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# Development of large current beam production by modifying magnetic filter in JT-60 negative ion source
改良型磁気フィルターを用いた大面積一様負イオン生成の開発


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A negative ion current of 32 A with an uniformity of 83 % has been succesfully produced in the extraction area of 1100 x 450 $mm^2$ by improving the magnetic structure. A tent-shaped filter has been introduced in the JT-60 negative ion source, based on experimetal results and electron trajectory calculations. The obtained beam current fulfills the requirement for JT-60SA.


## 1. Introduction

A negative ion based neutral beam injector (N-NBI) is one of the powerful tool for heating core plasmas and driving the plasma current with high efficiency in the fusion experimental machines such as 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 beams for 100 s [1]. One of key issues for such powerful beam productions is an improvement of the beam uniformity because the non-uniform beams cause degradation of the beam optics. This leads to reduction of the beam currents and increase of the local heat load on the grids.

In this work, we report R&D for the improvement of the beam uniformity toward high beam current production in the JT-60 negative ion source.

## 2. Magnetic structure on the JT-60 negative ion source

JT-60 negative ion source has a semi cylindrical shaped arc-discharge chamber with 450 mm in width and 1100 mm in length. The arc chamber is surrounded with 26 rod shaped permanent magnets to form multi-cusp magnetic field for the plasma confinement ($H^+$ and $H^0$). The $H^+$ and $H^0$ are produced by the primary electrons emitted from 48 filaments in the arc chamber. Both particles are converted to negative ions on the plasma grids (PGs) with cesium coverage, which lowers the work function of the production of the negative ions on the PGs and enhances the negative ion currents. The produced negative ions are extracted from the extraction areas of 1100 x 450 $mm^2$ with extraction voltage up to 8 kV. The co-extracted electrons with the negative ions are suppressed and intercepted at the EXGs by a magnetic field which is formed by permanent magnets embedded in the EXGs. The extracted negative ions are received at a beam target. The target is located at 4.5 cm downstream from the EXGs/ESGs. The spatial profiles of the beam intensity are evaluated from the temperature rise of the target, which is measured with an Infrared (IR) camera located behind the target.

It was experimentally found that non-uniform beam was caused by localization of the primary electrons due to a magnetic drift [1-3]. Figure 1 (a) and (b) show the arc discharge chamber and the magnetic structure of the original transvers field filter in the JT-60 negative ion source, respectively. In the original transverse filter, a transverse magnetic filter field is formed by large currents flowing the PGs and a pair of large magnets close to the PGs. The filter field reduces the electron temperature to suppress the destruction of the negative ions caused by the collisions with high temperature electrons (> 1eV). A part of the filter field is coupling with the cusp field near the filaments. The magnetic directions is inverse each other in the areas near the filaments, where the primary electrons are one-directionally drifted in the longitudinal direction and localized to the one side of the arc chamber.

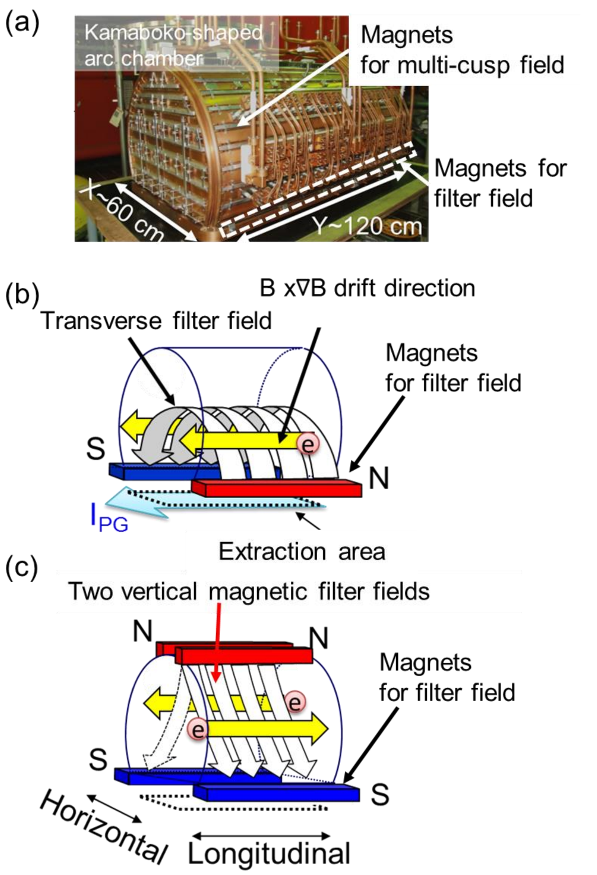


Fig. 1. (a) A semi cylindrical shaped arc-discharge chamber, (b) the original transverse filter and (c) the tent-shaped filter in JT-60 negative ion source

### 3. Improvement of beam uniformity by using the tent-shaped filter

It was also found from a trajectory calculation of the primary electrons that the localization of the primary electrons can be significantly suppressed by changing the magnetic structure from an original transverse filter to a tent-shaped filter [4, 5]. In order to improve the beam uniformity, the magnetic structure of the JT-60 negative ion source was modified to the tent-shaped filter and tested in the test stand.

Figure 1 (c) shows the magnetic structure of the tent-shaped filter. In the filter, the permanent magnets are symmetrically arranged to form two vertical magnetic filter fields. The vertical directions of the magnetic fields are the same in the areas near the filaments. This magnetic structure is expected to allow the primary electrons to drift bi-directionally in the longitudinal direction.

In order to clarify the beam uniformity, an equivalent constant area was evaluated. This was defined as the fraction of the measured beam current to the estimated beam current by assuming the peak beam intensity to be constant on the full extraction area. The longitudinal uniformity was improved from 78 % to 85 % over the longitudinal direction of 1100 mm by modifying the magnetic structure from the original transverse filter to the tent-shaped filter. We can conclude that longitudinal beam profile was determined by the profile of the primary electrons.

On the other hand, the beam uniformity in the shorter direction was degraded. In order to improve the shorter direction of beam uniformity, the magnetic filter was moved upward from the PG and field free region near the PG was enlarged. As the result, the shorter direction of beam uniformity was improved form 81 % to 94 % over the width of 450 mm without degrading the longitudinal beam uniformity. These optimizations of magnetic structure improved the beam uniformity of the total ion extraction area from 68 % to 83 %.

Figure 2 shows the spatial profile of the negative ion beams measured by an IR camera after the optimization of the tent-shaped filter in the JT-60 negative ion source. Uniform negative ion beams of 22 A were produced at the only centered three segments. This beam current fulfilled the requirement for JT-60SA. In addition, the negative ion beams of 32 A with an arc power of Parc = 180 kW, Vext = 8 kV and $T_{PG}$ = 250 $^{0}$C was produced in the total extraction areas.

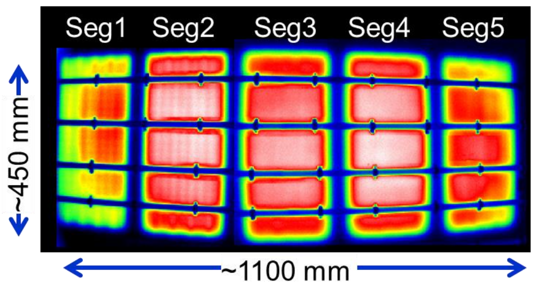


Fig. 2. Spatial profile of the negative ion beams measured by IR camera after the optimization of the magnetic structure of the tent-shaped filter in the JT-60 negative ion source

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