9–4 Production of a Negative Ion Beam with the Largest Current in the World

— Achievement of a 32 A Negative Ion Beam by Improvement of the Beam's Uniformity in the JT-60SA Negative Ion Source —

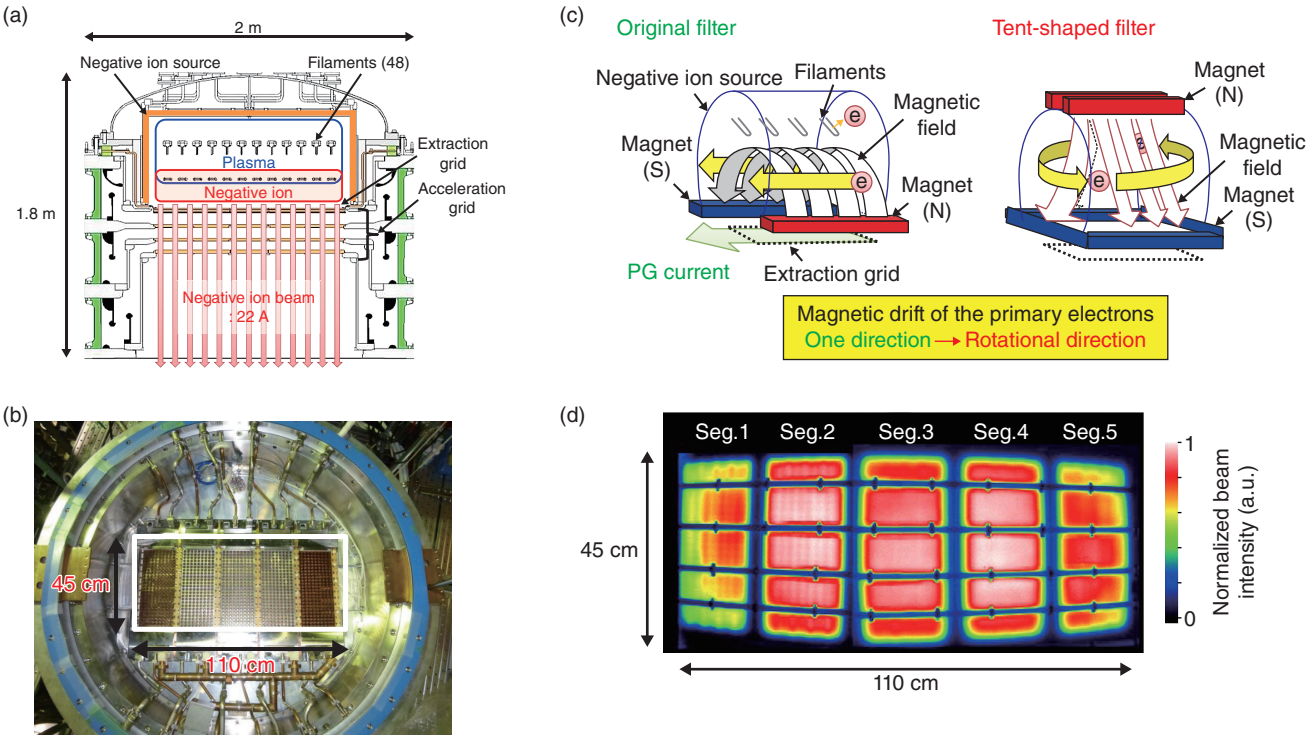

Fig.9-11 JT-60 negative ion source
(a) Cross-sectional view of the JT-60 negative ion source.
(b) Beam extraction grid with the world-largest area of 45 × 110 cm^2.

Fig.9-12 Production of the 32 A H$^-$ negative ion beam
(c) The magnetic field structure and direction of the primary electrons in the original filter and the newly applied tent-shaped filter.
(d) Beam profile of the negative ions produced by the tent-shaped filter.

A negative-ion-based neutral beam injector (N-NBI) is a powerful tool for heating core plasmas and driving plasma currents with high efficiency in fusion machines such as JT-60 Super Advanced (JT-60SA), which is currently under construction. In JT-60SA, the negative ion source for the N-NBI is designed to produce 22 A negative ion beam for 100 s (Fig.9-11(a)) with a large extraction area of 45 × 110 cm^2 (Fig.9-11(b)). One of key issue for such powerful beam production is the improvement of the beam's uniformity because non-uniform beams cause degradation of the beam optics. This leads to the reduction of the beam currents and increase of the local heat load on the extraction/acceleration grids.

We have examined the origin of the non-uniformity of the beams from the JT-60SA negative ion source using an original filter with a transverse magnetic field. As a result, it is experimentally determined that the non-uniform beam production is caused by the localization of the primary electrons emitted from filaments due to drift in the magnetic field. To improve the beam's uniformity, the magnetic structure of the JT-60 negative ion source is modified to a tent-shaped filter (Fig.9-12(c)).

This magnetic structure is expected to allow the primary electrons to rotationally drift in the longitudinal direction. Then, it is found from a trajectory calculation of the primary electrons that their localization can be significantly suppressed by changing the magnetic field filter. By suppressing the localization of the primary electrons, uniform plasma can be successfully produced. As a result, the beam's uniformity is improved from 68% to 83% over the entire extraction area of 45 × 110 cm^2. The improvement of the beam's uniformity leads to the production of 32 A H$^-$ ion beams over the entire extraction area. The obtained beam current fulfills the requirement for JT-60SA (Fig.9-12(d)).

Reference

Yoshida, M. et al., Improvement of Uniformity of the Negative Ion Beams by Tent-Shaped Magnetic Field in the JT-60 Negative Ion Source, Review of Scientific Instruments, vol.85, issue 2, 2014, p.02B314-1-02B314-4.