GENERATION OF FAST PARTICLES IN RF DISCHARGE PLASMA IN THE URAGAN-3M TORSATRON

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Results of the energy spectra of charge exchange neutrals and radioemission in the frequency range from the first to the second harmonics of electron cyclotron resonance measurement in RF discharge plasma of the Uragan-3M torsatron are presented. The energy spectra of charge exchange neutrals measured in tangential and perpendicular directions to the toroidal plane show a two temperature ion distribution. By changing the entrance slit width and position of the longitudinal charge exchange analyser is shown that high energy ion generation takes place at the plasma edge. The ECE spectrum was measured by heterodyne radiometers with spectral resolution $\Delta\omega/2\omega_{CE}$~0,036% and threshold sensitivity -0,5 eV. The spectrum of emission at $\Delta\omega/2\omega_{CE}$ is close to the thermal one, but it has peculiarities in the long-wavelength region $\omega/\omega_{CE}<1,85$ and in the short-wavelength region in the vicinity of the frequencies $\omega/\omega_{CE}\approx 2,02$ and $\omega/\omega_{CE}\approx 2,1$, respectively. The maximum of the emission is observed at $|B/B_o|=0,096$, i.e. on the axis of a magnetic configuration. The deviation of a measured spectrum from thermal one in the short-wavelength region corresponds to local maximum of the electron temperature in magnetic islands t=1/3 and t=1/4. The peculiarity of spectrum in the long-wavelength region corresponds to the localization of fast electrons with energy about 1.2 keV on the edge plasma.

Currentless plasma production and heating by RF waves in the ion cyclotron and Alfven resonance region have been studied in the Uragan-3M torsatron ($l=3$, $m=9$, $R=1$ m, $a=0$, 12 m, $B_o<1,5$ T) during the last years. Antennae of two types have been used in plasma production and heating experiments in the ion cyclotron range of frequencies $\omega<\omega_{ci}$. Both types of antennae use Alfven resonance excitation in a multimode regime. The first antenna, which is a frame type antenna (FTA), has been used for plasma production and heating with $n_e<5.10^{12}cm^{-3}$. The second antenna, a three-half-turn antenna (THTA), has been used for the heating of plasma initially produced by the FTA. As a result of THTA operation a new regime with improved global energy confinement time and steeper density and electron temperature profiles at the plasma edge were obtained [1]. However a quasistationary state of discharge in improved regime is rapidly disrupted due to impurity flux growth. To understand this effect the measurements of the energy spectra of charge exchange neutrals and radioemission in the frequency range from the first to the second harmonics of electron cyclotron resonance were performed. The energy spectra of charge exchange neutrals in tangential and perpendicular directions to the toroidal plane for low density plasma (FTA operation) show a two temperature ion distribution (Fig. 1). Doppler broadening of the C(V) line (227,l nm) indicates that these impurity ions are in equilibrium with the lower temperature part of the hydrogen ion distribution during almost the whole RF pulse duration. By changing the entrance slit width and position of the charge exchange analyser was shown that high energy ion generation takes place in the external region of plasma column and their region of localization shifts to the plasma edge with density growth.

The ECE emission was measured by three heterodyne radiometers with spectral resolution $\Delta\omega/2\omega_{CE}$~0,038% and threshold sensitivity ~0,5 eV. Fig. 2 shows the dependence of radiation temperature vs frequency obtained from the calibrated measurements of ECE signal intensity as a function of the emission frequency. The spectrum of emission at $\omega\approx2\omega_{CE}$ is close to the thermal one, but it has pecularities in the long-wavelength region $\omega/\omega_{CE}< 1,85$ and in the short-wavelength region in the vicinity of the frequencies $\omega/\omega_{CE}\approx2,02$ and $\omega/\omega_{CE}\approx2,1$.

The measurements made by the triode and luminescent techniques [2] have shown a complex structure of the magnetic surfaces in Uragan-3M. Configuration contains magnetic islands at t=1/3 and t=1/4. The shift of a magnetic axis from a geometrical axis of helical coils is equal to 5,5 cm.

The maximum of ECE is observed at $|B/B_o|=0,96$, i.e. on the axis of a magnetic configuration. The deviation of measured spectrum from thermal one in the short-wavelength part corresponds to a local maximum of the electron temperature in magnetic islands. The peculiarity of the spectrum in the long-wavelength region corresponds to the localization of fast electrons with energy about of 1.2 keV on the edge of plasma column. The region of localization of these electrons shifts to the plasma edge with density growth.

These effects are caused by the peculiarities of RF power input into the plasma by the FTA. Numerical simulation for FTA has shown that with density rise the region of local Alfven resonances for the whole antenna spectrum is shifted to the plasma periphery, reducing the plasma heating efficiency (Fig. 3)

To avoid the effect of the power deposition profile shift to the plasma periphery with the density rise THTA was proposed and has been studied numerically and adapted for the Uragan - 3M forsatron. The calculations showed that the power deposition profile of the THTA was better than that of the FTA (Fig. 3)

Efficient THTA operation was observed when the plasma density value was higher than $n_e\approx5.10^{12}cm^{-3}$. Turning on RF power to the THTA resulted in plasma density rise up to $3.10^{13}cm^{-3}$. During THTA operation the high energy neutral signal and deviations of a measured ECE spectrum from thermal one were not observed. Moreover, the shift of the THTA power deposition profile to the inner part of the plasma has made it possible to achieve an improved plasma confinement regime.

