§19. Characteristics of Stray Wave Radiation in Various ECRH Scenarios

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Measurement of the stray wave radiation that is originated from electron cyclotron (EC) waves injected for electron cyclotron resonance heating (ECRH) is used for examination of the ECRH performance, confirmation of the plasma initiation, and is beneficial to avoid damages on structures in the vacuum vessel by stray waves. In the LHD, sniffer probes to detect the stray radiation are installed in four ports. Characteristics of the stray radiation have been investigated in various ECRH scenarios. Fig. 1 shows the change of fundamental ECRH efficiency and the stray radiation levels measured at four different toroidal positions. The 77GHz millimeter waves were injected obliquely to the external magnetic field from the horizontal port antenna. The electron density was changed in each discharge. The stray radiation level 180° distant from the injection port in the toroidal direction increases as the ECRH efficiency decreases as increase of the line averaged electron density n_{e_bar}. On the other hand, the stray radiation level at the injection port remains almost the same. Fig. 2 shows the change of 2nd ECRH efficiency and the stray radiation levels when the 77GHz millimeter waves were injected also from the same antenna as the above case but almost perpendicular to the external magnetic field. The electron density was ramped up during one discharge and pulse train EC waves were injected. When n_{e_bar} is lower than the X-mode cutoff density, the stray radiation levels at any measurement ports obtained by the X-mode injection are lower than those obtained by the O-mode injection and increase as n_{e_bar} increases although the ECRH efficiency remains almost similar. When n_{e_bar} becomes higher than the X-mode cutoff density, the stray radiation levels saturate in the same levels at the port distant from the injection port in both cases of the X-mode and O-mode injections. On the other hand the stray radiation level obtained by the O-mode injection becomes lower than that obtained by the X-mode injection at the injection port. For the case of perpendicular injection, when n_{e_bar} becomes higher than the X-mode cutoff density, it can be guessed that the injected waves are reflected at the X-mode cutoff that is located in front of the injection port and almost directly return back to the injection port as the stray radiation therefore the stray radiation level may reflect the one-pass absorption rate. However for the cases of oblique injection from the same antenna without the existence of the cutoff, the stray waves might suffer more reflection before they reach the injection port, therefore the stray radiation level is not affected by the change of ECRH efficiency.

To examine the effect of the injection direction and the electron density, the 2nd ECRH efficiency and the stray radiation level is plotted versus the toroidal aiming point on the R=3.9 m vertical plane in Fig. 3 for two different density cases, where R is the radial distance from the torus center. In the case of the low ECRH efficiency (d), the stray radiation level measured at the port 180° distant from the injection port increases significantly compared to the decrease of the ECRH efficiency. On the other hand, the stray radiation level at the injection port does not significantly changes with change of the injection direction and the electron density. It has been suggested that the level of the stray radiation that suffers multi reflection through the plasma can be affected significantly by the plasma conditions.

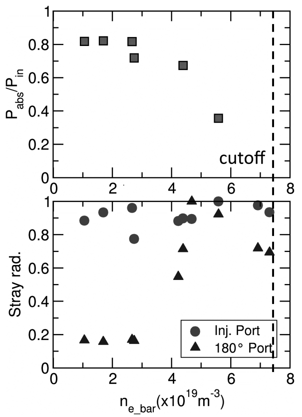

Fig.1: The ECRH efficiency (upper) and the level of the stray wave radiation (lower) plotted as functions of the line averaged electron density n_{e_bar} when the 77GHz millimeter waves are injected obliquely to the external magnetic field as the O-mode for the fundamental ECRH.

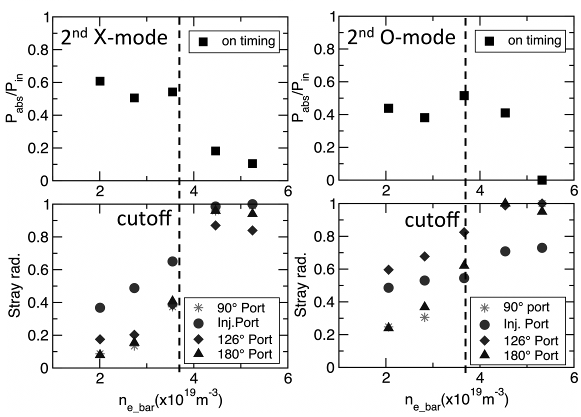

Fig. 2: Similar plots as Fig. 1 when the 77GHz millimeter waves were injected perpendicular to the external magnetic field with the X-mode (left) and the O-mode (right) for the 2nd ECRH.

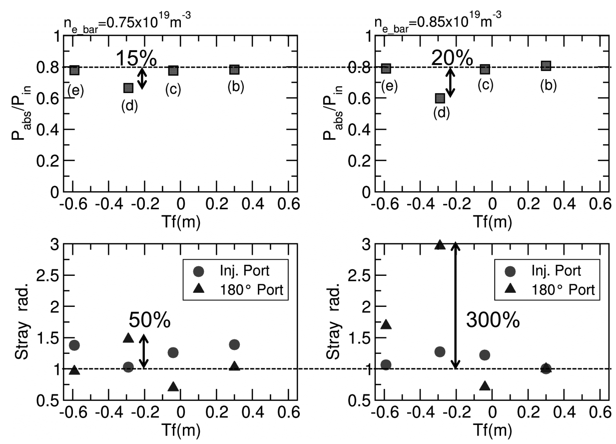

Fig. 3: The ECRH efficiency (upper) and the level of the stray wave radiation (lower) plotted versus the toroidal aiming point on the R=3.9m vertical plane T_f for the cases of n_{e_bar}= $0.75\times10^{19}m^{-3}$ (left) and $0.85\times10^{19}m^{-3}$ (right)