§21. Physics Study on 3-D Helical Equilibrium Plasmas in a LHD Plasma with 2-D Imaging Diagnostics

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The measurement of bremsstrahlung soft X-ray (SXR) radiation is one of the useful passive methods for diagnosing high-temperature plasmas, because contours of the SXR emissivity correspond to magnetic surfaces of the plasmas. SXR imaging has been applied to high-temperature toroidal plasma experiments for the study of pressure fluctuations either in the core or at the periphery[1]. The reversed field pinch (RFP) is a high-temperature and high-beta toroidal plasma. In the RFP, studies on the behavior of magnetic islands due to the tearing modes are quite important, because the RFP configuration is self-organized and sustained by nonlinear interaction of the tearing modes, which lead to magnetic chaos. One of the important issues of this study is the development of three dimensional (3-D) SXR measurement system, which will be applied for physics study on 3-D helical equilibrium on LHD.

Consecutive imaging measurement has been a useful tool for understanding the plasma dynamics and instabilities. Therefore, we have developed an SXR imaging diagnostic system that uses multiple pin-hole SXR cameras together with high-speed cameras to record the time evolution of the SXR images from the tangential and vertical directions simultaneously for studying the dynamic structures of 3-D SXR emissivity. A schematic drawing of the imaging system set on low-aspect-ratio RFP RELAX[2] is shown in Fig. 1.

The magnetic field topology for the QSH RFP phase in RELAX plasmas are obtained by the guiding center code ORBIT, given the magnetic field profiles, i.e., axisymmetric equilibrium component and helical perturbation component[3]. The equilibrium configuration was reconstructed with the following external quantities as the constraints: the plasma current $I_{\rm p}$, $< B_\phi >$, $B_\phi(a)$, edge poloidal field $B_\theta(a)$, and internal line-averaged density $n_{\rm e}$ obtained using an interferometer. Moreover, the radial position of $m/n = 1/5$ mode rational surface, estimated from obtained SXR images for QSH state was also used as a constraint. The amplitude of m/n tearing mode and ϕ of a magnetic island due to the corresponding can be estimated from the experimental data obtained by edge magnetic measurements and SXR images obtained during QSH state. The radial eigenfunctions of the resonant modes were obtained by solving the Newcomb equations with experimental boundary conditions.

Figure 2 shows a Poincare plot of the magnetic field lines in a poloidal cross section during the QSH phase in

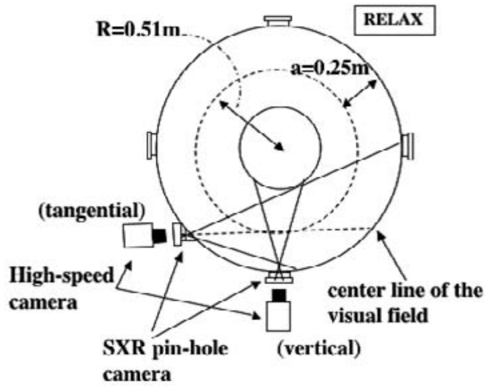

Fig. 1: Arrangement of the SXR pin-hole camera and the high-speed camera.

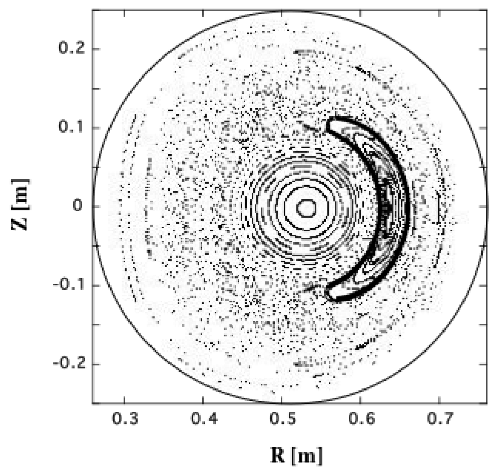

Fig. 2: Poincare plot of magnetic field lines from ORBIT code with experimental data in RELAX QSH phase. Thick curve indicates a separatrix of a conserved flux surface due to $m = 1/n = 5$ mode.

RELAX. In Fig. 2, we can identify the helically deformed nested flux surfaces in the rational surface $r_s \sim 10$ cm, embedded in a chaotic sea. The magnetic island width W is estimated about 4 cm. This conserved structure is generated by the dominant mode (with $m = 1/n = 5$) whose amplitude at the edge is 4 times higher than that of the secondary modes. We may conclude that the helical configuration has been realize during the QSH state in RELAX. This analyses would deepen our understanding of the helical transion phenomena in high-beta fusion plasma.

1) S. Ohdachi *et al.*, Plasma Fusion Res. **2**, S1016 (2007)

2) S. Masamune *et al.*, 24th IAEA Fusion Energy Conf., EX/P4-24 (2012).

3) R. B. White *et al.*, Phys. Fluids **27** 2455 (1984).