§50. Sustained Detachment - Serpens Mode

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Self-sustained detachment has been obtained since the 8th experimental campaign. In Fig. 1, shown are the waveforms from a neutral beam (NB) heated hydrogen discharge where detachment is self-sustained for 2 s. The NB port-through power, P_{NB}^{PT}, of ~ 8 MW is applied from 0.8 to 3.3 s (Fig. 1 (a)). The line-averaged electron density, $\bar{n}_e$, is rapidly increased to > 1×10^{20} m^{-3} by short but strong gas puffing of Φ_{puff} ~ 200 Pa•m^3/s at ~ 1.1 s, after the density feedback phase (Fig. 1 (b)). Then, the ion saturation current measured on the divertor plate, I_{sat} (Fig. 1 (b)) decreases significantly (I_{sat} normalized by $\bar{n}_e$ is ~1/10 of that in the attached phase), indicating that detachment is occurring. Correspondingly, the neutral pressure, p_0 (Fig. 1 (c)) and the H_α intensity (Fig. 1 (d)) also decrease. These suggest that the recycling flux is reduced. Since the high-density is sustained with the reduced recycling, an improved fueling efficiency for the recycling neutrals and/or an improved particle confinement is expected. It should be noted that ELM-like spikes are recognized in I_{sat}, H_α and C_{III} signals. Unlike the usual detachment in other devices, the detachment phase is sustained without gas puffing. No impurity gas puffing is applied in this case and the intrinsic carbon (sputtered from the divertor tiles) is thought to be the main radiator since the C_{III} intensity (Fig. 1 (d)) is well correlated with P_{rad}. The electron temperature at the edge region of ρ = 0.9 (ρ is the normalized minor radius), T_{e09}, decreases below 100 eV as shown in Fig. 1 (e). Here we define an effective radius of the hot plasma boundary, ρ_{100eV}, by an average of ρ where T_e is in the range of 50 to 150 eV (Fig. 1 (e)). In the attached phase before 1 s, ρ_{100eV} is slightly larger than 1, indicating that the hot plasma is filled to the last closed flux surface (LCFS). As the detachment proceeds, the hot plasma column shrinks and ρ_{100eV} decreases to 0.88±0.02, which corresponds to the radius of $\iota/(2\pi) = 1/q = 1$ rational surface, and destabilization of m/n = 1/1 MHD fluctuation is observed, where m and n denote the poloidal and toroidal mode number, respectively. Also in the other discharges obtained in the same magnetic configuration, ρ_{100eV} ranges from 0.85 to 0.9 as long as the detachment phase is sustained.

Slight shortage of the strong gas puffing results in the reattachment as shown in Fig. 2. It is apparent from this figure that I_{sat} decreases and stays at low level as long as ρ_{100eV} is less than 1. In other words, detachment takes place when the hot plasma boundary lies beneath the LCFS. In these cases, however, the detachment phases are not sustained. To achieve the Serpens mode as in Fig. 1, it is necessary to decrease ρ_{100eV} below 0.88. Excess reduction of ρ_{100eV} to less than 0.85 merely leads to the radiative collapse. There is no discharge where the detachment phase is self-sustained with 0.9 < ρ_{100eV} < 1, to date. This suggests that the transition to Serpens mode occurs when ρ_{100eV} becomes close to (or, slightly less than) the radius of the ι = 1 rational surface.

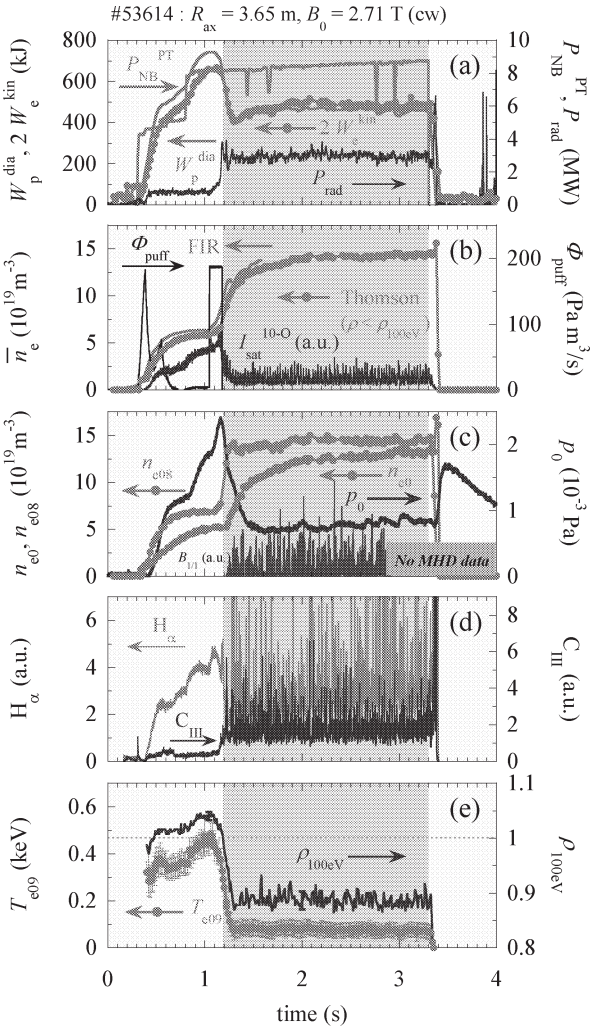

Fig. 1. Typical waveforms in the detachment discharge sustained for 2 seconds (Serpens mode).

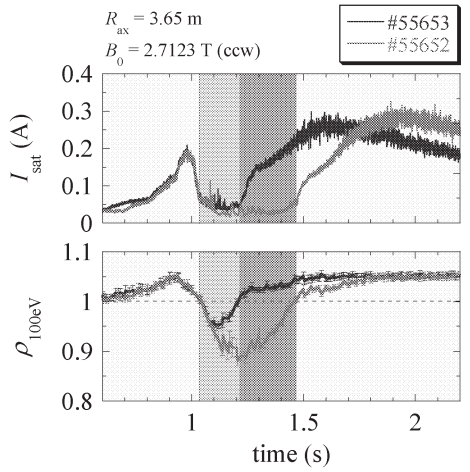

Fig. 2. Examples of reattachment after detachment.