

## §6. Development of a Compact 14 GHz ECR Plasma Production Unit for a Negative Hydrogen Ion Source

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Research on efficient production of negative hydrogen ( $H^-$ ) ions in electron cyclotron resonance (ECR) plasma is being carried out. The developed source has a resonant cavity structure with an alumina discharge chamber at the center of the microwave circuit. The source operated at 14 GHz frequency has produced  $H^-$  ions with good power efficiency, possibly because the short wavelength electromagnetic wave enhances production of rotationally and vibrationally excited molecules in the plasma. To confirm the enhanced excitation, photon emission in vacuum ultra violet (VUV) wavelength region was observed with a spectrometer.

The ion source was installed on one end of a vacuum chamber, while the VUV spectrometer was installed at the other end of the chamber as illustrated in Fig. 1. In the region between the ion source and the spectrometer, a beam detection probe travels in the direction perpendicular to the beam extraction axis. The probe has a Faraday cup on the front end, and an EXB Wien filter assembled downstream of the Faraday cup. The beam profile and the energy spectrum can be measured with the probe.

Figure 2 shows the measured VUV spectrum for different feeding rate of  $H_2$  gas.<sup>1)</sup> The pressure indicated in the graph was measured downstream of the chamber, and the pressure inside of the ion source was roughly 100 times that in the downstream. As shown in the graph, Lyman- $\alpha$  and the band spectrum around Lyman- $\alpha$  increases with the increase of  $H_2$  gas pressure. They tended to saturate at the pressure around  $5.0 \times 10^{-3}$  Pa. These characteristics are similar to VUV emission from a hydrogen plasma excited by high temperature cathodes. The observed VUV emission spectra were different from those obtained for a cathode arc discharge plasma.

Hydrogen arc discharges produce band spectra which are relatively flat in the wavelength region around Lyman- $\alpha$ . The spectra shown in Fig. 2 exhibit preferential emission of VUV near the wavelength of Lyman- $\alpha$ . The high frequency electromagnetic field coupled to a strong magnetic field can directly excite vibrational/rotational levels of molecular ions, and this can change the band spectrum intensity distribution of the hydrogen plasma. This hypothesis, however, has to be confirmed by a theoretical model calculation based upon study of plasma parameters depending upon the ion source operation conditions.

The small size of the 14 GHz ion source makes the

plasma diagnostics of the source plasma very difficult. The power density is as large as  $5 \text{ W/cm}^3$ , even when the discharge power is limited below 50 W.<sup>2)</sup> A smaller power density ECR ion source at 2.45 GHz frequency is under construction to deepen understanding the precise mechanism of  $H^-$  formation in a high frequency ECR  $H^-$  source. Figure 3 shows the structure of the ion source, and the source will be operated with smaller magnetic field intensity. The source size is substantially larger than the present source, and will be equipped with Langmuir probe to investigate plasma parameters.

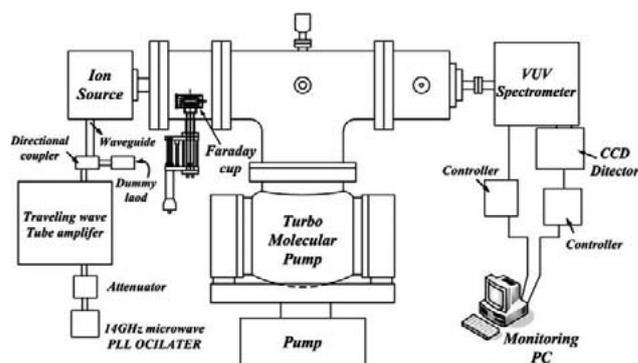


Fig. 1. The experimental setup used to measure the VUV spectrum emission from a 14 GHz ECR  $H^-$  ion source.

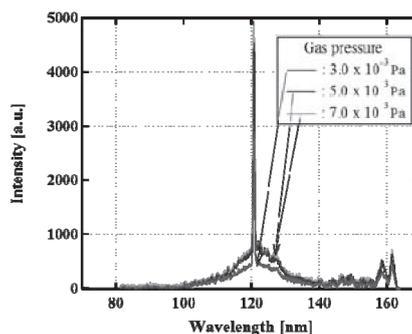


Fig. 2. The observed photon emission spectrum from a 14 GHz ECR  $H^-$  ion source.

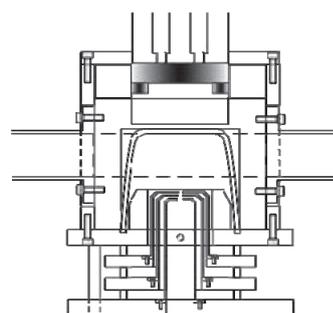


Fig. 3. The structure of a 2.45 GHz ECR  $H^-$  ion source to compare the performance with a 14 GHz source. The diameter of the ceramic discharge chamber is 5 cm.

- 1) T. Ichikawa, T. Kasuya, T. Kenmotsu, S. Maeno, M. Nishiura, T. Shimozuma, H. Yamaoka, and M. Wada,, Review of Scientific Instruments 85, 02B132 (2014).
- 2) M. Wada, T. Ichikawa, T. Kasuya, T. Kenmotsu, M. Nishiura, H. Takemura, H. Yamaoka, Plasma and Fusion Res. 8, 2401035 (2013).