22P150-P

Development of a 14 GHz microwave driven negative hydrogen ion source
14 GHzマイクロ波駆動水素負イオン源の開発

Tomoaki Nishida[1], Toshiro Kasuya[1], Syuichi Maeno[2], Masaki Nishiura[3], Katsuhiro Shinto[4], Motoi Wada[1]

西田睦聡[1], 粕谷俊郎[1], 前野修一[2], 西浦正樹[3], 神藤勝啓[4], 和田　元[1]

1 Graduate School of Engineering, Doshisha University, Kyotanabe, Kyoto 610-0321, Japan
2 Novelion Systems Co. Ltd , Kyotanabe, Kyoto 610-0394, Japan
3 National Institute for Fusion Science, Toki, Gifu, 509-5292, Japan
4 Japan Atomic Energy Agency, Rokkasho, Aomori,039-3212, Japan

1 同志社大学大学院工学研究科　〒610-0321　京都府京田辺市多々羅都谷1-3
2 ノベリオンシステムズ株式会社　〒610-0394　京都府京田辺市興戸地蔵谷1番地
3 核融合科学研究所　〒509-5292　岐阜県土岐市下石町322-6
4 日本原子力研究開発機構　〒039-3212　青森県上北郡六ヶ所村大字尾駮字表舘2-166

Development of a negative hydrogen ion (H^-) source for neutral beam injection (NBI) heating of future nuclear fusion device requires operation with RF power for simplification of the maintenance. We have been developing a compact H^- source driven by 14 GHz microwave power coupled to an elecroton cyclotron resonance (ECR) magnetic field. Preliminary beam extraction experiments had revealed beam deflection due to strong magnetic field at the extractor, and the modification to reduce magnetic field intensity at the extractor proved better extraction efficiency of the ion beam. A design to further reduce the magnetic field intensity at the extractor is proposed.

1. Introduction

High frequency microwaves can excite plasma with good efficiency as they are coupled to magnetic field intensity strong enough to realize electron cyclotron resonance (ECR) condition. However, magnetic field structure of an ECR ion source often becomes very complicated as the field structure have to match with efficient extraction of ions from produced plasma. Thus the size of the ion source together with the weight often becomes large. Reduction in microwave wavelength requires increased intensity of the ECR magnetic field, and we have chosen 14 GHz as the microwave frequency that gives a proper combination between the magnetic field intensity, and the wavelength of the electromagnetic radiation.

2. Dipole field configuration

Figure 1 shows the structure of the ion source that has a pair of permanent magnets forming enough intensity to realize ECR condition at 14 GHz microwave frequency. This ion source has the dimensions of 14 cm X 14 cm X 14 cm, and the microwave excites a hydrogen plasma in a 2 cm diameter 9 cm long alumina discharge chamber. The direction of the magnetic field to realize ECR condition is perpendicular to the beam extraction axis, and the region between the ECR zone and the extractor can work as a magnetic filter to reduce the mean energy of electrons in the plasma. This geometry can effectively produce H^- through electron volume process. However, the strong magnetic field intensity near the ECR zone should bend the H^- ions during beam extraction. In order to mitigate the beam deflection due to the field, iron magnetic shielding structure has been employed in the beam extraction structure. The adverse effect due to transverse magnetic field has been improved, and the ion source produces beam of negative hydrogen ions (H^-) with reasonable efficiency of 10 $\mu A/cm^2$-W.

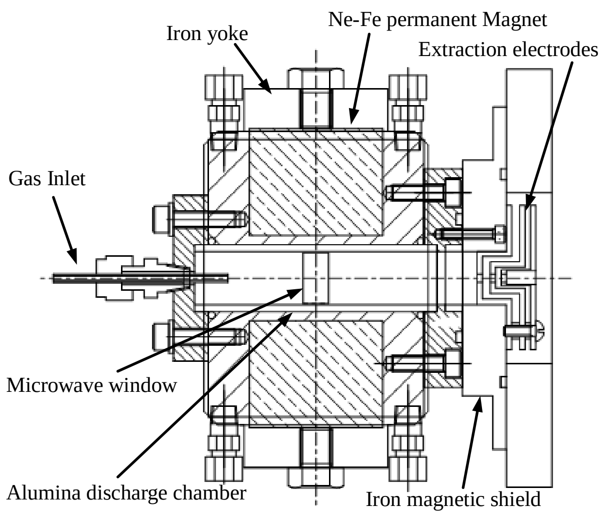

FIG.1.Schematic of double pole structure microwave ion source.

