§55. Physics of Plasma Production by Higher Harmonic ECH

Nagasaki, K., Mizuuchi, T., Kobayashi, S. (IAE, Kyoto Univ.),
Idei, H., Inagaki, S. (Kyushu Univ.),
Cappa, A., Fernandez, A., Castejon, F. (CIEMAT),
Notake, T. (Fukui Univ.),
Mutoh, T., Shimozuma, T., Kubo, S., Yoshimura, Y., Igami, H., Shoji, M.

Fundamental and second harmonic EC waves are routinely utilized for plasma production and heating in toroidal magnetic fusion devices. While several experimental and theoretical works has been made on the plasma breakdown in helical systems, very few systematic studies have been performed on the breakdown physics as compared to tokamaks. This may be because plasma start-up was easily achieved with any kind of wave launching regardless of wave polarization or wave beam focusing, as long as the EC resonance was located inside the last closed magnetic surface. However, the physics is not simple at the second harmonic plasma breakdown. The fundamental plasma breakdown can be explained simply by a linear theory, while the second harmonic plasma breakdown requires consideration of nonlinear wave-particle interactions, since the linear energy increment of seed electrons is proportional to the gyroradius squared, which is practically zero at the initial phase. According to a nonlinear theory, the accelerated electrons should be confined well for causing electron avalanche until they collide with neutrals [1]. Two kinds of physics conditions are required for effective plasma production using second harmonic ECH. One is that the peak energy of trapped electrons oscillating periodically should exceed the ionized potential of neutral particles. The other is that the collision frequency between electrons and neutral particles should be so low for nonlinear interactions, and it should be high for trapped electrons not to escape from the confinement region before ionization process.

In this report, we have experimentally studied a plasma production by using higher harmonic ECH, especially second harmonic ECH in helical systems. In Heliotron J, we have observed that the H_α signal rises up a few ms after the ECH turn-on, and then the electron density starts to increase. The H_α intensity has a peak during the density increase. Under the condition that the axial magnetic field is set as ω_0/ω=0.5 and the injected beam crosses the magnetic axis, the plasma is produced at the magnetic axis, and then the plasma extends toward the last closed magnetic surface. This kind of time evolution is observed in Heliotron J, CHS, TJ-II and LHD [1-4], indicating that these are common phenomena in helical systems. A two dimensional CCD camera measurement in LHD shows that for central heating, a plasma is produced near the magnetic axis, and the light emission position moves with the shift of vacuum magnetic axis. The plasma production depends also on the polarization of injected waves (see Fig. 1). The polarization scan experiment shows that the delay time is shortest at the pure X-mode injection. Although the single pass absorption should be low due to the thin optical depth, the cyclotron acceleration by the wave electric field perpendicular to the magnetic field has an important role on the plasma production.

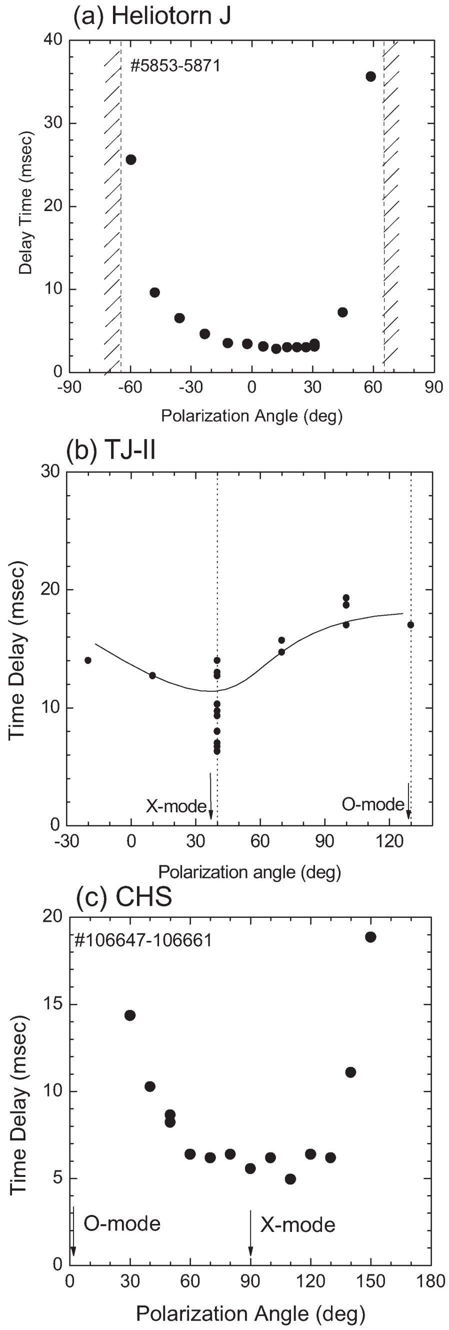

Fig. 1 Dependence of delay time for plasma breakdown on polarization of injected EC waves

1) Cappa, A., et al., Nucl. Fusion 41 (2001) 363
2) Nagasaki, K., et al., Nucl. Fusion 45 (2005) 13
3) Nagasaki, K., et al., J. Korean Phys. Soc. 49 (2006) 18
4) Nagasaki, K., et al., to be published in J. Plasma Fusion Res.