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Detached divertor plasma physics with a stochastic magnetic field

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Stable detachment control is demonstrated by superposing resonant magnetic perturbation of m/n=1/1 on the stochastic boundary of LHD, which introduces a remnant magnetic island outside the last closed flux surface (LCFS). A strongly radiating region is stabilized in the edge, without core plasma degradation. The diagnostics show, a significant reduction of divertor particle/heat flux, formation of very dense ($\sim 10^{20}$ m^{-3}) and cold (a few eV) plasma outside of LCFS, volume recombination in the hydrogen line emission, and strongly decreased intensity of iron emission (Fe VIII$\sim$XII). It is also demonstrated that the discharge is compatible with the internal diffusion barrier (IDB) type plasma, and that the detach-attach transition is readily controlled by gas puff adjustment. The field line structure of a remnant island outside the LCFS is considered responsible for stabilizing the radiating region with the core plasma being unperturbed, because of selective cooling at either O or X-point, where the thermal instability can favorably set in. Simulation of 3D edge transport shows a possibility of the radiative condensation around a remnant island structure at the detachment transition. The simulation also indicates that the geometry of low order (m=7$\sim$5) remnant islands effectively reduces the parallel temperature gradient by increased cross-field energy transport at high collisionality. This results in suppression of the thermal force that usually drives impurities towards the confinement region. Together with increased outward friction from background parallel plasma flow at high collisionality, the high density edge plasma with stochastic field leads to effective impurity screening. The measurements also indicate better screening for discharges with the m/n=1/1 perturbation.