References

[1] E.D. Volkov et al.: *14th Int. Conference*, Wurzburg 1992, IAEA, Vienna (1993) vol. 2, 679.

[2] G.G. Lesnyakov et al.: Nuclear Fusion **32** (1992) 2157.

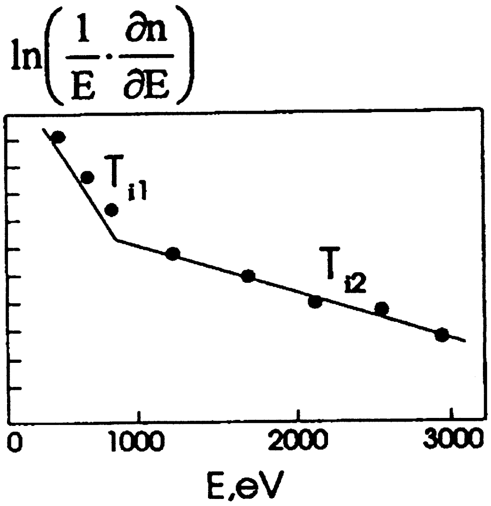

FIG. 1.

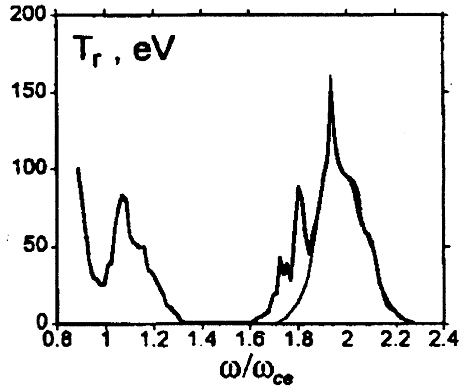

FIG. 2.

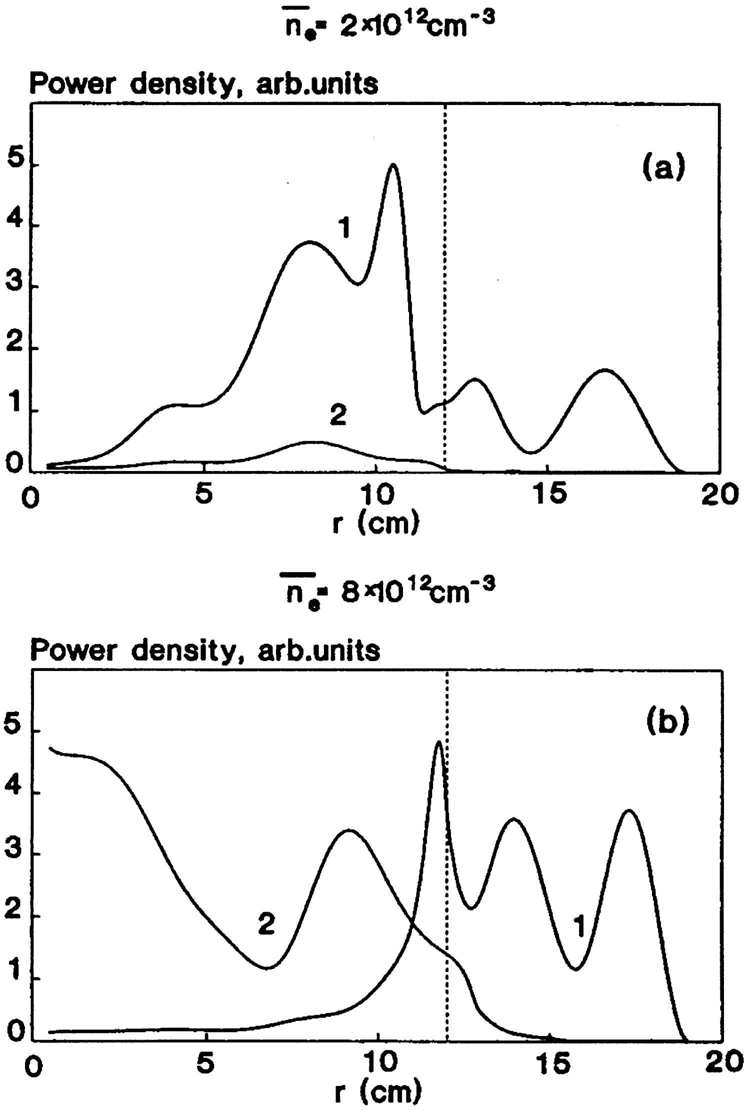

FIG. 3. *Power deposition profiles for the FTA and the THTA:*
(a) low density case: curve 1 — FTA, curve 2 — THTA;
(b) high density case: curve 1 — FTA, curve 2 — THTA.