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

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Anomalous cross-field transport is one of the most critical issues in improvement of magnetized fusion plasma confinement. Some regimes with reduced anomalous transverse transport have been observed in tokamaks.[1] It is of essential importance for the progress in fusion programs to control the transition toward such regimes.

According to recent theories[1], transition to an H-mode with improved plasma confinement or the formation of internal transport barriers (ITB) in toroidal systems is associated with an increase in non-uniform radial electric fields E_r and a corresponding enhancement of sheared plasma rotation. Remarkably, the low-frequency plasma turbulence and the resultant anomalous transport observed in various devices exhibit rather common features.[1-4]

Recently, intermittent turbulent vortex structures and effects of their suppression by strongly sheared plasma rotation were observed in the GAMMA 10 tandem mirror.[2-4] The suppression of turbulence and the associated significant reduction in cross-field transport in GAMMA 10 show behaviors that are similar to those seen for L-H transitions in tokamaks.[2-5] Mirror devices, having open-ended regions, provide intrinsic important advantages in terms of the control of radial-potential or sheared ***E***×***B*** rotation profiles on the basis of axial particle loss control for ambipolar potential formation.[2-4]

From these viewpoints of universal importance for plasma confinement improvements, experiments are carried out in GAMMA 10, and the recent results are summarized as follows:

(1) A ***transverse energy-transport barrier*** is ***externally controlled*** for the first time by *off-axis electron-cyclotron heating* (ECH). This ***internal energy-transport barrier*** is produced by ECH controlled cylindrical-layer formation ($4<r_c<7$ cm) with energetic electrons. The electrons flow through the whole device and are partially lost into the end region. As a result, a radially localized *ambipolar-potential bump*, with *strongly sheared electric fields* E_r (or peaked vorticity) is formed along with the direction reversal of $\boldsymbol{E}_r\times\boldsymbol{B}$ shear flow near the Φ_C peak. This leads to ***suppress*** *L-mode-like intermittent* ***turbulent vortex-like structures*** *near the layer* in the central cell, and results in $\boldsymbol{T_e}$ **and** $\boldsymbol{T_i}$ **rises** surrounded by this strong shear flow layer *just like* the *characteristics of an internal transport barrier* ***(ITB)*** *in tokamaks and stellarators*.

(2) Such results are based on ***four-time progress*** *in ion-confining potentials* (ϕ_c=3 kV) in comparison to ϕ_c attained 1992-2002 in association with the formation of a strong E_r shear. The data on ϕ_c well fit to a favorably increasing scaling with plug ECH powers. The advance in the potential formation leads to a finding of *remarkable effects of* $\mathbf{d}\boldsymbol{E_r}/\mathbf{d}\boldsymbol{r}$ on *turbulence suppression* and a *transverse-loss reduction*.

(3) Under such physics understanding, the first *preliminary* central ECH (250 kW) raises T_{e0}=750 eV *(a new* ***five-time larger*** $\boldsymbol{T_e}$ ***record)*** together with $T_{i\perp 0}$=6.5 keV, and $T_{i//0}$=2.5 keV. On-axis energy drag (confinement) time from central-mirror trapped '$T_{i\perp}$' ions to electrons is significantly improved to be 0.14 s. On-axis energy confinement time for ϕ_c (=2.5 kV) confined '$T_{i//}$' ions reaches 0.16 s with 380-kW plug ECH applied for *both axial* E_z plugging and strong $\boldsymbol{E}_r\times\boldsymbol{B}$ sheared flow formation simultaneously.

(4) *The* ***stored energy*** *of* ϕ_c ***potential confined ions*** between both plug regions ***exceeds*** *that (diamagnetism) of the central-cell* ***magnetically trapped ions*** for the first time.

(5) A *weak decrease in* ϕ_c *with increasing* n_c ranging to ~10^{19} m^{-3} along with the *recovery of* ϕ_c with *increasing plug ECH powers* is preferably obtained.

References

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