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§3. Super Dense Core Plasma (high beta)

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In order to study the MHD properties of the SDC plasmas, we have made an attempt to achieve higher β at B = 1.5 T. The maximum β value so far is $\langle\beta\rangle = 1.4$ % ($\beta(0) = 5.1$ %). We do not see any detrimental MHD activities such as a sawtooth crash or ELM, as seen in case of tokamak improvement modes. The time evolution of the SDC plasma (see Figure 1-a) shows that the SDC forms at 600 ms. After terminating the pellet injection (t = 700 ms), the stored plasma energy and hence $\langle\beta\rangle$ increases for 100 ms and reach the maximum. It is similar to the " reheat event", in which temperature rise occurs after gas puff is turned off. The SDC reheat is significantly drastic. During this phase, the NBI power is fixed. Fig. 1-b show a clear, significant change of the helical plasma equilibrium, i.e., the magnetic axis of the plasma moves outwards significantly (a large Shafranov shift). At t = 703 ms, the temperature and density profiles are those of the typical SDC mode, shown in Fig. 1-c. The temperature starts to increase except for the outer region (R > 4.45m, R<3.25 m)[Fig. 1-b] and the profile at t = 736 ms, maintains the SDC type profile. Because of lower field, the central density decay rate is much higher without pellet core fueling and thus the central density decreases by 25 % at t = 836 ms. During this evolution, the temperature nearly triples, a significant improvement of the confinement, The temperature gradients both in the core and outer regions also increase, deviating from the typical SDC profile, i.e., flat core profile. What causes the above evolution remain unclear. We note that the density profile beyond ρ = 0.8 at t = 703 ms is substantially higher than those at later times and thus termination of the pellets may cause a reduction in the density there, which in turn leads to higher temperature and confinement enhancement. There may be also responsible some kinds of MHD effects, as it discussed below.

The ideal MHD stability of these configurations has been examined by using the 3-D COBRA stability code. The core region inside the zero-shear radius has direct access to second stability, i.e., the stability margin increases with β. Outside the zero shear radius, the plasma becomes unstable to ballooning modes at β, much higher than the present experimental value. Of course, resistive versions of the modes are expected to appear at lower β. These results suggest that MHD effects may play a role in formation of the SDC and may also provide a useful mechanism to constrain the plasma pressure in the outer region. It is interesting to note that high density discharge similar to the SDC has been observed in the tokamak experiments despite significant difference in the MHD properties.

These results suggest a novel fusion ignition scenario in which an SDC is used to operate at very high density and relatively low temperature. Such a scheme is particularly attractive for helical devices because (a) they do not require current drive (which is the most effective at low density), and (b) operation at high collisionality reduces the effect of the helical ripple diffusion regime.

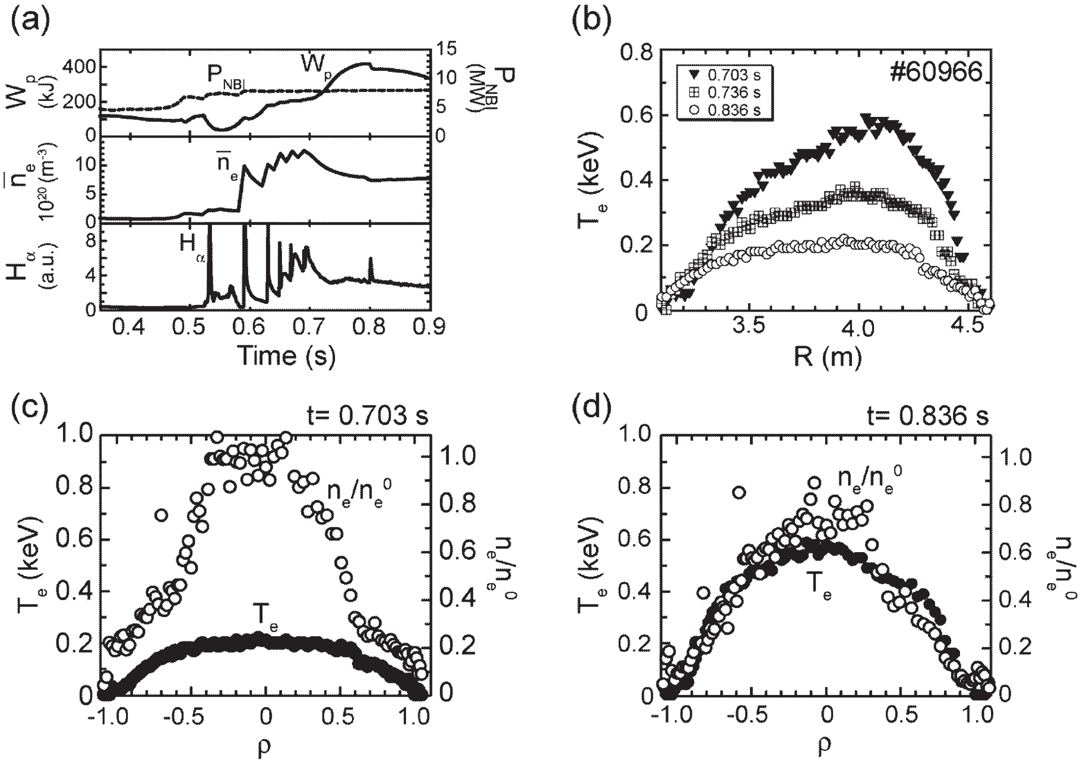

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Figure 1. (a) Time evoluti β discharge with a "reheat" event from t= 700 ms.
(b) Time evolution of the temperature profile (t = 703, 736, 836 ms). (c) The density and temperature profiles just before termination of the pellet injection (t= 703 ms). (d) The profiles near the peak of the W_p (stored energy) (t= 836 ms). $n^o = 3.3\times10^{20}$m^{-3}