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Superdense Plasma in LHD

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In reduced recycling discharges using a Local Island Divertor (LID) in the Large Helical Device (LHD), a stable superdense plasma develops spontaneously when a series of pellets are injected. A core region with $\sim 4.5 \times 10^{20}$ $m^{-3}$and temperature of 0.85 keV is maintained by an Internal Diffusion Barrier (IDB). The density gradient at the IDB ($r/a \sim 0.6$) is very high, and the particle confinement time in the core region is $\sim$ 300 ms. The temperature profile inside the IDB ($r/a < 0.6$) is flat, on the other hand, its gradient in the outer region is steep. Because of the increase in the central pressure, a large, stabilizing Shafranov shift up to $\sim$ 0.3 m is observed. The critical ingredients for IDB formation are a strongly pumped divertor to reduce edge recycling, and multiple pellet injection to ensure strong central fueling. Gas puffing results in broad, flat or slightly inverted density profiles, and does not lead to formation of a superdense plasma. Low density in the outer region helps to raise the edge temperature gradient there and hence the core temperature. In that sense, for the strong pumping, it does not take an LID to reduce the edge recycling, only if a conventional Helical Divertor (HD) has sufficient pumping capability. Similar discharges can actually be achieved in the HD configuration under exhaustive wall conditioning, although it cannot last for a long time because of the saturation of the pumping capability of the wall. Although use of the island divertor reduces the confinement volume by $\sim$40 % from its nominal value, superdense LID discharges exhibit the highest performance ($n_0 T_0 \tau_E = 4.4 \times 10^{19} m^{-3} \cdot keV \cdot s$) obtained so far in LHD. These plasmas provide unique opportunities for exploration of high-beta MHD stability in heliotron/stellarator configurations, and may extrapolate to a novel scenario for fusion ignition at very high density and relatively low temperature.