Plasma position measurements of tokamak plasmas by dual-polarization reflectometry system

Y.Q. Shen[1], Z.C. Yang[1], W.L. Zhong[1], M. Jiang[1], Z.B. Shi[1], J. Santos[2], P.W. Shi[1], R.H. Tong[1], J. Wen[1], X. Yu[1], G.Q. Xue[1], Y. Zhou[1], W.C. Deng[1]

[1] *Southwestern Institute of Physics, Chengdu 610041, China*

[2] *Associação EURATOM/IST, Instituto de Plasmas e Fusão Nuclear—Laboratório Associado, Instituto Superior Técnico, 1049-001 Lisboa, Portugal*

Email address of the main author: shenyuqi@swip.ac.cn

In tokamaks, real-time feedback control of the plasma position, which plays a crucial role in disruption avoidance and machine protection, is usually performed by magnetic diagnostics [1]. During the long pulse operation of future fusion reactors such as ITER and DEMO, the position deduced from magnetic diagnostics may be subject to substantial errors due to the drift of integrators [2]. The harsh radiation environment may also induce potential changes in the mechanical and electrical properties of magnetic coils. Plasma Position Reflectometry (PPR) was originally proposed to backup or supplement the standard magnetic-based control in ITER during the long steady-state flat-top periods as a result of its unique capability to measure the location of a specified density layer in the vicinity of separatrix, with sub-centimeter spatial resolution and microsecond temporal resolution, and of its robustness to withstand the harsh ITER environment [3].

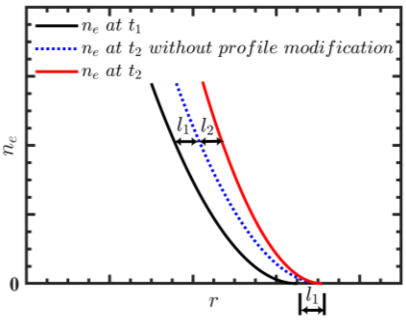

Fig. 1. Boundary density profiles at two moments, used to interpret the cut-off layer displacement consisting of the first cut-off layer displacement and the profile

Generally, the cut-off density layer movement is generated by the combination of plasma displacement (more precisely, the displacement of the first cut-off layer where the electron density is zero) and profile modification, which can be explained by the Fig. 1. When density profile changes from moment t_1 to moment t_2, the cut-off layer moves by $l_1 + l_2$. The displacement of any cut-off layer is equivalent to the displacement of the first cut-off layer l_1 if density profile maintains its stiffness without density modification. Accordingly, l_1 is due to the displacement of the first cut-off layer and l_2 is due to profile modification. We can use the first cut-off layer displacement detected by X-mode reflectometry to modify the results calculated based on O-mode reflectometry in order to increase the precision of cut-off layer displacement.

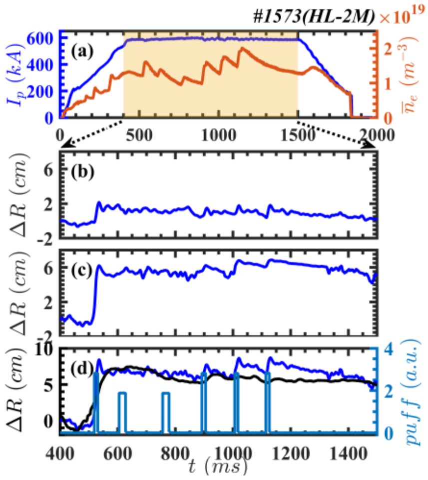

Fig. 2. (a) Plasma current I_p and line-averaged density $\bar{n}_e$, (b) relative displacement of the first cut-off layer, (c) relative displacement of the density layer for $1.16 \times 10^{19} m^{-3}$ based on phase shift, (d) comparison of the horizontal relative displacement (black line) from magnetic measurement and the displacement of the cut-off layer for $1.16 \times 10^{19} m^{-3}$ (blue line) which has been modified by the first cut-off layer displacement

We have tried to measure the cut-off layer displacement by dual-polarization reflectometry on the HL-2M tokamak, as depicted in Fig. 2. Here a new physical model based on the phase shift is proposed to deduce the relative movement of the plasma column without density inversion. A comparison of the cut-off layer displacement (blue line) and the horizontal relative displacement (black line) is displayed in Fig. 2(e) after the O-mode calculation is adjusted by the displacement of the first cut-off layer. In overall, there is a good agreement between the two curves, especially during the significant horizontal displacement that takes place between 400 and 600 ms. Additionally, when the active gas puffing pulses are stronger, the cut-off layer shifts significantly outward, which laterally demonstrates the accuracy of the cut-off layer displacement [4].

This is preliminary evidence that the specified cut-off layer from reflectometric measurement is an alternative position estimation for monitoring the plasma-wall gaps. These results could provide an important technical basis for the further development of a real-time control system based on PPR.

References

[1] D. Gates *et al* 2005 *Nucl. Fusion* **46** 17.
[2] A. Donné *et al* 2012 *Nucl. Fusion* **52** 074015.
[3] J. Santos *et al* 2012 *Nucl. Fusion* **52** 032003.
[7] Y. Shen *et al* submitted to *Rev. Sci. Instrum.*.