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Advanced diagnostics for negative ion plasmas

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Negative hydrogen ion sources are utilized for neutral beam injector in fusion energy field and accelerators in the particle and nuclear physics field and in the particle therapy field. Negative hydrogen ions are mainly generated on a plasma facing grid, so called Plasma Grid (PG), lowered the work function with coverage of cesium atoms. In the vicinity of the PG, the negative hydrogen ion is a main component of negative charged particles, that is, electron density is much lower than that of the negative hydrogen ion. Diagnostics in the vicinity of the PG is important for elucidating physics of such negative-ion rich plasma, especially from the negative ion production to extraction as beams. Some of the most important physical quantities are the negative hydrogen ion related values; density, temperature, mean flow. Cavity RingDown technique (CRD) with pulsed laser is applied to measure the density of negative hydrogen ion. In the CRD, the negative-hydrogen-ion density is evaluated from the decay time of the laser intensity in a pair of well-axially-aligned concave mirrors installed at the both sides of the plasma. The CRD was extended to the density "profile" measurement by moving the laser axis and the pair of mirrors with keeping the alignment [1]. Result of the density profile indicated that the production region of the negative hydrogen ion changes from volume in the bulk plasma to the PG surface by cesium seeding. Using saturation effect observed in the CRD by entering intense laser to the pair of mirrors, we have successfully evaluated the negative hydrogen ion temperature [2].

The mean flow pattern of the negative ion was measured with Photo-detachment Directional Langmuir Probe (PDLP), which is combined photo-neutralization process of negative ions with a directional Langmuir probe [3]. In the PDLP, the mean flow of the negative ion is evaluated by the comparison of the recovery times of the photo-detached electron current flowing to the Langmuir probe tips, which is located at upstream and downstream of the ceramic rod shielding the negative-ion flow. The measured mean flow pattern is interpreted that the negative ions emitted from the PG surface move toward the plasma and bend back to the beam extraction aperture of the PG during beam extraction. The bending point is at approximately 20 mm from the PG. Since the distance of the tips of the directional probe is 10 mm, it is difficult to measure the negative ion motion in a few mm from the PG. To estimate the motion in such area, we developed the beamlet measurement combined with tips in the vicinity of the PG [4]. The tip disturbs the plasma including the negative hydrogen ion motion in front of the PG surface. The response of the beamlet intensity to the tip shape and position provided that the negative ion motion could be affected by the magnetic field generated by permanent magnet installed in a beam extraction grid, which was typically equipped in the negative ion source.

In this paper, we report the diagnostics for the negative ion plasma, especially related to negative hydrogen ion.

References

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