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Development of dual SXR imaging system for three-dimensional structural studies in a low-A RFP
低アスペクト比RFPにおける3次元構造研究のための二方向軟X線イメージングシステムの開発

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In order to study time evolution of the 3-D structure of a high-temperature plasma, soft-X ray (SXR) imaging systems for simultaneous imaging from tangential and vertical directions have been developed. Initial experimental have been carried out in the low-aspect-ratio (low-*A*) reversed field pinch (RFP) plasmas in RELAX. It is shown that subtraction technique is effective in characterization of the fluctuating component of the SXR emission, with the results of demonstration of rotating simple helix.

1. Introduction

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. Tangential SXR imaging has been applied to high-temperature toroidal plasma experiments for the study of pressure fluctuations either in the core or at the edge [1].

In the reversed field pinch (RFP), toroidal pitch of the equilibrium field is relatively short and fluctuation component resulting from internally resonant global instabilities forms three-dimensional (3-D) helical structure. Equilibrium analyses have shown that the innermost mode rational surface can be located away from the axis in a lower aspect ratio ($A = R/a$) RFP configuration, where R (a) is the major (minor) radius of the plasma column. Therefore, growth of a single mode to a higher amplitude can be expected in a low-*A* RFP than in medium- and high-*A* RFPs, which may allow easier access to quasi-single helicity (QSH) state, in which the internally resonant single tearing mode grows significantly larger than other modes.

In a low-*A* RFP machine RELAX [2], (R = 0.51 m/a = 0.25 m (A = 2)), a quasi-periodic transition to QSH state has been observed [3]. During the QSH state, the fluctuation power is concentrated to the dominant single m = 1 mode. We have developed SXR imaging diagnostics using multiple SXR cameras, which are constructed with microchannel plate (MCP) and fluorescent plate, for the identification of structures of dominant MHD instabilities in the QSH state in the RFP [4,5]. Detailed design of the SXR camera has been reported in ref.[6]. Moreover, we have constructed a fast successive SXR imaging system. As a preliminary experiment, we have taken tangential SXR pin-hole pictures with time resolution of 10 micro sec, to identify time evolution of a simple helix structure in RELAX plasmas.[7,8] As a next step, we have developed a SXR imaging diagnostic systems, which uses multiple pin-hole SXR cameras together with high-speed cameras to take time evolution of the SXR images from tangential and vertical directions simultaneously for the study of dynamic structures of 3-D SXR emissivity, through which we expect to discuss 3-D dynamics of MHD instabilities associated with the QSH state.

2. Experimental Set-up and Results

A schematic drawing of the dual imaging system is illustrated in Fig. 1. One unit is for the tangential imaging, and the other for the vertical imaging, with two synchronized high-speed cameras. In the initial experiment described here, the two cameras are not synchronized, but with different frame rates: 100k frame/s for horizontal measurement, and 150 kfps for vertical measurement.

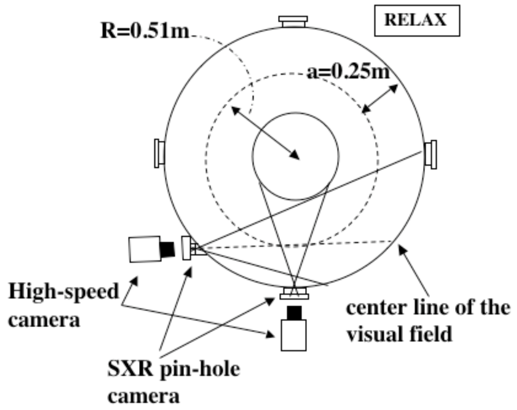

Fig.1. Top view of dual imaging system.

Raw images of SXR emission contain both the equilibrium and fluctuating component. To clearly illustrate the fluctuating component, we have applied the subtraction technique, which is subtracting a SXR image from another one with 10 micro sec time interval. Figure 2 shows an example of the experimental results obtained from tangential port. A simple helical structure has been observed clearly in the central part of the tangential viewing area. An equilibrium reconstruction has shown that the minor radial location of the m=1/n=4 resonant surface is consistent with the experimental observation.[8]

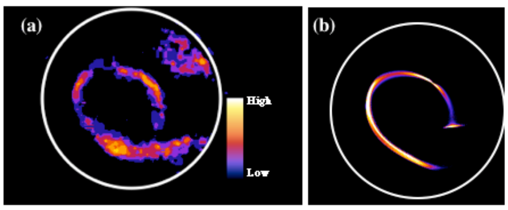

Fig.2. Subtracted images of emissivity structure obtained from tangential port in RELAX. (a) Experimental result: The image is obtained by subtracting a SXR image from another one with 10 micro sec time interval. (b) Simulated image: Finite SXR emissivity is assumed only inside the m=1/n=4 magnetic island. The phase change (in 10 micro sec) is based on the experimental phase velocity.

Figure.3 shows subtracted images of emissivity structure obtained from vertical port in RELAX with 150kfps of time resolution. We can recognize that a zonal structure moves to the upper or left direction as time goes on. By comparison of experimental and simulated images, vertical images suggest rotating helical SXR emissivity.

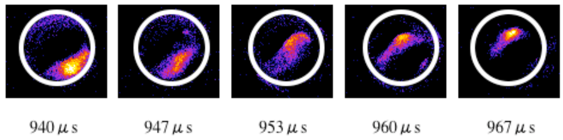

Fig.3. Subtracted images of emissivity structure obtained from vertical port in RELAX. These images are obtained by subtracting a SXR image from another one with 6.6 micro sec time interval.

The most recent results using synchronized two high-speed cameras will also be presented, together with discussion on possible reconstruction methods for 3-D imaging.

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