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Investigate pre-ionization plasma structure with 3-wavelength imaging diagnostic system

3波長同時計測可能なイメージング計測システムを用いた予備電離プラズマの内部構造の解明

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The triple-channel optical imaging diagnostic system has been developed to research pre-ionization plasma structure. The optical system is possible to observe 3-wavelength radiations from the plasma, such as bremssshtralung, line spectrum of hydrogen, deuterium or helium atom, at the same time and position. In addition, we have developed visible light computer tomography that is able to reconstruct a distribution of multiple wavelength radiation. Using this new system, we investigate pre-ionized plasma structure to prolong the lifetime of FRC plasma.

1. Introduction

A field-reversed configuration (FRC) plasma has been attended for an advanced fuel (D-^{3}He, p-^{11}B) fusion reactor core plasma because the plasma has extremely high average beta value (β~1). There are so many studies of the FRC plasma mostly in Japan and USA. Furthermore, FRC plasma has a simply-connected structure, which is shown in Fig.1, thus it is able to translate to axial direction along the open magnetic field line. But the plasma was disrupted rapidly by n=2 rotational instability. Therefore, we need to improve confinement properties to use for a reactor core plasma. [1]

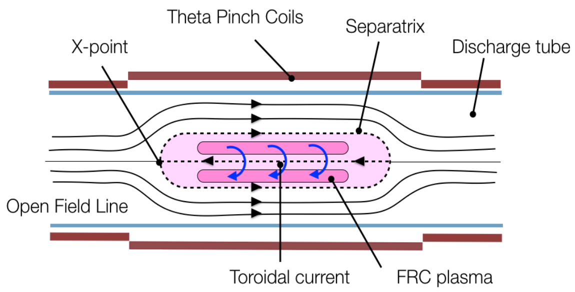

Fig.1 The schematic view of FRC plasma.

We have produced FRC plasmas using field-reversed theta pinch (FRTP) method. It is found that the parameter of the plasma, such as a trapped poloidal flux, a plasma density, and a plasma temperature, correlate with a pre-ionization plasma structure. Thus we must optimize the pre-ionization plasma to improve the confinement properties of the FRC plasma.

Hence we have developed optical imaging diagnostic system and measured profile of line spectrum, for example, hydrogen, deuterium or helium atom and bremsstrahlung radiations at the same time and position to estimate the inner structure of the pre-heating plasma and the FRC plasma.

2. Formation of FRC plasma

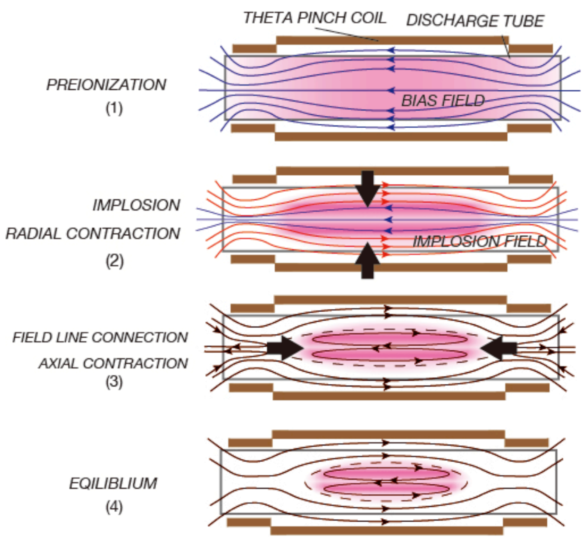

Fig.2 Formation of Field-Reversed Configuration plasma.

A formation sequence of FRC plasma is shown in Fig.2. First, working neutral gases are enclosed in discharge tube and a bias magnetic field is applied. Subsequently, an oscillate current is applied to theta pinch coils to ionizes the gas and cerate pre-ionized plasma (1). The magnetic filed is reversed very quickly and compress the plasma to radial direction (2). Fields tear and reconnect at the both ends of the theta pinch coil and a closed field line is formed. The plasma compresses to axial direction until reach an equilibrium (3), (4).

