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Reduction of thermal diffusivity inside a magnetic island in tokamak plasmas
トカマクプラズマの磁気島内部の熱拡散係数の減少

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Ion temperature profile peaked inside the m/n = 2/1 magnetic island is observed in the locked tearing mode phase in JT-60U after the back transition from the H-mode to the L-mode phase. This peaked ion temperature profile is sustained in the steady state. The ion thermal diffusivity inside the magnetic island is evaluated in the power balance analysis using the island flux surface The thermal diffusivity inside the magnetic island is found to be much lower than that outside the magnetic island by an order of magnitude..

1. Introduction

Since the discovery of ITB formation associated with a single-helicity state in RFP plasma[1], it has been recognized that the helical structure of magnetic configuration may contribute the improvement of transport. In general, the power balance transport analysis in the steady state plasma fail to derive thermal diffusivity, because of a lack of heat flux across the O-point of the magnetic island. Therefore there are few experiments to investigate the transport inside the magnetic island. The electron thermal diffusivity was evaluated inside the magnetic island by focusing ECH into the O-point of the magnetic island[2].

2. Experimental results

In JT-60U, the transport inside the magnetic island is investigated in the plasma during the transient phase after the back transition from H-mode to L-mode, where a sudden drop of temperature outside the magnetic island causes a peaking of ion temperature at the O-point inside the magnetic island. The peaked ion temperature profiles can be sustained until the plasma rotation starts and the magnetic island disappears. The radial heat flux inside the magnetic island (O-point) is much smaller than the heat flux outside the magnetic island, because the major heat flux flows across the X-point of the magnetic island. Therefore long decay time of peaked ion temperature suggests the reduction of ion thermal transport.

3. Transport analysis

The heat flux inside the magnetic island (from the O-point to the separatrix of magnetic island) is calculated based on the magnetic flux surface with m/n=2/1 magnetic island. As seen in Fig.1, the flux surface label Φ is modeled as

$$\Phi = 2(r - r_s)^2/w_h^2 - \cos(m\xi) \qquad (1)$$

and

$$\xi = \theta - (n/m)\varphi \qquad (2)$$

where the flux surface label Φ = -1 in the O-point and Φ = 1.

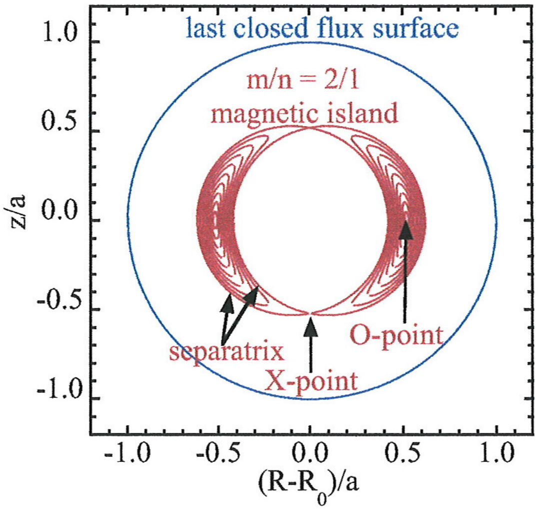

Fig.1 Flux surface using the island model expressed with equation (1).

The flux surface can be expressed as

$$r = r_s \pm [w_h^2\{-1+\cos(m\xi)\}/2]^{1/2} \quad \text{in the O-point}$$
$$= r_s \quad \text{for } m\xi = 0$$

$$r = r_s \pm [w_h^2\{1+\cos(m\xi)\}/2]^{1/2} \quad \text{on the separatrix}$$
$$= r_s \pm w_h \quad \text{for } m\xi = 0$$
$$= r_s \quad \text{for } m\xi = \pi \text{ (X-point)}$$

The heat flux inside the magnetic island (from the O-point to the sseparatrix of magnetic island) is calculated based on the magnetic flux surface with m/n=2/1 magnetic island expressed in this flux surface model. As a result, the heat flux inside the magnetic island (from the O-point to the separatrix of magnetic island) is 15 – 20% of the heat flux outside magnetic island (from the plasma center to the separatrix of magnetic island and from the separatrix towards the plasma periphery).

