Effects of electrode biasing on density limit in the J-TEXT tokamak

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The economics of operating future magnetic confinement fusion reactors at high densities is critical. However, a large number of experimental studies have shown a general empirical scaling of the density limit: $n_G[10^{20}\mathrm{m}^{-3}] = I_p[\mathrm{MA}]/\pi a^2[\mathrm{m}^2]$, which is also known as the Greenwald density limit. It is commonly believed that the formation of the Greenwald density limit is directly related to the plasma cooling in the edge region at high densities. On the HL-2A tokamak device, a gradual collapse of the shear layer in the edge region and enhanced turbulence-induced particle transport are observed as the plasma density rises[1]. The enhanced collapse of the edge shear layer and turbulent particle transport may lead to cooling of the edge region, which in turn generates secondary phenomena such as destructive MHD instability and even disruption, and may be the mechanism by which the Greenwald density limit arises. Theoretic study of zonal flow generation at high density region shows that with electron response transiting from adiabatic ($k_{//}^2 v_{th}^2/\omega\nu > 1$) to hydrodynamic region ($k_{//}^2 v_{th}^2/\omega\nu < 1$), the edge shear layer collapses and turbulent particle transport increases[2]. These experimental and theoretic studies suggest strong relation between edge shear layers and density limit phenomenon.

In the J-TEXT tokamak, by sticking an electrode with a high electric bias in the main plasma, a strong radial current can be formed in the plasma between the electrode and the ground, which drives the poloidal rotation of the plasma and generates a radial shear electric field. In these experiments, we demonstrate the use of biased electrodes to maintain shear flow in the edge region under high-density discharge conditions at the J-TEXT tokamak device, resulting in a stable discharge density enhancement. With electrode biasing, zonal flows are excited and turbulent particle transport is reduced. The edge electron cooling is also mitigated. However, the experimental results were limited by biasing probe performance, since higher bias voltage is not available up to now. These results suggest that collapse of the edge shear layer is one of the important reasons for the generation of the Greenwald density limit.

References

[1] R. Hong et al, Nuclear Fusion. 58(1):016041 (2018)
[2] R. J. Hajjar et al, Physics of Plasmas. 25(6):062306 (2018)

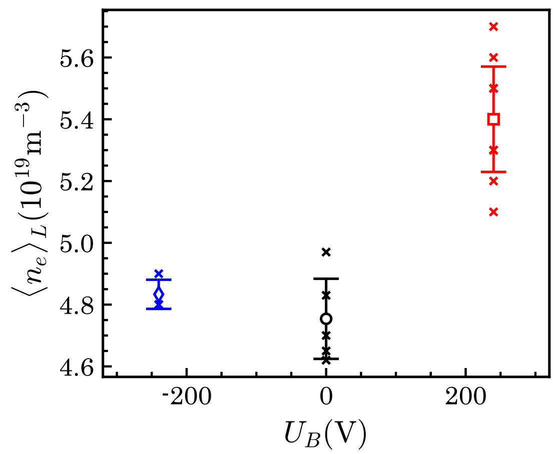

Figure 1 The maximum density achieved before the plasma has a strong TM or disruption with -240V (blue diamond) biasing, floating or 0V biasing (black circle), and +240V biasing (red rectangle).