3. Diagnostic system

To estimate the internal structure of D-^{3}He plasma, for example, we have to observe the behavior of multiple species of particles, such as Deuterium, He atom and those ions (D^+, He^+ and He^{++}). Thus, new spectroscopic system has been developing that is able to observe light emission of 3-wavelength at the same time and same positions, which to know the different particles, such as electrons, ions and neutral particles in a shot. The schematic view of 3-wavelength diagnostic system is shown in Fig.3.

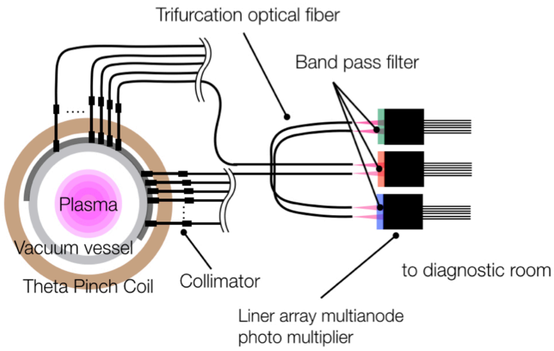

Fig.3 The schematic view of 3-wavelength diagnostic system

The system is consists of a trifurcation optical fiber with the aperture angle of 15 degree, a collimator with $f=100$ mm or $f=30$ mm plane convex lens, narrow band pass filter with the width of 10 nm and multianode photo multiplier. The spatial resolution of the optical system is shown in Fig.4. From the obtained special resolution, the collimators observe the light intensity line-integrated along its optical pass. In the case of the lens with $f=30mm$, spatial resolution is decrease with the increase distance from light source. In the case of $f=100mm$, the detectable light intensity is lower than the case of $f=30mm$ and it is difficult to observe the plasma radiations because of the increase of an inductive noise of magnetic fields,

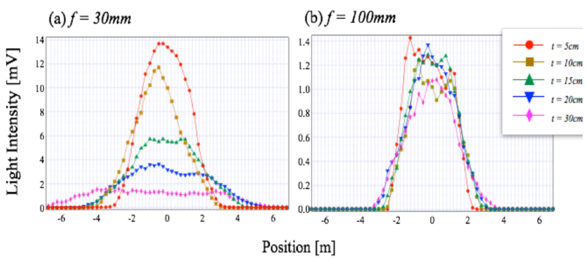

Fig.4 Collimator's spatial resolution with the focal length of 30mm and 100mm The closed circles indicate the experimental values and solid line is the estimated profile. The graph (a) is the case of a convex plane lens with 30mm focal length and (b) is 100mm focal length.

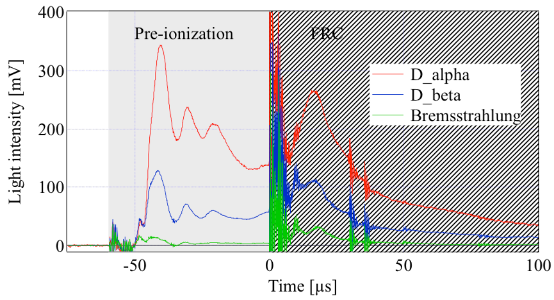

Fig.5 Time evolution of the light intensities of D_α (λ=656nm), D_β (λ=486nm) line spectrums and bremsstrahlung radiation (λ=550nm). t=0 indicates the time that the reversed compression field is applied. The gray and hatched areas indicate pre-ionization and the FRC plasma, respectively.

thus we have to optimize the structure of the collimator to improve the ratio of signals to a noise.

Figure 5 shows the time evolutions of the line integrated light intensity of D_α and D_β spectrum and bremsstrahlung radiation. The radiations are measured by $f=30mm$ collimator and hatched area indicates pre-ionized plasma, no hatched area does FRC plasma respectively.

In addition, we have developed visible light computer tomography system that is able to reconstruct a distribution of multiple wavelength light and the per-ionized plasma structure will be clarified from the reconstructed radiation profile with the combination with the internal measured magnetic field.

4. Summary

The triple-channel optical imaging diagnostic system has been developed to research internal structure of pre-ionization and FRC plasmas. The performance of the diagnostic system is investigated. Tripe wavelength of D_α, D_β and bremsstrahlung radiation of 550 nm are observed at the same time and position and improvement of the ratio of signal to noise is needed to reconstruct using computer tomography method

Acknowledgments

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References

[1] T.Asai et al: Plasma and Fusion Research. **84** (2008) 489-510.