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球状RFP装置RELAXにおけるMHDダイナミクス研究のための軟X線CT手法の開発

Development of Soft-X Ray Computed Tomography Diagnostic System for MHD Dynamics Study in RELAX RFP

青木陽祐，三瓶明希夫，牧澤遼，長野友幸，樋口真行，軸原健太，坪井涼介，中ノ坊俊，比村治彦，政宗貞男
Y. AOKI, A. SANPEI, H. MAKIZAWA, H. HIMURA, S. MASAMUNE, et al.

京都工繊大・電子システム工学専攻
Department of Electronics, Kyoto Institute of Technology

The reversed-field pinch (RFP) is one of the magnetic confinement systems for high beta fusion plasmas. One of the notable topics is quasi-single helicity (QSH) state we called, spontaneous transition of RFP configuration from axisymmetric to non-axisymmetric helical structure. In this QSH state, improved confinement was realized in the helical core, either inside a large magnetic island or helically deformed nested flux surfaces having helical axis, with increased electron temperature and/or higher density [1].

RELAX is an RFP machine with major radius R = 0.5 m and the minor radius a = 0.25 m. So this machine has low aspect ratio A = 2, whose research objectives include geometrical optimization of the RFP configuration [2]. Generally speaking, the q value on axis increases as the aspect ratio is lowered, while the edge value does not change so much because the field reversal surface (q = 0) is close to the edge. Therefore, if we could avoid the resonance near the core, relatively large space is available in the core region without major resonance; the single island of a core resonant tearing mode can grow without interacting neighboring islands associated with the tearing modes. This picture has been demonstrated experimentally in RELAX in which transition to QSH occurs at lower current density and lower Lundquist number than in other machines such as RFX-mod and MST [3].

When the plasma is in equilibrium, the Soft-X ray (SXR) emissivity contours coincide with magnetic flux surfaces because both the electron temperature and density can be regarded as surface quantities. Therefore, the SXR computed tomography (CT) is a powerful tool to identify the thermal or magnetic structure inside high temperature plasmas. We are developing a new SXR CT system consisting of two 20-channel photodiode arrays. The cross-sectional view of the diagnostic system is shown in Fig.1 where two arrays are set at the top and bottom at a single toroidal location. Our interest includes time evolution of the SXR emissivity contours at transition to and back-transition from the QSH in RELAX; the process was studied by magnetic diagnostics and SXR camera, the latter providing SXR images with 10-μs time resolution. We expect to obtain time evolution of the magnetic flux surfaces with 1-μs time resolution (typical sampling time), which would be useful to study the dynamic processes of transition or self-organization associated with QSH.

For this diagnostic system, we have verified our CT algorithm based on the Fourier-Bessel expansion using test SXR emissivity profiles. The reconstructed SXR emissivity contours showed good agreement with the test data. We will discuss results from the initial experiments.

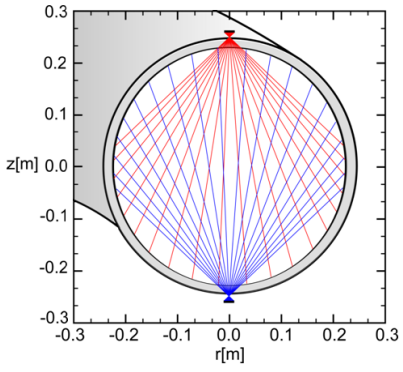

Fig.1 Poloidal cross-section of RELAX with lines of sight covered by two photodiodes.

[1] D. Escande, “What is a reversed field pinch?” 2013 <hal-00909102>.
[2] S. Masamune et al., J. Phys. Soc. Jpn. 76, 123501 (2007).
[3] K. Oki et al., PFR 7, 1402028 (2012); Fusion Sci. Technol. 63, 1T, 386 (2013).