

§35. Folded Waveguide Antenna Experiment on LHD

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In the 4th experimental campaign, a plasma production and heating experiments were performed using the ion cyclotron range of frequency (ICRF) wave launched by a folded waveguide (FWG) antenna.

The FWG antenna is a simple waveguide antenna and has many advantages in the comparison with a conventional loop antenna; a radiation power is larger than the loop antenna, the wave number is able to be changed, it has a large Q value, it can launch a higher power density, etc.

The FWG antenna was installed in the horizontal vacuum port on the LHD. To launch a slow wave, the installed angle of the antenna is 38.9 degree for the rf electric field to be parallel to the magnetic field at the last closed magnetic flux surface. The dimension is 1,050mm in width, 428mm in height, and 3,950mm in length. It can be moved by 1,150mm in the radial direction. The antenna consists of 24 areas separated by 23 vanes, which made a wide effective width to lower the cutoff frequency to the ICRF. Some exits of separated areas are covered with polarization plates, so a desired wavenumber parallel to the magnetic field, k_{\parallel} can be excited. Polarization plates were set on the exit of the antenna to launch the $k_{\parallel} = (2\pi/1.0)\text{m}^{-1}$ wave.

A series of experiment using the FWG antenna carried out at the 4th LHD experimental campaign in 2000–2001. The plasma was produced by above 200kW of RF power at $f \sim 25\text{MHz}$ and $B \sim 2.6\text{--}2.8\text{T}$, which was the first success on the torus devices for the FWG antenna.

Time evolutions of the typical discharge are shown in Fig.1; W_p , Power, and \bar{n}_e are the plasma stored energy, the injected ICRF heating power, and the line averaged electron density, respectively. In this discharge, the magnetic field strength at magnetic axis, $B=2.75\text{T}$, (i.e., $R_{ax} = 3.6\text{m}$), and hydrogen gas was only puffed in the vessel. The plasma stored energy, W_p , reached 4.4kJ at the end of discharge and the line averaged electron density, \bar{n}_e , was $0.25 \times 10^{19}\text{m}^{-3}$. With the target plasma, a neutral beam injection heating will be applied to sustain the high temperature and high density plasma.

A series of the plasma production experiments with FWG antenna was carried out varying the magnetic field strength, i.e., $B=2.6, 2.7,$ and 2.8T . In the experiment, the RF power transmitting from the RF generator was kept constant at 500kW. Figure 2 shows the dependence of the line averaged electron density on the hydrogen gas puffing rate at the magnetic field strength.

The electron density was increased with the gas puffing rate; however, the achieved electron density was gradually decreased with the excessive gas puffing rate. The optimum amount of gas puffing rate is determined to acquire the high density plasma produced by the FWG antenna. Here it was readily found that the higher electron

density can be obtained with the higher magnetic field; the maximum electron density at $B=2.6, 2.7,$ and 2.8T are about $0.10, 0.15,$ and $0.20 \times 10^{19}\text{m}^{-3}$, respectively. This phenomena is explained with the propagation region of shear Alfvén wave (SAW); SAW can propagate in the higher density plasma with the increase in the magnetic field strength. The propagation regions of SAW in the three different cases are calculated using an electron density profile and a magnetic field strength. The area of SAW propagating region, which locates between the R cutoff layer and the Alfvén resonance layer, reaches maximum at the central electron density of $n_e=0.20, 0.23, 0.26 \times 10^{19}\text{m}^{-3}$ in the case of $B=2.6, 2.7,$ and 2.8T , respectively.

The FWG antenna launches the slow wave to produce the target plasma. However, the electron density is limited by the wave propagation of the slow wave. The fast wave has no density limit. The experiment of the plasma sustainment using the fast wave after the target plasma production using FWG antenna was tried. After the plasma production by the FWG antenna the plasma sustainment was tried using the loop antenna; however the electron density was limited by the slow wave propagation because of the plasma of the hydrogen ions.

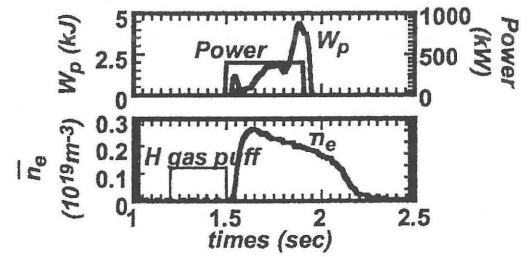


Fig.1: Time history of typical FWGA production plasma

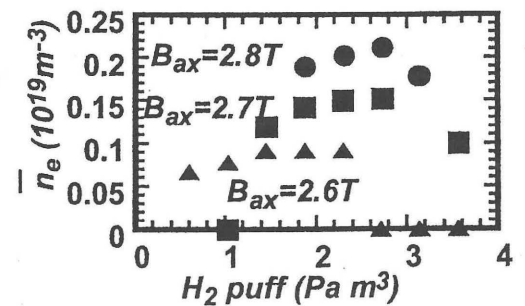


Fig.2: Achieved line averaged electron density versus H_2 gas puffing flux at each field strength. Triangles denote the plots at $B = 2.6\text{T}$, squares, $B = 2.7\text{T}$, and circles, $B = 2.8\text{T}$.