§14. Design of Negative Ion Source for NBI #1 in LHD

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We have investigated characteristics of arc plasma and of H^- extraction using 1/6 and 1/3 scaled negative ion sources[1),2),3)]. On the basis of the database on those ion sources, a 1/1-scaled negative ion source has been designed and built for neutral beam line #1 in LHD. The beam line will consist of two ion sources, and extracted negative ion beams will be merged into one neutral beam via a pair of gas neutralizers. The beam energy and current are expected to attain 180 keV and 40 A per an ion source.

The arc chamber, which is shown in Fig. 1, has a rectangular shape and its size is 1400 mm(H) x 350 mm(W) x 250 mm(D). The chamber is made of oxygen-free copper (OFC) with water-cooling channels and is surrounded by permanent magnets forming a multi-cusp configuration. To make the magnetic field unform in a longest direction, the bending parts of the cusp magnets are concentrated at the narrowest plates of the chamber wall, which are the top and the bottom parts of the chamber. The external magnetic filter is applied to improve the efficiency of H^- extraction. The filter field is produced by a pair of magnets forming a dipole field near H^- extraction region. The magnetic thickness of the filter is set at 500 Gauss•cm. In order to match the filter field and the cusp field, the arrays of cusp magnets are separated symmetrically at the vertical center plane of the arc chamber. Furthermore, field correcting magnets are installed near the external magnets to extend the field uniformity. The arc chamber has 48 filament ports and has three ports for Cs lines.

A cross section of the ion source is shown in Fig. 2. A beam-acceleration system consists of three electrodes, which are a plasma electrode, PE, an extraction electrode, EE, and a grounded electrode, GE. Each electrode is separated horizontally into five grids. These grids are aligned to focus the H^- beam geometrically in the vertical direction at a point 15 m from teh grounded electrode. A grid consists of 22(H) times 16(V) apertures. The diameter of each aperture in PE is 9.0 mm and the beam transparency is 38 %. The total beam extraction area is 250 mm(H) x 1200 mm(V). The material of the PE is Mo and the PE is not cooled by water to increase its temperature for enhancement of surface effect on H^- production. The EE is made of OFC with a magnet array to deflect the electron beam extracted with H^-. The GE is also made of OFC and the axes of the apertures are shifted to correct the H^- beam trajectories deflected by the magnet array in EE. Both of these grids are equipped with water-cooling channels to remove heat loads due to electron beams. The aperture diameter of these grids is 10.5 mm.

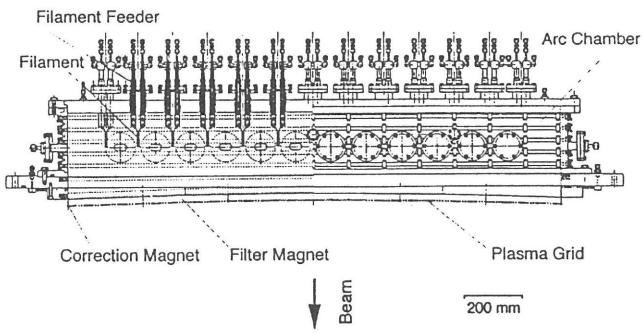

Fig. 1. An arc chamber of a negative ion source for LHD NBI #1 (side view).

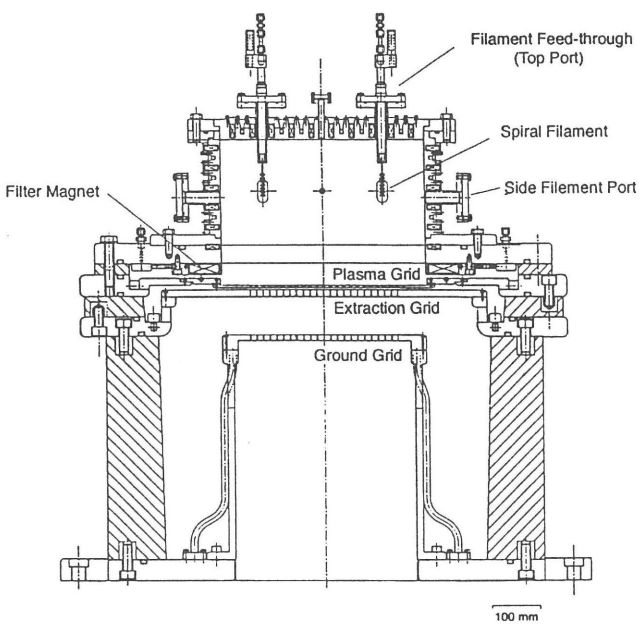

Fig. 2. A cross section of the negative ion source (horizontal view).

1) A. Ando, et. al, Rev. Sci. Instrum. **63** (1992) 2683.
2) K. Tsumori, et. al, Fusion Engineering and Design. **26** (1995) 473
3) Y. Takeiri, et al, Rev. Sci. Instrum. **67** (1996) 1021.