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Exploring Deuterium Beam Operation and Behavior of Co-Extracted Electron in Negative-Ion-Based Neutral Beam Injector

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Deuterium beam operation of the negative-ion-based neutral beam injector (N-NBI) was initiated in the Large Helical Device (LHD) in 2017. Both hydrogen (H) and deuterium (D) neutral beams were generated by changing the operation gas using the same accelerator. Comparison of the beam properties such as the extracted negative ion current and the co-extracted electron current, obtained with H_2 and D_2 gases, will clarify the production and extraction mechanism of the negative ions. Remarkable results are as follows: (i) 46 A deuterium negative ion current (I_{D-}) has been extracted with the averaged negative ion current density of 190 A/m^2 by two negative ion sources in the injector. (ii) The current ratio of co-extracted electrons to negative ions (I_e/I_{D-}) was 0.39 using 0.43 Pa source gas pressure. Although the configuration of the ion source is not optimized for D, the observed current of D^- ions reached 82 % of the LHD requirement and those results were comparable to the ITER-NBI specification (I_{D-} = 40 A with the current density of 200 A/m^2 at 0.3 Pa). (iii) Linear dependence of the minimum value of the I_e/I_{D-} on the arc-discharge power is found, and is stronger in the D^- operation than I_e/I_{H-} in the H^- operation. The degradations of the negative ion current and the increase in the co-extracted electrons are probably caused by decrease of the surface production rate of D^- ions which strongly depends on the incident D^0 atom velocity to the plasma grid (PG) surface. In addition, caesium (Cs) sputtering became enhanced in the deuterium discharge. This Cs behavior suggests that larger energy transfer by the deuterium ions impinging onto the PG surface removes the Cs layer required for surface production of the negative ions. These features could be a technical issue in D^- beam operation in future NBI where a higher power and a longer pulse duration are required.

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