§22. Beam Characteristics of a Prototype Negative Hydrogen-Ion Source for LHD-NBI#1

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We have started a series of tests for prototype negative ion sources for LHD-NBI #1 and #2 since last year. The sources for NBI #1, which is shown in Fig,. 1, consist of multi-cusp configuration with external magnetic filters and internal size of the arc chamber is 140 cm (H) x 35 cm (W) x 25 cm (D). A single-stage acceleration is applied to form H^- ion beam and the beam-extraction area is 125 cm (H) x 25 cm (W). The extraction electrode is horizontally separated into five segments and the segments are geometrically arraigned to focus H^- beam vertically at 13 m apart from grounded grids. Three Cs lines are set at back plate to seed Cs vapor into the arc chamber.

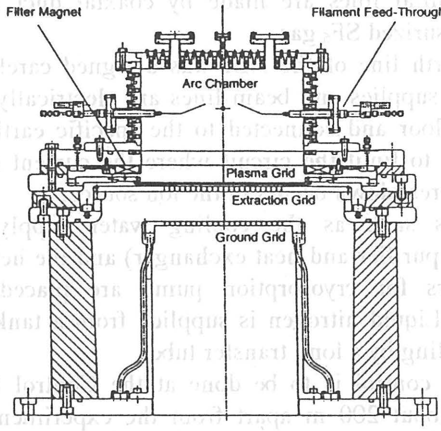

Fig. 1. Cross-section view of a prototype negative ion source for LHD-NBI #1.

In the beginning four segments of electrode except for central one were masked to investigate fundamental beam characteristics of H^- beam. Low leakage of extracted electron to an acceleration area is necessary to reduce a heat load to a grounded grid. In order to reduce the leakage the extraction electrode has a combination of strong magnetic field for electron deflection and an electron trapping structure. The electron leakage was reduced less than 6 % to the total extracted electron current in pure hydrogen discharges. A maximum current of 6 A was obtained from the 1/5 area of electrode at a beam energy of 109 keV. A minimum beam divergent angle of 9.5 mrad was obtained by a calorimeter array located at 11.4 m apart from the grounded grid. About 3 A of H^- current was extracted for 10 second at a beam energy of 80 keV in this configuration. To achieve the long pulse operation it is important to make uniformity of arc plasma in longitudinal direction. The uniformity is controlled by adjusting a set of external resister inserted between filaments and arc power supplies.

In the next H^- beam was extracted from 1/5 to full electrode area. Hydrogen negative ion current is shown in Fig. 2 as a function of input arc power. About 25 A of H- current was obtained at an in put arc power of 260 kW and the beam energy was 114 keV. The H^- current was measured by means of water calorimetry using a beam dump at 13 m downstream of the grounded grid.

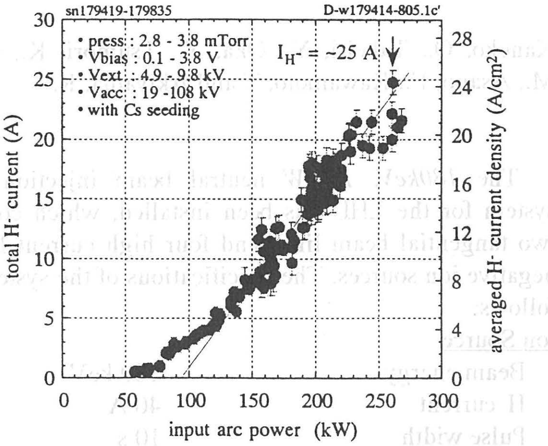

Fig. 2. Arc-power dependence of H- current extracted from full beam extraction area.

Beam divergent angle is represented by a ratio of acceleration field to extraction field. When the extraction and acceleration gaps are fixed, the angle can approximately represented by a voltage ratio of Vacc / Vext, where Vacc and Vext are acceleration and extraction voltages, respectively. Figure 3 presents beam divergent angle in horizontal direction with respect to the voltage ratio. A minimum divergent angle of about 11 mrad was obtained at a voltage ratio around 11. A beam transparency through neutralization cell, which is the narrowest part of the beam line, is also shown in Fig. 3. The transparency attains 90 % at a voltage ratio of 11 as well.

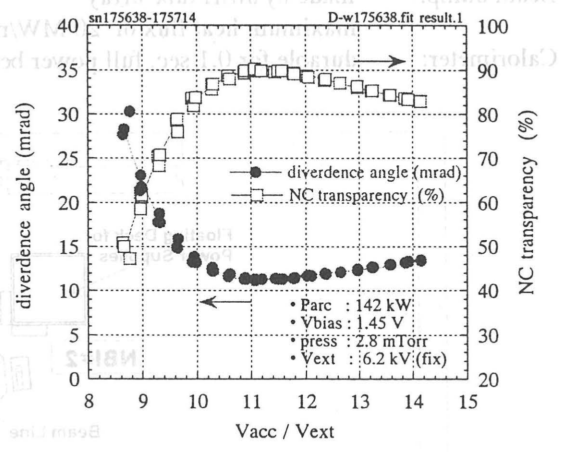

Fig. 3. Beam divergent angle and beam transparency through neutralization cell as functions of a ratio of acceleration voltage to extraction voltage.

Port through power is estimated as a product of detected power at beam dump and neutralization efficiency of H^- beam. The experimental values are about 2.8 MW and 50 - 60 %. A beam line for LHD is installed two ion sources, and the estimated port through power is about 2.8 - 3.4 MW. This value is well exceeds a required injection power of 2.5 MW per beam line in the second cycle of LHD experiment.