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Effect of Lower Hybrid Current Drive on Edge Plasma Flows on HL-2A

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In magnetically confined plasmas, plasma rotation and the rotation velocity shear are considered as the key factor for stabilizing micro- and macro-instabilities (such as drift wave turbulence [1] or resistive wall modes [2]). Thus, the generation, as well as the control of plasma rotation or rotation velocity shear, is one of the most intriguing topics in magnetic fusion plasma physics. Strong plasma rotation can be driven by Neutral Beam Injection (NBI) heating, which provides a significant external momentum source inducing plasma rotation. Moreover, it has been found that the plasma rotation shear can also be generated by externally driven radio-frequency waves [3]. In the past decade, extensive research of toroidal rotation effects with lower hybrid current drive (LHCD) has been made [4]. In this work, the effect of LHCD on edge plasma perpendicular rotation velocity $u_\perp$ and the turbulence have been studied by using multi-channel Doppler reflectometry on the HL-2A tokamak.

It has been shown in L-mode plasmas, $u_\perp$ is positive in the plasma core and near the separatrix. In the edge region $(0.9 < r/a < 0.98)$, $u_\perp$ turns into negative, formatting a negative $u_\perp$ well. With LHCD heating, the $u_\perp$ well becomes deeper. Correspondingly, both the positive velocity shear ($\partial u_\perp/\partial r > 0$, which is calculated from the outside of $u_\perp$ well) and negative velocity shear ($\partial u_\perp/\partial r < 0$, which is calculated from the inside of $u_\perp$ well) increase. The increase of velocity shear with LHCD heating is possibly explained by the decrease of plasma collisionality, which is proportional to $nT^{-3/2}$, with n the plasma density and T the plasma temperature. Statistical analysis shows that the velocity shear increases with LHCD heating power, as shown in figure 1. It should be noted that the positive and negative velocity shear are asymmetric in the magnitude, with positive velocity shear greater than the negative velocity shear.

The edge plasma turbulence is measured by Doppler reflectometry and the measured wave-number is in $k_\theta = 6\sim10\ cm^{-1}$. It has been shown that the turbulence intensity increases simultaneously with LHCD heating. In addition, plasma turbulence can also be measured by beam emission spectroscopy (BES), with the measured wave-number in $k_\theta = 1\sim2\ cm^{-1}$, which is relatively lower than that by Doppler reflectometry. Unlike the intensity of relatively small scale turbulence measured by Doppler reflectometry, the intensity of relatively large scale turbulence measured by BES decreases with LHCD heating. The contrary behavior of these turbulence intensities with different wave-number are possibly due to the difference in turbulence linear growth rate. For the turbulence suppression during the L-H transition, it has been shown that the turbulence intensity in negative velocity shear layer is significantly reduced, leading to the formation of edge transport barrier, while the turbulence intensity in positive velocity shear layer is basically unchanged, even the positive velocity shear is greater than the negative velocity shear.

References

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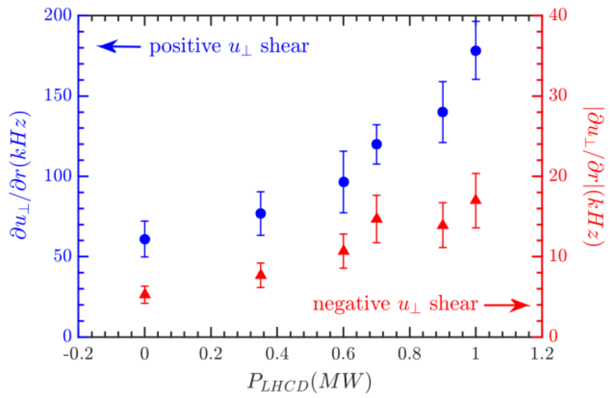

Figure 1. Velocity shear ($\partial u_\perp/\partial r$) versus the LHCD heating power. The blue dots represent the positive velocity shear, and red triangles represent the negative velocity shear.