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Long-pulse acceleration of 1MeV negative ion beams toward ITER and JT-60SA neutral beam injectors

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In order to realize the negative-ion-based neutral beam (NB) systems for ITER and JT-60SA, development of the Multi-Aperture and Multi-Grid (MAMuG) electrostatic accelerator is one of common critical issues. For these NB injectors, 5- and 3-stage MAMuG accelerators are being developed to achieve the acceleration of negative ion beams up to 1 MeV, 40 A (200 A/m^2) for 3600 s and 0.5 MeV, 22 A (130 A/m^2) for 100 s, respectively. However, there were no experiments of long-pulse MeV-class beam acceleration. Though JAEA achieved the rated beam energy of 1 MeV, the pulse duration was limited to be less than 1 s [1] due to a low voltage holding capability and high grid power loads.

After the last FEC conference, following issues were investigated such as multi-grid effect on the voltage holding capability and reduction of the grid power loads. New accelerators have been designed to realize stable voltage holding by taking into account the multi-grid effect on voltage holding capability, which satisfies the requirement of beam energy for ITER and JT-60SA with 5-stage and 3-stage, respectively. The grid power load has been suppressed less than a half of the design values of the accelerators by modifying the geometry of the extractor and the acceleration grids to suppress generation of secondary electrons.

By applying the developed techniques based on the R&D results, the hydrogen negative ion beams of 0.97 MeV, 190 A/m^2 have been successfully accelerated up to 60 s from the ITER prototype accelerator. The pulse duration of such high power density negative ion beams (~184 MW/m^2) has been extended from 0.4 to 60 s, which is the longest pulse length in the world. There is no limitation to extend the pulse duration, since no degradation of the voltage holding has been observed during the long-pulse operations neither by cesium accumulation nor by thermal damage of the acceleration grids. This achievement is one of breakthroughs toward the realization of the high-energy NB systems.

[1] A. Kojima, et al., Nucl. Fusion 55 (2015) 063006.

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