§13. Progress in Potential Formation and Radial-Transport-Barrier Production for Turbulence Suppression and Improved Confinement in GAMMA 10

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(1) *Four-time progress in ion-confining potentials* ϕ_c to 3.0 kV in comparison to ϕ_c attained 1992-2002 is achieved in the hot-ion mode (T_i=several keV) [Fig. 1]. A scaling of ϕ_c, which favorably increases with plug electron-cyclotron heating (ECH) powers (P_{PECH}), is obtained. [1)]

(2) The advance in ϕ_c leads to a finding of remarkable effects of radially sheared electric fields (dE_r/dr) on turbulence suppression and transverse-loss reduction. [2)]

(3) A weak decrease in ϕ_c with increasing n_c to $\sim 10^{19}$ m^{-3} with the recovery of ϕ_c with increasing P_{PECH} is obtained. [1)]

(4) The first achievement of active control and formation of an internal transport barrier (ITB) has been carried out with the improvement of transverse energy confinement [Fig. 2]. Off-axis ECH in an axisymmetric barrier mirror produces a cylindrical layer with energetic electrons, which flow through the central cell and into the end region. The layer, which produces a localized bumped ambipolar potential Φ_c, generates a strong E_r shear and peaked vorticity with the direction reversal of $E_r \times B$ sheared flow near the Φ_c peak. Intermittent vortex-like turbulent structures near the layer are suppressed in the central cell. This results in *T_e and T_i rises surrounded by the layer*. The phenomena are analogous to those in tokamaks with ITB. [3)]

(5) Preliminary central ECH (170 kW, 20 ms) in a standard tandem-mirror operation raises T_{e0} from 70 to 300 eV together with $T_{i\perp 0}$ from 4.5 to 6.1 keV, and $T_{i//0}$ from 0.5 to 1.2 keV with τ_{p0}=95 ms for ϕ_c (=1.4 kV) trapped ions. The on-axis particle to energy confining ratio of τ_{p0}/τ_{E0} is observed to be 1.7 for ϕ_c trapped ions (consistent with Pastukhov's theory) and 2.4 for central mirror-trapped ions with 240-kW plug ECH and 90-kW ICH (η_{ICH}~0.3; $nl_c=4.5\times10^{17} m^{-2}$). [1)]

(6) Recently, a 200 kW central ECH with 430 kW plug ECH produces stable central-cell plasmas (T_e=600 eV and T_i=6.6 keV) with azimuthal $E_r \times B$ sheared flow. However, in the absence of the shear flow, hot plasmas migrate unstably towards vacuum wall with plasma degradation. [1)]

References

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2) Cho, T. *et al.* Phys. Rev. Lett. **94** (2005) 085002.

3) Cho, T. *et al.* Phys. Rev. Lett. **97**, No.5 (2006).

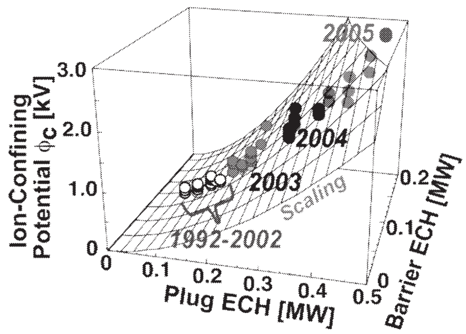

Fig. 1. Four-time progress in ϕ_c including a new record of 3.0 kV for confining central-cell ions (filled symbols) [see ϕ_c during 1992-2002 (open circles)] in accordance with a favorably rising scaling surface of ϕ_c with plug (P_{PECH}) and barrier (P_{BECH}) ECH powers. T_i=several keV (the hot-ion mode).

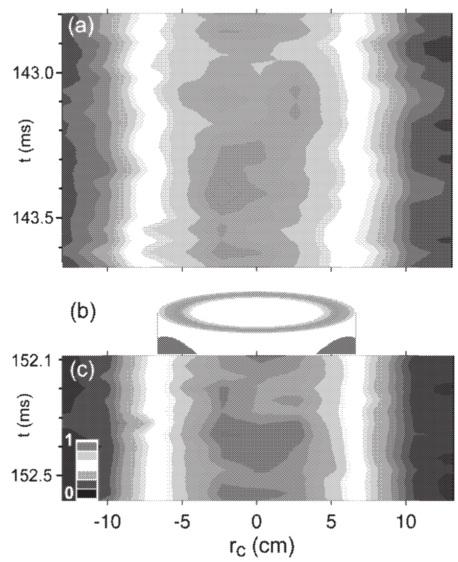

Fig. 2. Contours of central-cell x-ray brightness in (a) the absence and (c) presence of (b) cylindrically shaped energetic-electron-layer formation due to off-axis barrier-cell ECH. The hot-colored core region displays higher plasma-pressure locations. Strong turbulence with vortex-like structures continues to exist at r_c<4 cm in (a) and (c). However, a quietly suppressed region in (c) is observed in the energetic-electron layer [5<r_c<7 cm; see (b)] and the outer surrounding cylindrical layer (7≤r_c<10 cm); ($I \propto n_e n_i T_e^{2.3}$).