§40. Relationship between Magnetic Field Structure and Plasma Density Profile in LHD Edge Region

Matsuura, H., Iguchi, S. (Osaka Pref. Univ.)
Morisaki, T.

The last closed flux surface (LCFS), which defines the boundary between nested magnetic surfaces and the so-called separatrix layer, is one of the key parameters for the coil winding design of the helical experimental devices. Due to the complicated ergodic properties, however, its position is still unclear. Moreover, this ergodicity is thought to change with the magnetic axis shift or the plasma beta effect. Unfortunately we have no measure to quantify the magnetic structure of the separatrix layer yet. Lyapunov exponents, which are one of most popular tools for detecting the onset of chaos of the reconstructed attractor, may become promising measures.

In the 6th experimental campaign, detailed electron density profiles of the large helical device(LHD) edge region are measured experimentally with a 20keV lithium beam probe(LiBP) [1]. Especially in low density plasma, density profiles are thought to show some properties of the vacuum magnetic field ergodicity. In Fig. 1, flattening in the edge density profile is seen at outside of the LCFS($x \sim 0.6$[m]) in the outward-shifted magnetic axis configuration, where x is a new coordinate along the Li beam path. Sub peak around $x \sim 1.0$[m] is thought to correspond to the plasma at the divertor leg.

Firstly we compare above experimental results with magnetic field line calculation. One example of the Poincaré map of Li-beam propagation surface is shown in Fig. 2. Starting points of field line tracing are set along the Li-beam path. Li-beam proceeds along the holizontal line at $Z = 0.3$[m], which crosses the large island at $x \sim 0.6$[m]. The position of this island is well corresponding to the inner boundary of the density flattening observed in low density discharge. Since islands are poloidally elongated and radially narrow, however, it is often hard to see whether regular structures(ie. magnetic surfaces) still exist at other positions or not. In Fig. 3, the maximum Lyapunov exponents(λ_1) estimated with Wolf's method [2] are plotted for the field lines of Fig. 2. In most points Lyapunov exponents(λ_1) are positive and magnetic field lines are chaotic. But in some places, $\lambda_1 \sim 0$ and regular structure is formed. These correspond to natural magnetic islands. In $R_{ax} = 3.75$[m] case, besides a big island at $x \sim 0.6$[m], it is expected that other small islands exist around $x \sim 0.54$ and 0.57[m] .

As the lack of Poincaré map data for divertor leg, we can not deduce λ_1 there with Wolf's method. Nevertheless, Lyapunov exponents are very useful tools to distinguish small elongated natural islands in the separatrix layer.

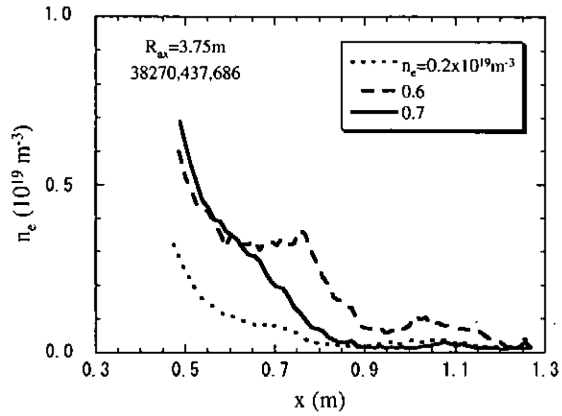

Fig. 1: Flattening in the edge density profile (R_{ax} = 3.75[m]).

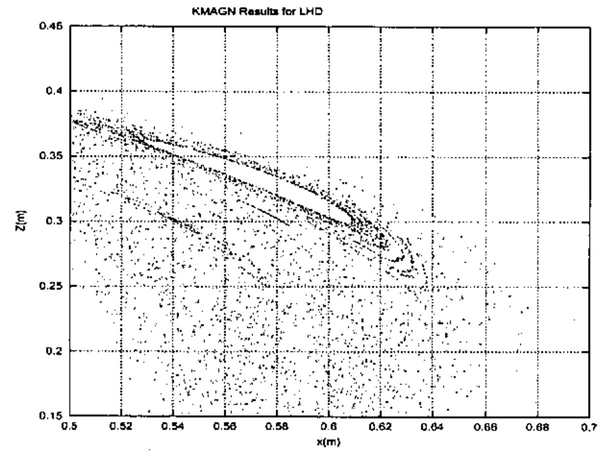

Fig. 2: Poincaré plot on the Li-beam plane (R_{ax} = 3.75[m]).

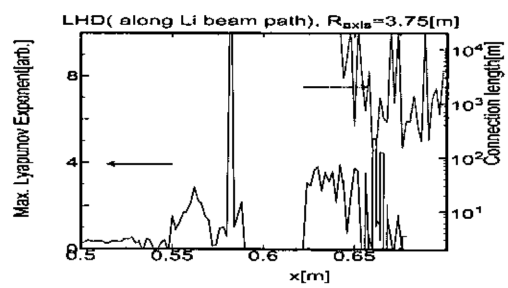

Fig. 3: The Lyapunov exponent for $R_{ax} = 3.75$[m] case.

References

1) Morisaki T., et al.: 27th EPS ECA **24B**, (2000) 780.
2) Matsuura H., et al.: to be published in JPFR seri. 6.