§3. Self-regulated Oscillation of Transport and Topology of Magnetic Islands in Toroidal Plasmas in DIII-D

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The coupling between the transport and magnetic topology is an important issue because the structure of magnetic island, embedded in a toroidal equilibrium field, depends on the nature of the transport at the edge of the island. Measurements of modulated heat pulse propagation in the DIII-D tokamak have revealed the existence of self-regulated oscillations in the radial energy transport into magnetic islands that are indicative of bifurcations in the island structure and transport near the $q=2$ surface. Large amplitude heat pulses are seen in one state followed by small amplitude pulses later in the discharge resulting in a repeating cycle of island states. These two states are interpreted as a bifurcation of magnetic island with high and low heat pulse accessibility. This report describes the discovery of a bifurcation in the coupled dynamics between transport and topology of magnetic islands in tokamak plasmas[1)] .

The electron temperature measured with ECE shows a clear 50Hz modulation with the amplitude of 5–10 eV associated with the ECH pulse. An important finding is that the modulation amplitude oscillates with a frequency of 5 Hz, although the ECH modulation and the phase of the C-coil is constant. The modulation envelope is evaluated from the amplitude of fundamental component (50Hz) of the ECE signal in running FFT analysis. There are two states of modulation amplitude: one is with large modulation amplitude and the other is small modulation amplitude. The former corresponds to the magnetic island with high heat pulse accessibility and the later corresponds to the magnetic island with low heat pulse accessibility. The relative modulation amplitude is 2-3% in the magnetic island with high accessibility, while it is less than 1% in the magnetic island with low accessibility. Two states of magnetic island (high and low heat pulse accessibility) are clearly observed both in the temperature at the magnetic island and magnetic field $B(200°) - B(307°)$ measured with two probes located at the low field side for the C-coil toroidal phase of 185°.

Figure 1(a) shows the contour of relative modulation amplitude of electron temperature in space and time during the transition from high accessibility ($\tau < 0$) to low accessibility ($\tau > 0$) magnetic island and figure 1(b) shows the back transition from low accessibility to the high accessibility magnetic island at O-point. Here, the timing of the conditional averaging is the zero crossing of the $\delta T_e/T_e - \overline{\delta T_e/T_e}$ with negative slope for forward transition and with positive slope for backward transition. The region of the low relative modulation amplitude indicates the region with nested magnetic flux surfaces. Therefore, the magnetic island phase with a high heat pulse accessibility is interpreted as highly accessibility with a large edge accessible layer and a small region of nested flux surfaces inside the island. Two states of the heat transport across a magnetic island can be explained by the hypothesis that turbulence spreading can occur in the island. This could trigger a self-regulated feedback oscillation of the island dynamics that is qualitatively consistent with the experimental observations. In one state the turbulence does not penetrate into the magnetic island, and the other the turbulence penetrates into magnetic island due to the process of turbulence tunneling.

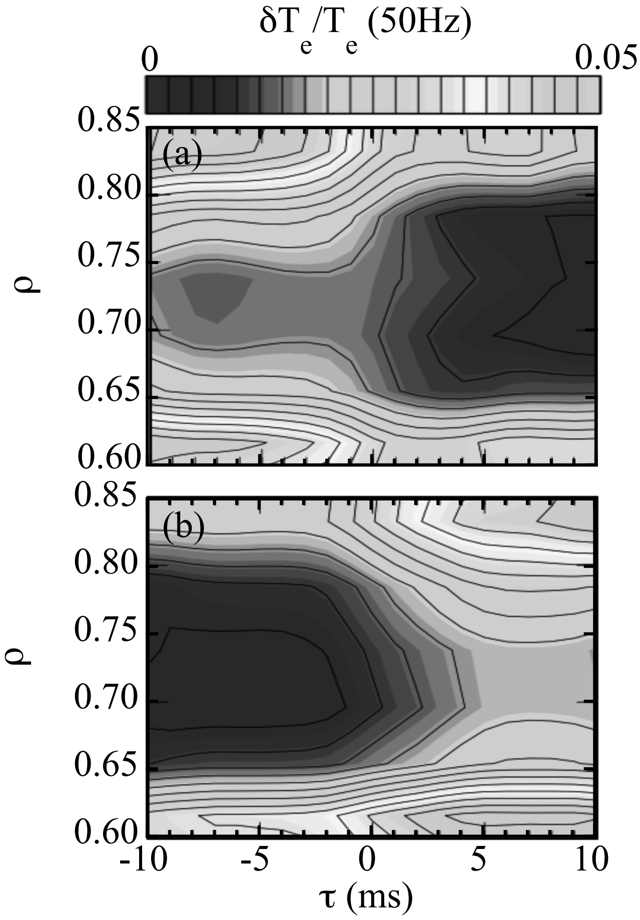

Fig. 1: Contour of relative modulation amplitude of electron temperature in space and time during the (a) forward transition (from high accessibility to low accessibility magnetic island) and (b) backward transition (from low accessibility to high accessibility magnetic island) at O-point.

1) K.Ida, et. al., Sci. Rep. 5 (2015) 16165.