3. New concept magnetic field design

To further increase the H^- extraction efficiency, the ion source is being modified to form ECR field with a single permanent magnet. The ion source design is shown in Fig. 2. About 5cm diameter 4 cm long Nd-Fe magnet is attached to a cylindrical iron bases, which forms a closed magnetic field circuit realized by iron yokes. A 56 mm outside diameter 44 mm high alumina cup serves as a discharge chamber.

Figure 3 shows the calculated magnetic flux intensity distribution near the ECR zone on a central axis of the ion source. The field intensity distribution has been calculated by a general-purpose three-dimensional magnetic field analysis program TRI-Comp®. The zero point on the abscissa indicates the position of the plasma electrode of the extractor. This diagram describes that the ECR point is formed at 13 mm from the extraction hole.

Figure 4 shows the magnetic flux density distribution near the ECR zone along the microwave propagation axis. The figure shows that the ECR point is formed at about 15 mm from the axis of the ion source. This size is far much larger than the size of the extraction hole of 4 mm diameter.

Microwave power is launched into the discharge chamber from a rectangular waveguide that intersects the axis of the ion source at the end of the discharge chamber. A plunger structure to control microwave field intensity distribution around the discharge chamber has been formed at the opposite side of the power introducing waveguide across the discharge chamber.

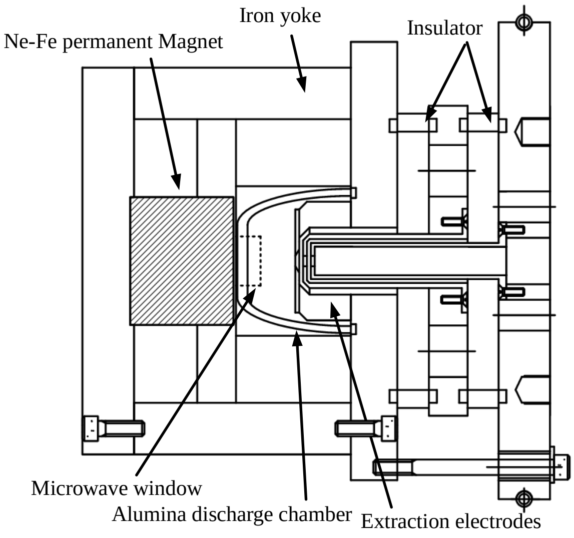

FIG.2.Schematic of single pole structure microwave ion source.

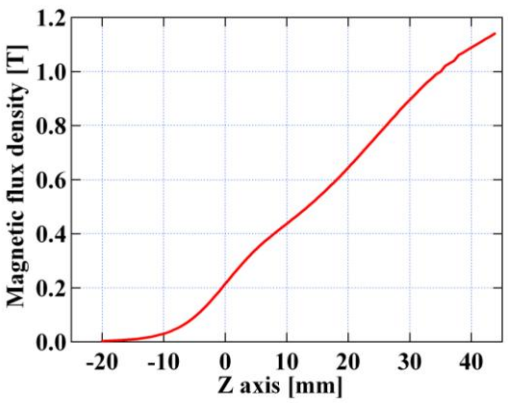

FIG.3. Simulation result of Magnetic flux density distribution on axis direction inside of ECR chamber.

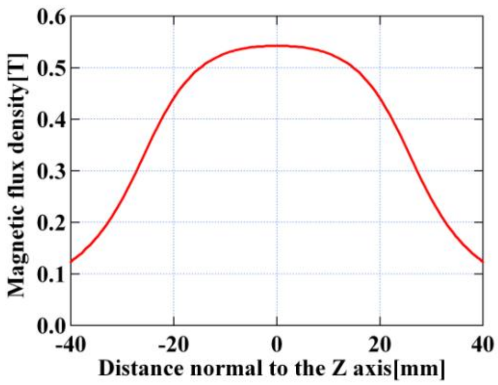

FIG.4. Simulation result of Magnetic flux density in a radial direction inside of ECR chamber.

4. Performance test

The source will be put into operation as H^- source. The magnetic field intensity of the dipole structure ion source could have been too strong to produce H^- ions efficiently, and the beam extraction currents were nearly the same for positive and negative ion extractions. This may be attributable to smaller electron drain current, but it also suggests the smaller positive ion extraction efficiency. This will be confirmed with the extractor structure with negligible intensity of the transverse magnetic field.

Acknowledgments

This work is performed with the support and under the auspices of the NIFS Collaboration Research program (NIFS10KOAR011).

References

[1] M. Wada, Y. Demura, T. Kasuya, T. Kenmotsu, S. Maeno, T. Nishida, M. Nishiura, K. Shintoh, H. Yamaoka, Plasma Fusion Res. 6, 2406100 (2011).