

## §81. Fast Wave Frequency Broadening for the Poloidal Array Antenna and the Toroidal Array Antenna

Kasahara, H., Seki, T., Saito, K., Kumazawa, R., Mutoh, T.

Two types of ICRF antennas are installed in the LHD, and these two antennas have two single loop coils in each other. Geometrical installation of these antennas are different, and then excited wave-field patterns of radio-frequency (RF) are different. One is the poloidal array antenna (PA), which is vertically installed along to magnetic field line, and the other is the toroidal array antenna, which is installed along to magnetic field line. The antenna shape for toroidal array antenna is similar to hand-shake form, and the antenna is named as “the HAS antenna” (HAS). Mainly excited wavenumber for the PA is approximately zero with broadening wavenumber to  $5 \text{ m}^{-1}$ , and the other of the HAS with dipole phase has the peak wavenumber of  $6\text{--}8 \text{ m}^{-1}$ . Initial Hydrogen minority heating experiments in Helium majority plasma for the HAS is carried to evaluate heating efficiency by using amplitude modulation method [1], and heating efficiency is over 90 % with dipole phasing [2]. The heating efficiency by the PA is approximately 70 %, and it is similar to the heating efficiency by the HAS with monopole phase.

In order to distinguish heating efficiency on two antennas, propagated frequency spectrum are measured by magneto-sonic probes with wide-band frequency range [3]. Figure 1 shows a schematic view for ICRF antennas at 3.5 port and 7.5 port and measurement probes at 5.5 port and 6.5 port in the LHD, and there are two magneto-sonic probes in the each ports. Although there are four magneto-sonic probes in the LHD, we can not use two probes at the same time because of the limitation for fast data acquisition system. Figure 2 shows a discharge waveform in various plasma parameters, and plasma is sustained by only ICRF heating except at plasma start-up phase. Favorable heating efficiency by the HAS is achieved on the Hydrogen minority ratio of 10 %, and in this experimental condition the heating efficiency is poor for the HAS. For observed intensity of pump-wave, these propagation distance to probes are different between the excitation antenna and the measurement probe close to the antenna. In order to study wave absorption on plasma propagation, a wave-power decrement ratio is compared. The wave-power decrement ratio of the HAS is approximately  $10^{-2}$  on the steady-state condition after 3 sec, and that is approximately  $10^{-1}$  for the PA. The decrement ratio for the HAS is 10 times smaller than that for the PA, and it indicates that fast wave by the HAS is easily damped through the propagation than that by the PA. Figure 3 shows the frequency broadening between the HAS and the PA, and the nearest probe is different between the HAS and the PA. On the HAS case, the HAS antenna is installed at 3.5 port, and the nearest probe is probe B at 5.5 port. On the other hand, the nearest probe for the PA is probe D at 6.5 port. In this minority heating experiments, pump-wave frequency is 38.5 MHz, and peak frequencies of 38.5 MHz are observed for all probes. For the frequency spectrum of the HAS, the spectrum pattern is not clearly different between the probe B

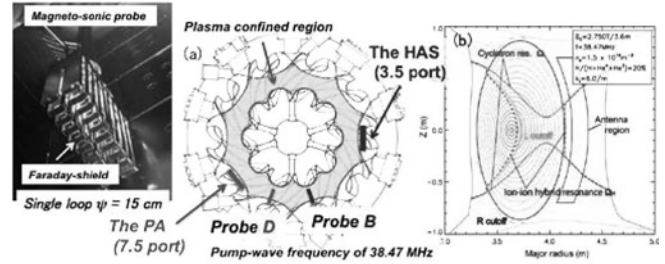


Fig. 1. The picture of magneto-sonic probe and a schematic view for ICRF antennas and magneto-sonic probes in the LHD. Hydrogen cyclotron resonances in front of ICRF antennas in Fig. 1(b).

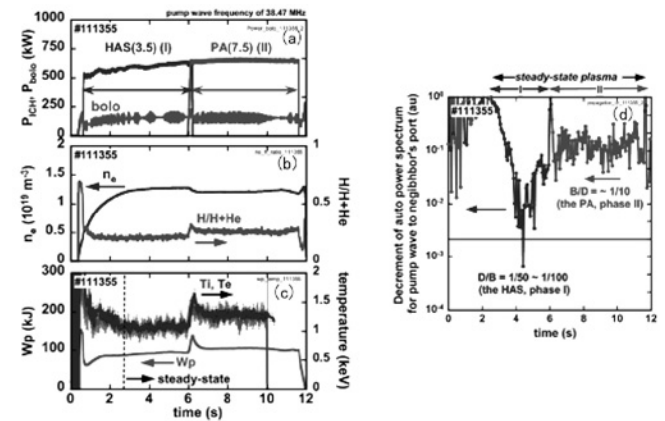


Fig. 2. Discharge waveforms in various plasma parameters. Figure 2(d) shows a wave-power decrement ratio for fast wave propagation through one port.

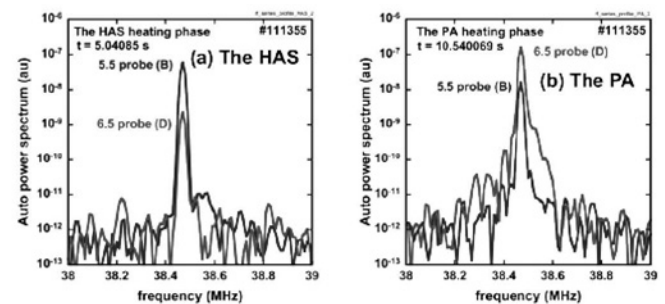


Fig. 3. Frequency broadening by using the HAS and the PA, these plasmas are sustained by only each ICRF antenna.

and the probe D, and the peak intensity of the pump-wave is decreased as propagation distance is increased. For the frequency spectrum of the PA, frequency broadening is observed for both probes, and strongly frequency broadening is carried out around the PA. In previous theoretical works, frequency broadening for fast wave is carried out around plasma edge around two ion-ion hybrid resonance [4], and the fast wave by the PA is easily propagating around plasma edge around the PA antenna than the HAS.

- [1] Y. Tori, et al., *Plasma Phys. Contr. Fusion* **43**, 1191 (2001).
- [2] T. Seki, et al., *J. Plasma Fusion Res.* Submitted (2011).
- [3] K. Saito, et al., *Plasma Sci. and Technol.* submitted (2011).
- [4] M. Ono, *Phys. Fluids* **20**, 990 (1982).