larger according to the grid thickness to extract high-density beams. The grid gap length should be also enlarged according to the aperture diameter for formation of a non-distorted beam emission surface. On the other hand, since the specified beam energy is as low as 40keV, the gap length should be kept short for preventing the beam current from being lowered.

To optimize the design of the grid system in the low-energy and steady-state ion source, we tested a fully cooled grid system with a test positive-ion source. Figure 1 shows the plasma grid of the test source, a lower half of which delivers positive ion beams. As shown in the figure, the grid is designed as fully water-cooled for steady-state operation, in which the cooling channels are silver-brazed in the vicinity of every aperture row.

In the ion source test, high-current ion beams of 40A are delivered from the half grid-area with a current density of $200 mA/cm^2$ in a short-pulse operation below 1sec. The beam duration is limited by heat load of the calorimeter. Since the heat load of the plasma grid is due to the arc plasma, grid distortion due to the heat load in the long-pulse operation can be verified by extending the arc duration prior to the beam extraction.

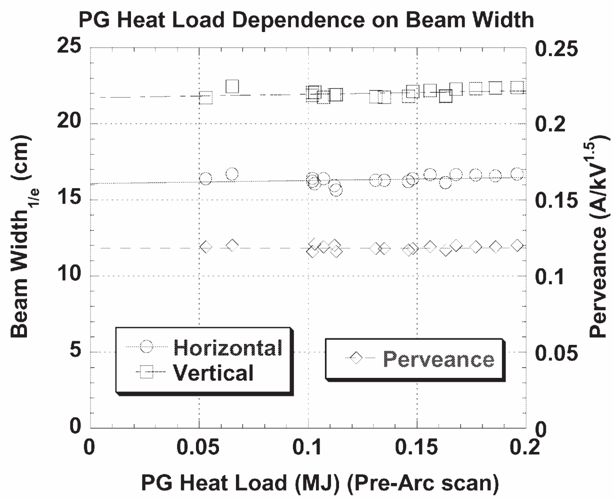

Fig. 2. Variations of the horizontal and the vertical beam widths as a function of the heat load of the plasma grid.

Figure 2 shows the variations of the beam widths in both the horizontal and the vertical directions as a function of the heat load of the plasma grid, which is scanned by extending the arc duration prior to the beam extraction. The maximum heat load corresponds to 10-sec beam extraction. The beam widths are not changed against the increase in the heat load of the plasma grid, as shown in the figure. This result shows that no heat distortion should be observed in the steady-state operation.

The further optimization to the design of the steady-state ion source will be carried out for the QUEST-NBI system.