§13. Compact Microwave Ion Source for Plasma Diagnostics

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Active plasma diagnostics methods based upon ion beam injection into a target plasma give information on local plasma parameters of fusion experiment devices.[1] Core plasma diagnostics require higher beam energy as the size of plasmas become larger. Downsizing the ion source for a beam probe diagnostic system reduces complexity and enhances the reliability of the system. We have been developing several compact beam sources to fulfill this goal,[2] and have started to develop a microwave driven compact ion source to produce multiply charged ions.

Microwave power at higher frequency can produce plasma of electron density up to the cut off condition. Proper arrangements of magnetic fields enhances absorption of microwave power to the plasma, and improves confinement of the produced plasma. A typical electron cyclotron resonance source has a magnetic field produced by the combination of sextupole magnets and mirror field magnets.[3] The magnetic field structure can realize efficient plasma confinement and production of multiply charged ions, but the source inevitably becomes massive. Thus, we decided to design and test a compact microwave ion source with simple magnetic field geometry formed by a light weight permanent magnet assembly.

We have chosen 14 GHz microwave frequency to drive an ion source for two reasons. First, the waveguide should not be large compared with the size of the ion source itself. Second, commercially available microwave power sources are supposedly reliable during long operation time. Substantially shorter wavelength compared with respect to currently employed 2.45 GHz system enables transmission of microwave power to the ion source at a high voltage end via an antenna based power coupling through narrow crowded space around a confinement experiment devices. Use of Ku-band microwave components, which are widely used in space communication applications, reduces cost to assemble microwave circuit.

After installing a power supply to the ion source test stand assembled at the National Institute of Fusion Science, we have checked the operation of the power supply with a dummy load. We have finished the design and installation of a waveguide structure that delivers microwave power to the ion source, and the power can be supplied to any ion source through a Ku-band flange. We are currently designing three ion sources of different magnetic field configuration adaptive to the present geometrical configuration at the test stand. These include a magnetic multicusp ion source having a center magnetic field free region, a small field free ion source of dielectric wall, and a compact ion source equipped with a dielectric microwave inlet in a linear magnetic field.

Figure 1 shows the current design of a compact microwave ion source with a linear magnetic field. The size of the source is as small as 8.0 cm diameter and 15 cm long. Microwave from the power supply passes through an alumina window and excites a plasma in a narrow magnetized region. A three electrodes extraction system forms a beam, and an Einzel lens focuses the beam image to the entrance of a magnetic-deflection-type-momentum-analyzer located downstream of the beam extraction system.

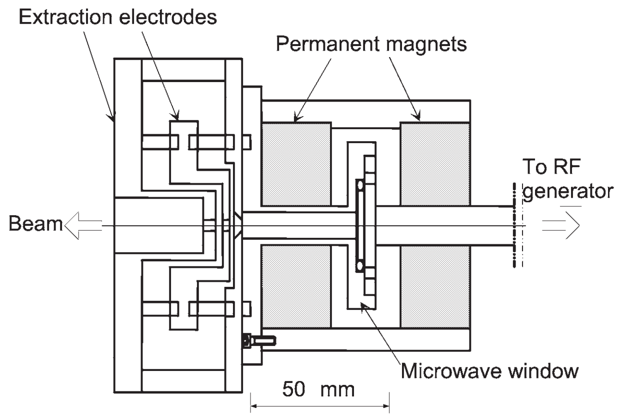

Fig. 1. Schematic drawing of a compact microwave ion source for plasma diagnostics applications.

Magnetic yokes of various sizes and shapes realize different magnetic field configurations of the ion source. We start the test of the ion source with the magnetic field geometry producing the largest intensity at the surface of the microwave window. After optimizing the magnetic field configuration to realize the largest extraction current of multiply charged ions, we examine the beam stability and qualities to evaluate the ion source performance as the component for a plasma diagnostic system. The first series of experiments for He^{++} extraction should clarify the merits and demerits against those of high temperature cathode excited ion sources.

1) M. Sasao, M. Nishiura, M. Wada *et al.* IEEE Trans. Plasma Sci. 33, 1872 (2005).
2) M. Nishiura, M. Wada *et al.* Rev. Sci. Instrum. 79, 02C713 (2008).
3) R. Geller, Rev. Sci. Instrum. 69, 1302 (1998).