CQL3D-GENRAY Simulations of Suppression of Impurity-Induced Current Quench Using LH Current Drive in C-Mod

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In C-Mod lower hybrid current drive experiments (LHCD), Reinke [1] has examined rare discharges which undergo an abrupt thermal quench (TQ) to low Te due to radiation from incoming tungsten flake material. Surprisingly, the TQ did not lead to a runaway electron (RE) current quench (CQ), normally expected to follow the TQ. Rather, the toroidal current continued at its pre-TQ value without large enhancement of the toroidal electric field, implying that the LH is instrumental in maintaining the current. We simulate the driven LHCD and compare with experiment using the coupled CQL3D Fokker-Planck [2] and GENRAY ray tracing codes, based on experimental traces of the background densities, temperatures, and one-turn voltage. Self-consistent internal toroidal electric field from the Ampere-Faraday equations is included. Simulations show evolution of a quasilinear plateau on the electron distribution, with collisional decay of the plateau from lower to higher velocity ($\tau_{slow} \sim v^3$) giving an inverted distribution during TQ, and self-consistent instability of the injected LH waves. That is, the LH waves growth as they pass through the plasma center; they then damp off-axis by Landau and collisional damping, thus broadening the current profile.

The phenomena are similar to recently reported TQ in DIII-D discharges due to error magnetic induced field stochasticity, followed by healing due to sudden off-axis confinement improvement in a large 1/1 island, giving an off-axis Te-increase [3]. The above LH C-Mod interpretation further supports a new, hopefully robust, disruption control approach.

[1] M.L. Reinke, S. Scott, R. Granetz, *et al*, Nucl. Fusion 59, 066003 (2019).

[2] R.W. Harvey, M.G. McCoy, "The CQL3D Fokker-Planck Code," www.compxco.com/cql3d.html.

[3] X.D. Du, M.W. Shafer, T.E. Evans, *et al.*, Nucl. Fusion 59, 094002 (2019); X.D. Du, Personal communication (2020).