§7. Extraction of Multiply Charged Ions from a Microwave Ion Source for a Beam-probe-system

Wada, M., Demura, Y. (Doshisha Univ.),
Shinto, K. (J.A.E.A.),
Yamaoka, H. (RIKEN),
Shimozuma, T., Nishiura, M.

Active beam probe systems are effective diagnostics tools for measuring local electron density, ion temperature, potential fluctuation, and other parameters of both edge and core plasmas. However, a high energy beam probe system requires a sizable volume for beam acceleration, and makes the installation to a plasma confinement experimental device more complicated. High energy beams can be easily produced with a low voltage electrostatic acceleration by extracting multiply charged ions. The compactness of the beam system enables one to install the beam injector close to an experimental device, and the trajectory of the beam can be properly arranged to let the beam reach to a specific point of the device. The promising versatility for applications to plasma diagnostics motivated us to develop a compact ion source for multiply charged beams.

Magnetic field structure with the intensity high enough to realize electron cyclotron resonance (ECR) condition is considered effective in producing multiply charged ions. However, the required field strength B increases linearly with the microwave frequency f through the relation

$$B = 2\pi \frac{m_e f}{e} \qquad (1),$$

where m_e is the electron mass and e is the elementary charge. Meanwhile, microwave launched into a plasma cannot propagate as the electron density exceeds the cutoff density

$$n_{cr} = 4\pi^2 f^2 \frac{\varepsilon_0 m_e}{e^2} \qquad (2),$$

where ε_0 is the permittivity of vacuum. Higher frequency microwave is preferred as the size of the waveguide becomes smaller in inverse proportion to the frequency. Thus, strong magnets are required to utilize ECR condition at a higher frequency operation of an ion source.

Shown in Fig. 1 is a possible design to achieve an ECR condition inside a dielectric (alumina) microwave cavity for 14 GHz frequency. On the side wall of a cylindrical ion source, 8 Nd-Fe magnets are attached to form a ring-cusp magnetic field geometry coupled to a point cusp produced by a large magnet installed at the end plate. As shown in Fig. 2, ECR zone with the magnetic field intensity as strong as 5 kG is confirmed formed at the central region inside of the cavity. The produced high energy electrons drift in the azimuthal direction to further enhance ionization in the source.

Development of the dielectric cavity is being made with 2.45 GHz microwave. The microwave power is injected into the source with a coaxial cable instead of a waveguide. As shown in Fig. 3, the current cavity exhibits a strong inhomogeneity of the produced plasma. The shift of the brighter plasma is observed toward the direction of the microwave input terminal. The result of a preliminary work on the field intensity distribution inside the cavity suggests the size of the present cavity is small to realize a homogeneous distribution of microwave field intensity in the dielectrics.

The gas pressure at which the source stably operates has turned out to be higher than it had been expected. Improvement of the gas introduction system to reduce the operation pressure, and those of cavity structure, and the extractor and the extractor design are being made with the 2.45 GHz system.

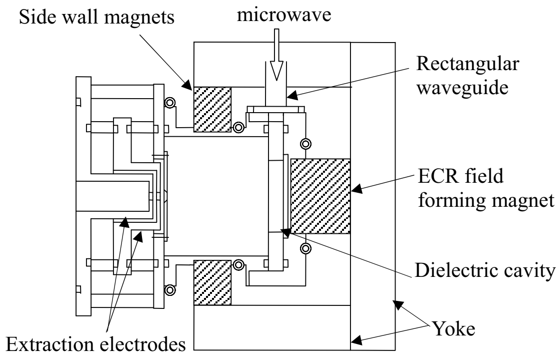

Fig. 1. A schematic of a compact 14 GHz microwave ion source.

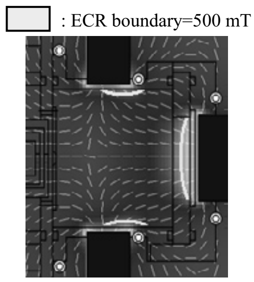

Fig. 2. Magnetic field distribution inside of a 14 GHz microwave ion source.

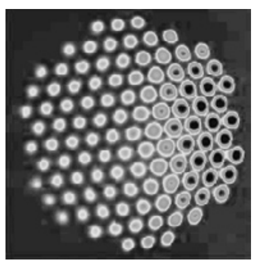

Fig. 3. Optical intensity distribution of Ar plasma excited by a ring cavity microwave ion source.