4. Thermal diffusivity inside the magnetic island

Figure 2(a) shows the ion temperature profile and ion thermal diffusivity in this experiment. There is no structure of magnetic island observed ub the ion temperature profile in the H-mode phase (t=6.4s). After the back transition from the H-mode phase to the L-mode phase, the m/n=2/1 locked tearing take place and the peaked ion temperature profile is observed inside the magnetic island. The peaking of the ion temperature is significant (ΔT_i = 2keV), although the peaking of electron temperature is small (ΔT_e = 0.1keV). It is also interesting that there is no peaking of electron density observed. The intensity profile of carbon charge exchange line suggests that the carbon density profile is slightly hollow inside the magnetic island, which is contract to the peaked electron/impurity density profile in the "snake" mode.

Since the heat flux from the plasma center flow through the X-point of the separatix the heat flux inside the magnetic island is small. Therefore the thermal diffusivity evaluated inside the magnetic island in the L-mode phase is also small (0.1 m^2/s), which is much lower than that outside the magnetic island by an order of magnitude as seen in Fig.2 (b). The ion thermal diffusivity outside magnetic island is 1 m^2/s at the half of plasma minor radius and increases sharply toward the plasma periphery.

5. Discussion

The observation of peaked ion temperature profiles inside the magnetic island shows that the transport inside the magnetic island is significantly reduced. One of the candidates for the possible mechanism of improvement of heat transport inside the magnetic island is "helicity" of the magnetic flux. However, the detailed mechanism for the transport improvement by this 3D effect of magnetic topology on transport is still open to questions.

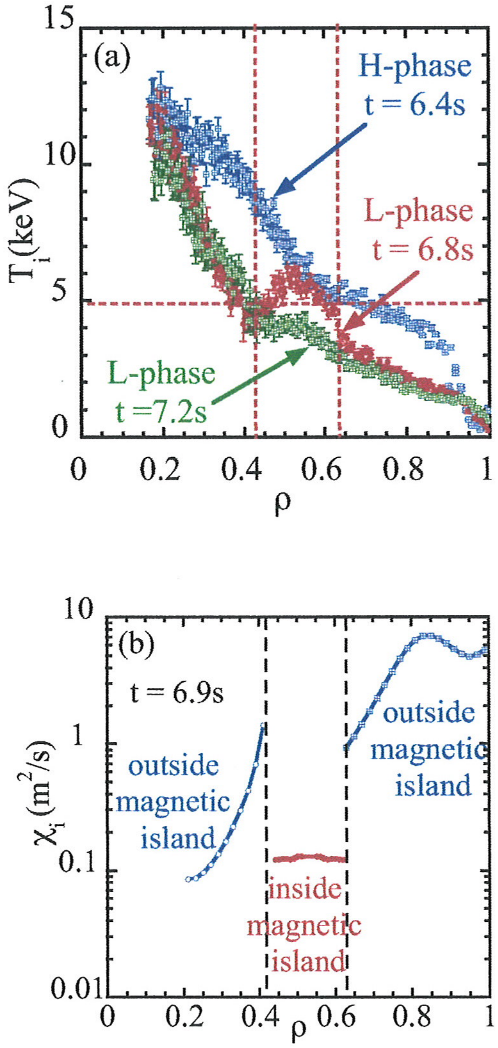

Fig.2 Radial profiles of (a) ion temperature and ion thermal diffusivity.

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References

[1] R. Lorenzini, et. al., Nature Physics 5 (2009) 570.
[2] I. G. J. Classen, et al., Phy. Rev. Lett. 98 (2007) 035001.