A new divertor concept - Fishtail Divertor for heat load control on divertor target plate in EAST tokamak experiments

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The divertor heat load is one of the most critical problems for future fusion reactors. A number of new divertor concepts, such as the Snowflake divertor (SFD), X-point, Super-X divertor (SXD), and X-point target divertor (XPT), have been proposed to broaden the distance between adjacent magnetic surfaces and increase heat flux channel widths in the region from X point to target. On EAST tokamak, an innovation divertor technology, Fish Tail Divertor (FTD) [1], which can quickly move the strike point along the radial and poloidal direction like a fishtail swing by additional alternating magnetic field, is proposed aiming at reducing the heat load as well as ELM mitigation.

The FTD concept has been confirmed successfully in EAST tokamak experiment. A PF like conducting coil was installed behind the lower outboard (LO) divertor target near the strike point, as shown in Fig. 1(a), on which the AC current with maximum value of +/- 8 kA is imposed in a sinusoidal waveform at the specified frequency from 10 to 100 Hz. As a result, the strike point swings along the divertor plate, which is seen from the ion saturation current density profile measured by divertor probes, seeing the Fig. 1(b). The maximum movement of strike point can be 6 cm so that the wetted area of the heat flux can be equivalently broadened. During FTD application, a stable plasma shape and position control is obtained by subtracting the FTD perturbation from the measurement of magnetic probes for equilibrium reconstruction. It is found that the control error for each segment can be minimized to several mWb and the vertical plasma oscillation induced by FTD is less than 1 cm. No obvious reduction of the plasma confinement is observed.

The head load on the divertor plate, viewed by IR camera, is also found to be reduced significantly [2], as shown in Fig. 2. As the strike point swung by FTD, the peak heat flux is moved periodically away from the fixed position and therefore the surface temperature is reduced due to the active cooling capacity of the target plate. The Fig. 2 shows that both the peak heat flux and averaged heat load on the divertor target are periodically reduced by a factor 50%. Furthermore, the thermal analysis with COMSOL indicates that the pulse heat load of ELMs can also be reduced by FTD with AC current frequency of only 100 Hz, by which the maximum temperature of the divertor target plate is reduced by 80% [3]. In the future, the FTD concept will be updated by a new coil structure and installed on HL-2M tokamak for the cross-machine validation. This talk will introduce systematically the FTD as an innovation approach to active control of heat load, including the concept design, the engineering achievement, the physics and experimental study.

References

[1] X. D. Zhang, Y. Zhang, *et al.*, IAEA second technical meeting on Divertor Concepts, 13-16 November 2017.

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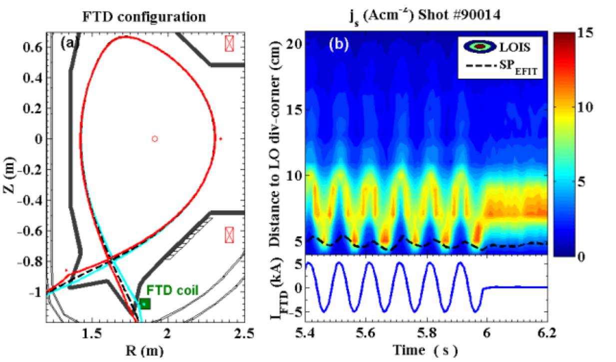

Fig 1. (a) FTD configuration and (b) strike point swing by applying AC current in FTD coil obtained from the contour of ion saturation current density, which is measured by Langmuir probes along the divertor target from the corner, and the strike point position given by EFIT is shown by black dotted line.

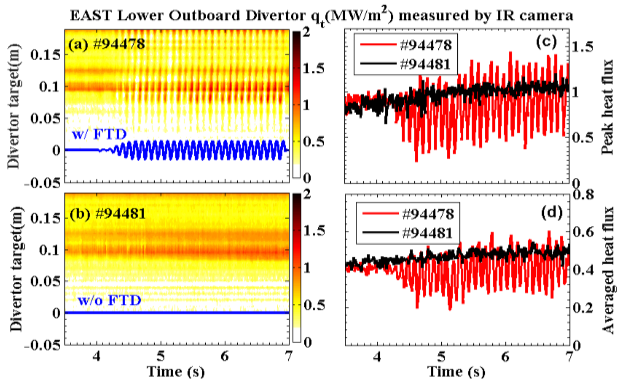

Fig 2. The heat flux distribution measured by IR camera is shown along the lower divertor target with (a) and without (b) FTD current, where the strike point position provided by EFIT is shown by black line. Both peak heat flux (c) and average heat load (d) on divertor target are reduced by 50% with FTD