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Simulation Study on a Negative Ion Source with the Accelerator Equipped Iron Steering Grid

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In the Large Helical Device (LHD), neutral beams have been successfully injected with the repetition of 3 min intervals. Especially, the injection power with three negative-ion-based NBIs achieved 16 MW using hydrogen negative ion (H^-) beams and contributed the hydrogen plasma experiment in the LHD [1]. As the next LHD project, deuterium-plasma experiments are scheduled in the LHD and deuterium beam will be provided. In the case of deuterium-negative-ion (D^-) beam with the same accelerating configuration, the current density decreases down to ~1/√2 according to Child-Langmuir's low. In addition, it is also reported the current density of co-extracted electron increases in D^- beams [2].

In our recent research, we have presented the detailed mechanism of the transport form production to extraction of hydrogen negative ions in the beam extraction region, and formation mechanism of negative ion plasma was also explained [3]. Electron deflection field induced with the magnet array embedded in extraction grid (EG) works as a "second electron filter" and the concentration and strength of the field near plasma grid (PG) is considered to increase the density of negative ion plasma. For this reason, the normal SG made of Cu (non-magnetic material) has been replaced to Fe (ferromagnetic) SG for the NIFS R&D negative ion source as shown in Fig. 1. The increment of the magnetic field in the beam extraction reason is shown in bleu coloured area in Fig. 1(c).

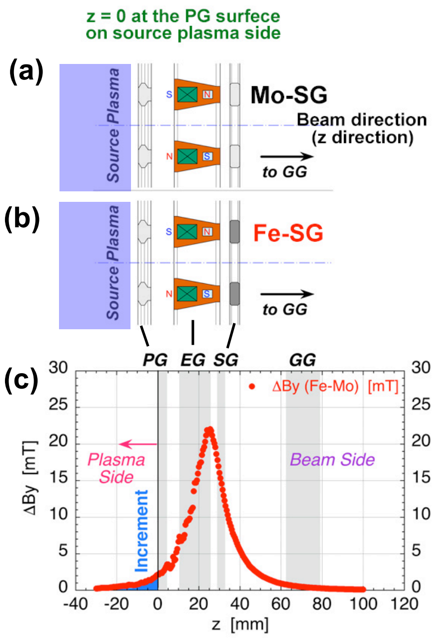

Fig.1. Cross-sectional views of Plasma Grid (PG), Extraction Grid (EG) and Steering Grid (SG), which are made of molybdenum (a) and iron (b). Difference of the magnetic strengths in y direction with the configurations of (a) and (b) is shown in (c).

The Fe SG is also effective to decrease the aperture displacement of the grid, because the perpendicular component of the returning electron deflection field is reduced on the downstream side of EG. Beamlet simulation result with a deflection angles with respect to the aperture displacements are indicated in Fig. 2. The red circles and blue square show the case of Cu and Fe grids, respectively. The beamlet deflections are compared in both of the accelerators with Cu and Fe SG. The beamlets shift row by row in Cu SG case, while it align better in the Fe SG case at the same aperture shifts as shown in Fig. 3 (a) and (b), respectively.

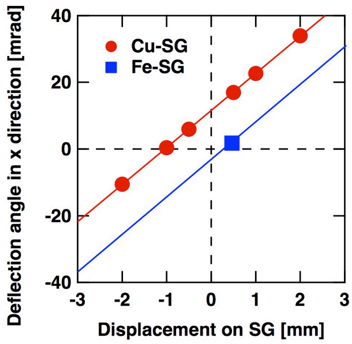

Fig. 2. Deflection angles with respect to the displacements of the aperture axes of the steering grids, which made of cupper (non- magnetic and red circles) and iron (ferromagnetic and blue square).

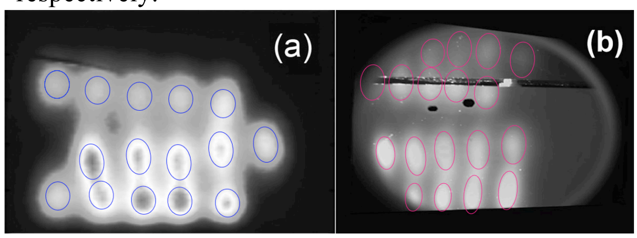

Fig. 3. Beamlet images obtained with the accelerators equipping (a) Cu and (b) Fe steering grids.

References

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