§17. Characteristics of ICRF Heating Using Antenna with Toroidal Phase Control Capability

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In the 14^{th} experiment cycle (2010) a new one pair of ICRF heating antennas was installed in LHD. This pair consists of two antennas arrayed in the toroidal direction and has a controllability of the wave number along the magnetic field line with changing the phase difference between them. When two antennas are seen from the plasma axis, they look like to handshake each other and so they are called as HAS (Handshake) antenna [1]. The HAS antenna consists of two identical antennas. They are installed from the upper and the lower vertical vacuum ports, respectively. The antenna is 75cm in the length and 20cm in the width. The antenna width including the Faraday shield and the side protector of graphite is 54cm. The distance between the antenna strap and the back plate is 12cm. The separation between two antennas is 10cm. These antennas are movable in radial direction by 15cm. An RF power with a frequency of 38.5MHz was supplied to each antenna from the each RF generator.

A minority heating method for the ICRF heating was employed: The minority ion was a hydrogen ion with the He ion as the majority. The magnetic strength on the plasma axis, i.e., R_{ax}=3.6m was B=2.75T. The plasma loading resistance is an important parameter to evaluate how much the ICRF heating power can be injected from the RF antenna. Figure 1 shows the plasma loading resistance for the (0, π) phasing in HAS antenna and the poloidal array (PA) antenna, which has been used so far. It is found that the plasma loading resistance decreases with the distance between the antenna and the plasma last closed surface. The resistance of PA antenna is larger than those of HAS antenna. A fast wave in the ion cyclotron range of frequency wave is evanescent in the lower density than that of the R-cutoff. It is proportional to the square of the refractive index of the fast wave along the magnetic field line, i.e., $N_{//}=ck_{//}/\omega$. Here c, $k_{//}$ and ω are a light velocity, a parallel wave number along the magnetic field line and an applied frequency. As the $k_{//}$ becomes larger in (0, π), the density at the R-cutoff is higher and the R-cutoff moves to the plasma core. Therefore the distance between the antenna and the plasma becomes longer. The electromagnetic RF wave is evanescent there and damps exponentially in accordance with the imaginary of $k_{\perp}$. It is reported that the plasma heat load to the divertor plates and the side-protector of the ICRF heating antenna during the long-pulse operation was smaller in the (0, π) phasing of HAS antenna by H.Kasahara [2]. This is also caused with the fast wave evanescent in the scrape-off plasma.

Generally the plasma with a higher density can be sustained with the higher ICRF heating power. As described by T.Seki [3], the higher density was sustained in (0, π) phasing than in (0, 0) phasing with the same ICRF heating power. In the series of the experiments it was tried how high the electron density was sustained with the various ICRF heating power for (0, π) (with solid circles) and (0, 0) (with solid squares) phasing. Figure 2 shows the dependence of the electron density on the ICRF heating power. It is found that the higher density can be sustained with (0, π) phasing than with (0, 0) phasing. The results obtained using the PA antenna so far obtained are also plotted with open circles and they are almost similar to those with (0, 0) phasing. It is reported that the ICRF heating efficiency η was higher in (0, π) phasing [2]. When P_{ICH} of the abscissa is changed to ηP_{ICH} as the RF power absorbed with the plasma, the maximum electron density becomes almost the same in (0, π) and (0, 0)

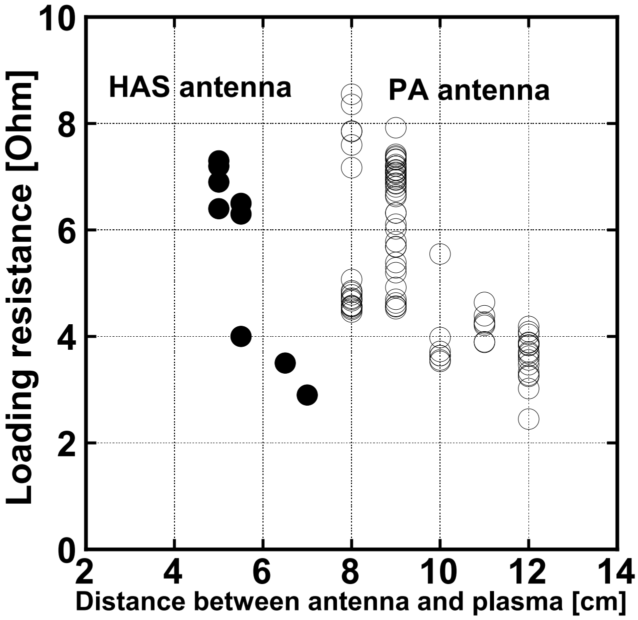

Fig.1 Dependence of antenna loading resistance on the distance between antenna and plasma for (0, π) phasing of HAS antenna and poloidal array antenna.

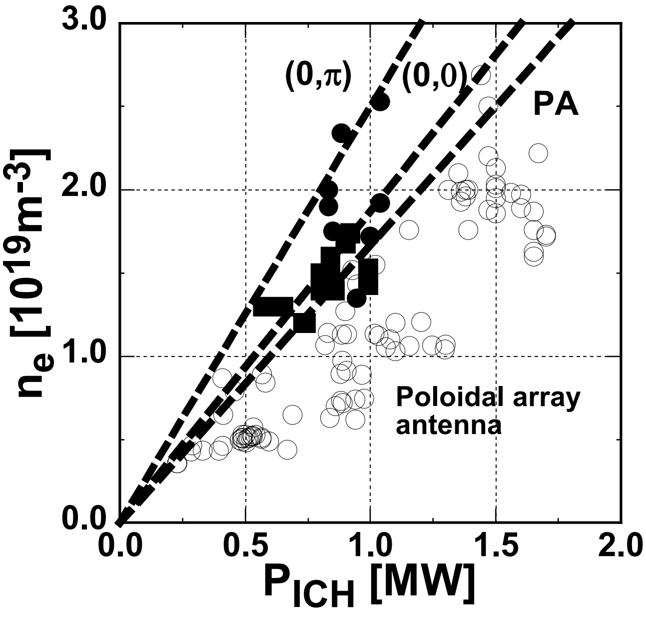

Fig.2 Dependence of the electron density on ICRF heating power with (0, π), (0, 0) phasing and poloidal array antenna. phasing.

[1] H.Kasahara et al., J. Plasma Fusion Res., Vol. 5, S2090 (2010).
[2] H.Kasahara et al., Annual Report Apr.2010 - Mar.2011,184
[3] T.Seki et al., Annual Report Apr.2010 - Mar.2011,88