Parameter Dependence of Antenna Loading for the Ion Bernstein Wave in a Tokamak

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Recent results obtained by an ion Bernstein wave (IBW) have shown attractive means of auxiliary heating in tokamaks. Although a study on antenna coupling of IBW using a $E_z$ type antenna (the antenna current is parallel to the toroidal field) is important from a view point of an efficiency of the energy transfer, there are only few results on antenna loading studies. The larger antenna length along the toroidal direction is desirable from ref. 6 to obtain good antenna coupling in addition to have the larger antenna surface. In this present paper, the dependence of plasma loading on various parameters by the $E_z$ antenna, considering the above conditions, is investigated in TNT-A tokamak. Before the study of antenna loading of the $E_z$ antenna, the excitation and propagation of IBW have been checked.

Typical experimental parameters are the followings; major radius $R = 40$ cm, minor radius $a = 8.8$ cm, elongation ratio $\kappa = 1.2$, plasma current $I_p = 4 - 6$ kA, loop voltage $V_i = 5 - 7$ V, mean plasma density $n_e = (3 - 8) \times 10^{12}$ cm$^{-3}$, central electron and ion temperatures $T_e(0) \sim 30$ eV, $T_i(0) \sim 15$ eV, respectively, discharge duration time $= 20 - 30$ ms, ratio of radiated power to ohmic power $= 0.5 - 0.7$.

A cross-sectional view of the $E_z$ antenna, located on the low field side of the torus, has a copper central conductor, 0.8 cm thick and 10 cm wide, and is 30 cm long along the toroidal direction. Single screens of the Faraday shield with 0.1 cm thickness are used to reduce the excited electric field perpendicular to the antenna current. This antenna is located at the nearly same radial position as the fixed limiter, $a = 8.8$ cm.

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loading on the concentration $n_{H}/(n_{H} + n_{D})$ is weak ($n_{H}$ and $n_{D}$: hydrogen and deuterium densities, respectively).

Figure 2 shows the dependence of $R_{p}$ on the mean plasma density $\bar{n}_{e}$ with $f/f_{0} = 5$. From this, a relatively strong increase in $R_{p}$ with the increase in $\bar{n}_{e}$ is found. This feature is the same with that of ref. 6 ($f/f_{0} = 4$), but the threshold of $\bar{n}_{e}$ (the minimum value of the electron density to have plasma loading) = $(2-3) \times 10^{12} \text{cm}^{-3}$ and absolute value of $R_{p} \sim 0.1 \Omega$ are different from the previous results ($\bar{n}_{e} = (4 - 5) \times 10^{12} \text{cm}^{-3}$, $R_{p} \sim 0.05 \Omega$).

Finally, the relation between $R_{p}$ and $f$ is studied. As is shown in Fig. 3, a strong dependence of $R_{p}$ on $f$ with the fixed toroidal field $B_{T} = 3.33 \text{ kG}$ is found, regardless of the harmonic number of $f/f_{0}$. This dependence is roughly expressed as $R_{p} \propto f^{-1/7}$, whereas $R_{p} \propto f^{3.3}$ in the previous fast wave heating experiments in TFR.\(^{14}\) According to ref. 15 in the limited case of $f \sim 2f_{0}$, the inverse dependence of $R_{p}$ on $f$ is found. From ray tracing calculations,\(^{10}\) a ray does not propagate into the plasma due to the strong electron damping when the parallel refractive index $n_{z}$ is greater than $\sim 100$ in the TNT-A device. Uses of Sy's formula and upper limit of $n_{z} \sim 100$ lead to the nearly same dependence of $R_{p}$ on $f$ with the experimental one. However, the further analysis is needed in order to get the qualitative agreements.

In conclusion, parameter dependence of plasma loading $R_{p}$ is investigated in the TNT-A tokamak for the ion Bernstein wave. The $R_{p}$ value increases with $\bar{n}_{e}$ and $f$, but it is weakly dependent on $B_{T}$ and inverse dependent on $P_{\text{inj}}$ are found.

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References