Vertical Launch Third Harmonic Electron Cyclotron Resonance Heating of H-mode on TCV and Access to Quasi-Stationary ELM-free H-mode

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The Tokamak à Configuration Variable (TCV) is equipped with three 480kW gyrotrons operating at 118GHz. Radiation is launched in the extraordinary mode allowing plasma heating using third harmonic X-mode electron cyclotron resonance heating (ECRH) at density above X2 cut-off. This system (X3) [1] allows high beta and ion heating, through electron-ion collisions, to be produced. Power is transmitted to the tokamak along 3 evacuated waveguides where it is projected onto one plasma facing mirror that can be translated radially, between shots, and rotated poloidally during a shot.

Linear ray-tracing [2] has been shown [3] to be an adequate tool for estimating the X3 coupled power in H-mode plasma and all estimates of X3 coupled power presented in this paper have been obtained using ray tracing.

Experiments were performed to heat H-mode using X3. The target was an ohmic H-mode. Up to 90% of the launched X3 power was coupled to the plasma so that the total heating power (1.5MW) was about three times greater than the ohmic H-mode threshold power (500kW). This level of coupled power was maintained even in the presence of significant perturbations to the plasma; ELMS. The radiated power was 300kW during the X3 heated phase. Typically, the X3 heated H-mode discharges entered a large ELMy regime where the energy loss per ELM was ≈12%. The electron temperature increased from 1keV to 3keV and the stored energy and β_N were doubled. The energy confinement time in the large ELM phase was up to 25msec ($H_{IPB(y,2)} = 1.3$) and the high confinement was maintained for 30 confinement times. On other occasions the X3 heated H-modes transited into an ELM free H-mode regime with constant electron density and stored energy. During the X3 phase the stored energy and β_{tor} both doubled ($\beta_N = 2$). The maximum, achieved β_{tor} was 2.5% while the ideal β-limit for these discharges was 3.5%. The recycling light level was high compared to the baseline ohmic H-mode level and the fluctuations in the recycling light level were correlated with core MHD. The confinement time for these discharges was found to be as high as 30ms ($H_{IPB(y,2)} = 1.7$). Measurements of carbon ion temperature profiles and carbon rotation velocity using charge exchange recombination spectroscopy were made and during the quiescent phase the ion temperature, near mid radius, increased from 500eV to 1keV. The plasma rotation increased also from 5kms^{-1} to 50kms^{-1} in the direction of plasma current.

[1] S. ALBERTI et al, Nucl. Fusion **45**, 1224 (2005)

[2] K. MATSUDA, IEEE Trans. Plasma Sci. **17** 6 (1989)

[3] G. ARNOUX Ph.D. Thesis 3401, Ecole Polytechnique Fédérale de Lausanne (2005).