

## §15. Interaction between Resistive Interchange Mode and Helically Trapped Energetic Ions and its Effects on the Energetic Ions and Bulk Plasmas in LHD

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A strong and repetitive bursting instability in a current-free helical plasma has been observed at high toroidal magnetic field  $B_t \sim 2.75T$  in the Large Helical Device (LHD). It locates at the  $\iota/2\pi = 1$  surface near plasma edge having  $m = 1/n = 1$  structure and propagates in the electron diamagnetic drift direction poloidally and counter-Bt direction toroidally with  $f_{mode} \sim 8.6kHz$  in plasma frame. This bursting mode is excited by perpendicular neutral beam injection (PERP-NBI) alone without tangential beam injection. The resonance condition between the observed mode frequency and precession frequency of helically trapped fast ions is estimated following the resonance condition in stellarators:

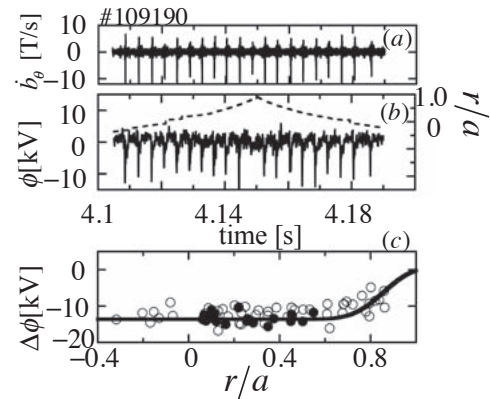
$$\omega_{res} - (m + j\mu)\langle\omega_{\theta}^{EP}\rangle + (n + j\nu N)\langle\omega_{\phi}^{EP}\rangle = 0$$

Here, the bounce averaged angular frequencies are employed for  $\langle\omega_{\theta}^{EP}\rangle$  and  $\langle\omega_{\phi}^{EP}\rangle$ . For  $j = 1, \nu = 1, \mu = 0$  case, resonant frequency is of  $\sim 8.3kHz$ , which indicates that the mode can resonate with the precession motion of helically trapped fast ions. The mode structure of EIC burst is quite similar to that of the ‘‘oscillatory mode’’ excited before each burst, which is thought to be resistive interchange mode destabilized by pressure gradient near the plasma edge. The transition from usual RIC mode to EIC burst is observed by gradually decreasing the line averaged electron density  $\langle n_e \rangle$ . The threshold in the energetic trapped ion pressure  $P_{hot}$  for the transition is estimated by the beam deposition code, suggesting that  $P_{hot}/P_{bulk} \sim 20\%$ , where  $P_{bulk}$  is the bulk plasma pressure.

Various impacts of EIC bursts on plasma performance are observed. First, the increase of neutral flux with energy  $\sim 34keV$  synchronizing with each burst, which is monitored by a Compact Neutral Particle Analyzer system (CNPA), is observed. It suggests the enhanced radial transport of energetic ions, since the neutral density is higher at the plasma edge. Meanwhile, the plasma potential profile measured using 10Hz radial beam scanning of a Heavy Ion Beam

Probe system (HIBP) shows a significant potential change of  $\sim 13kV$  drop in wide core

region during the EIC bursts as shown in Fig 1. It indicates a generation of negative radial electric field near the plasma edge of  $E_r \sim -85kV/m$ . Moreover, significant modification of the plasma flow induced by each EIC burst is measured by Charge exchange Recombination Spectroscopy (CXRS). The toroidal flow is enhanced in counter-Bt direction in  $0.6 \leq \rho \leq 0.92$  and enhanced in co-Bt direction in  $0.92 \leq \rho \leq 1.0$ . It can be explained by a model based on neoclassical theory of non-axisymmetric net-current-free toroidal plasmas<sup>1)</sup>:  $\Delta u_{\phi} \approx -(J/R)^2 \langle G_{BS} \rangle / r E_r$ , where  $J \equiv RB_{\phi}$ ,  $\langle G_{BS} \rangle$  is the geometric factor and  $E_r$  is the radial electric field inferred from Fig. 1. Furthermore, obvious reduction of  $H_{\alpha}$  emission and slight increase of the line electron density near the  $\iota/2\pi = 1$  surface are induced by the bursts. Simultaneously, the transient increase of carbon temperature at plasma edge is observed by CXRS. The density fluctuations related with micro-turbulence, which locate at  $0.5 < \rho < 1.0$  and propagate in the ion diamagnetic drift direction having the phase velocity of 5km/s in laboratory frame, are clearly suppressed during each burst. These data suggest transient improvement of plasma performance with EIC bursts.



**FIG. 1.** Time evolution of the magnetic fluctuation (a), the plasma potential measured at various radial positions by a probe beam radial scan (b) and radial profile of the plasma potential change during EIC burst in Rax=3.75m (cycle) and Rax=3.6m (solid cycle) and the fitted radial profile (black) by employing model  $E_r = -85 \exp(-(\frac{\rho-0.85}{0.15})^2)$  (c).

1) N. Nakajima, M. Okamoto, J. Phys. Soc. Japan 60, 12 (1991)