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Visible-Light Imaging of Merging Formed FRCs by Wide-View Tomography Camera

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The Field-Reversed Configuration (FRC) plasma is an extremely high beta compact torus confined solely by poloidal flux. At Nihon University, collisional merging experiments of FRC have been conducted on FAT-CM device. Two initial FRC-like plasmoids are formed within two conical theta-pinch formation sections coaxially connected to the both ends of confinement vessel. They are accelerated by magnetic pressure gradient to collide and merge at relative velocity exceeding the Alfvén velocity to form a single FRC. While previous experiments have validated a significant increment in plasma volume/magnetic flux and extended configuration lifetime, the time evolution of the internal structure during the collisional merging process, presumed to be accompanied by dynamic structural transitions, has yet to be observed [1, 2].

The tomography camera (T-cam) has been developed to measure the translation and collisional-merging process of FRCs via visible light imaging [3, 4]. The developed T-cam consists of a multi-anode photomultiplier tube (PMT) as a photo detector for fast response in microseconds, an interference filter (optical bandpass filter: BPF) for observing specific wavelength range, a slit to regulate incident lights intensity and a planoconcave cylindrical lens for expansion of the field of view.

The previous model of T-cam had successfully reconstructed the internal structure of FRC and estimated the center of gravity of plasmoids in the translation process. The view angle of T-cam was designed to observe the FRC with a typical plasma radius of 0.25 m at the collision. However, the field of view of the T-cam before update was narrower than previously assumed to observe the edge of plasma or outside. Consequently, it was impossible for T-cam to reconstruct the internal structure of FRC. In order to extend the field of view of the T-cam to perform tomographic imaging of the collision/merging processes and after merged FRCs, a new incident optics system was designed.

To avoid the view being obstructed by the inner wall of the port, a viewport extended into the vacuum side was designed and adopted. The incident optics is placed inside (Fig. 1). In addition, using the developed ray tracing program, the configuration of the incident optical system was designed by ray tracing including the lens system and the shape of the window. This program loads the radius of curvature, height, and position for each lens and uses Snell's law at the boundary of them for processing refraction. The result of ray tracing shows that two plano-concave cylindrical lenses with different focal lengths can be used to obtain a wider field of view. The view angle is expanded from 60° to 105°. This corresponds to an expand in the measurement range from a radius of 250 mm to 300 mm. The observable range covers most of the area inside the confinement chamber (Fig. 2). The viewing angle was measured using an LED light source with a narrowed solid angle by a pinhole. This verification confirmed that the field of view was almost actualized result of ray tracing. In this work, we report the findings derived from observations utilizing the wide-view visible-light tomography camera.

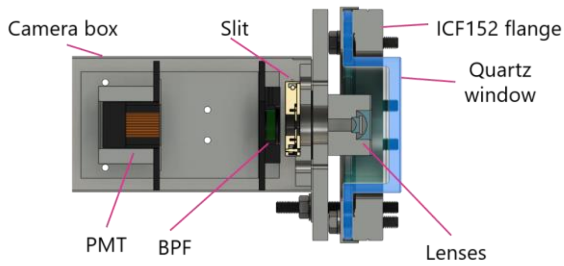

Figure 1. The incident optics is placed inside of the window (cross-section view).

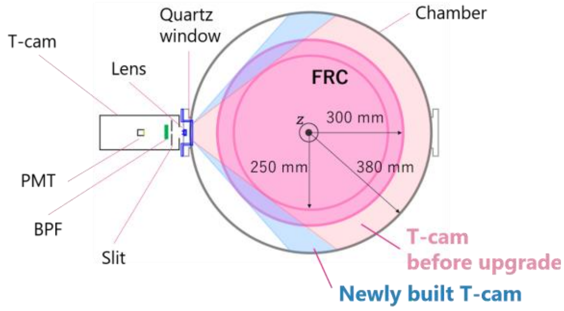

Figure 2. Comparison of the field of view, newly built T-cam and before upgrade.

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