

Steering of multiple beamlets in the JT-60U negative ion source

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To inject 10 MW D⁰ beams, two large negative ion sources, each of which produces 22 A, 500 keV, D⁻ ion beams for 10 s, was designed and installed with JT-60U. Recently, the beam pulse length is required to be extended up to 30 s in order to study the quasi-steady state plasma. One of key issues to realize a long pulse beam production is suppression of heat loading of acceleration grids. The direct interception of the D⁻ ions is one of the origins of the grid power loading. In particular, the outmost beamlets are deflected outward by beamlet-beamlet interaction, and then intercepted by the grids. In JT-60U negative ion source, a thin plat for shaping electric field (FSP) was attached on the extraction grid in order to suppress the outward deflection of the outmost beamlets. However, the previous FSP excessively deflected inward the D⁻ ion beams, resulting in the high power loading of the grounded grid, 9 % of the drain power of the acceleration power supply [1].

To determine the FSP configuration, the steering angles of the outmost beamlets were measured for the different distances between the FSP and the aperture in the JT-60U negative ion source, and compared with 3D simulation results. The footprint of the beamlets was measured at 3.5 m downstream from the grounded grid by infra-red camera with spatial resolution of 1.8 mm, from which the steering angles of the outmost beamlets were estimated. The steering angle linearly decreased with the distance between the FSP and aperture. The measured steering angle agreed well with the 3D simulation where the space charge effect and the stray magnetic field were taken into account.

Using this 3D simulation code, the FSP was newly designed to steer the beamlets that are produced through five grid segments, on each of which 9 apertures are distributed in vertical direction and 24 in horizontal direction. To suppress vertical deflection of the outmost beamlets by beamlet-beamlet interaction, the FSP's of 1.0 mm in thickness are designed to be placed on upper and lower periphery of the grid segments at the distance of 12.75 mm from the center of the outmost apertures. Since the D⁻ ions are horizontally deflected left-side or right-side every row by dipole magnets in the extraction grid, the FSP's of 1.5 mm in thickness are designed to be placed on both sides of the grid segments at different distances of 11.0 and 14.0 mm from the aperture center every row. These FSP's were installed in JT-60U negative ion source and tested. The FSP significantly reduce the power loading of the grounded grid to 7 % of the drain power. This level of the power loading is allowable in JT-60SA where the D⁻ ion beam with 500 keV, 22 A is required to be produced for 100 s.

References

[1] M. Kamada et al., "Beamlet deflection due to beamlet beamlet interaction in a large-area multiaperture negative ion source for JT-60U", Rev. Sci. Instrum., 79, 02C114 (2007).

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