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Ion Temperature Measurement using Ion Sensitive Probe and Laser Induced Fluorescence in Recombining Plasma
イオンセンシティブプローブとレーザー誘起蛍光法による再結合プラズマのイオン温度計測

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Ion temperature is one of the important parameters for energy balance in detached recombining plasma. The ion temperature measurement has been done in a linear plasma device CTP-HC using an ion sensitive probe (ISP) and a laser induced fluorescence (LIF). Detail comparisons between ISP and LIF measurements contribute to precious evaluation of the temperature. Based on the results, energy balance in recombining plasmas are discussed.

1. Introduction

Handling of high heat flux to plasma facing components of magnetic confinement fusion experimental reactors is one of the critical issues. It is planned that partial detachment is reliable operation for avoiding serious heat load in the ITER divertor [1]. In the detached recombining plasma, the plasma density and temperature are dramatically dropped toward the end plate along the magnetic field line. These phenomena are caused by the plasma cooling due to ionization, radiation and charge exchange process between hot ions and cold neutral particles. If the electron temperature T_e is decreasing to be less than 1 eV, electron-ion recombination becomes a dominating process to reduce the plasma pressure along the magnetic field. In order to decrease T_e enough, it is also important to decrease ion temperature T_i because energy transfer through electron–ion collision is dominant energy loss channel in a high density and low temperature plasma [2,3]. In this study, we report the results of T_i measurement in detached recombining plasma using ion sensitive probe (ISP) and laser induced fluorescence (LIF) in the linear plasma device.

2. Experimental preparations

2.1 *Linear plasma device CTP-HC*

Experiments were performed by using the Compact Test Plasma device with Hot Cathode (CTP-HC), which had been constructed in Nagano College as shown in Fig. 1. The device has a glass vacuum vessel with 0.8 m in length and 0.14 m in diameter. Argon plasmas were produced in steady state by using a direct heated LaB_6 spiral coil cathode in the magnetic field B ~ 0.1 T. Typical plasma density ~ 1-5 x 10^{18} m^{-3} and the T_e < 10 eV. The plasma diameter is about 20 mm. Neutral gas pressure in the plasma test region Pn was changed 0.2 to 1.0 Pa in this study. The anode orifice divides the plasma source from the plasma test region.

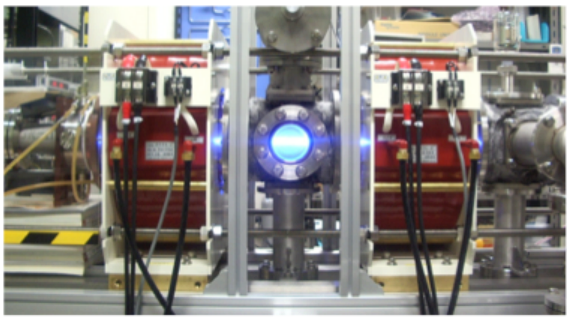

Fig. 1. Ar plasma discharge in CTP-HC

2.2 *ISP setup in CTP-HC*

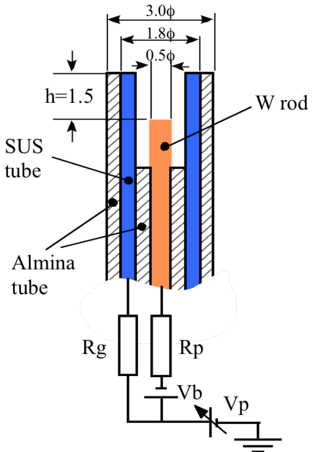

Fig. 2. ISP setup

ISP is electrical probe used for measuring T_i in the magnetized plasmas [4,5]. It consists of two cylindrical electrodes, the ion collector (P) and the electron guard electrode (G). The ion collector collects ions only on the probe bias voltage near the plasma space potential (V_s). The guard electrode works as a fence to prevent electrons flowing into the ion collector. These behaviors are based on the difference of the Larmor radius between ions and electrons in a magnetic field.

Figure 2 shows the schematics of an ISP used in the linear devices. The ISP was connected to the reciprocating probe drive system which located on 0.34 m away from the anode orifice, where is between two magnetic coils. The probe currents are obtained from the voltage measured across the resistors R_p = 1 kΩ and R_g = 1 Ω, respectively. Characteristics are typically taken by applying a saw-tooth wave to both probe electrodes.

2.3 *LIF setup in CTP-HC*

LIF measurement has a potential to evaluate spatial profile of ion temperature. Moreover, parallel and perpendicular components of ion velocity distribution functions can be resolved by changing the directions of the incident laser. Hence, the influence of ion temperature anisotropy on ISP can be also evaluated. In this study, we have developed a LIF system for Argon plasma using a tunable diode laser as shown in Fig. 3. In this system we use following LIF transitions; ArII $3d^4F_{7/2}$ → $4p^4D_{5/2}$ for pumping (668.61 nm) and $4p^4D_{5/2}$ → 4s4P3/2 for fluorescence radiation (442.72 nm) [6]. Expected LIF spectra calculated by assuming Maxwell distribution for T_i = 1 eV and 2 eV are shown in Fig. 4. Since our system has enough resolution, these temperatures can be distinguished.

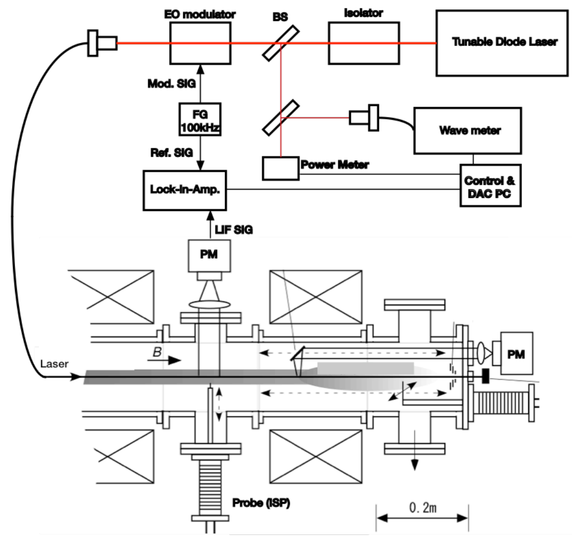

Fig. 3. LIF setup

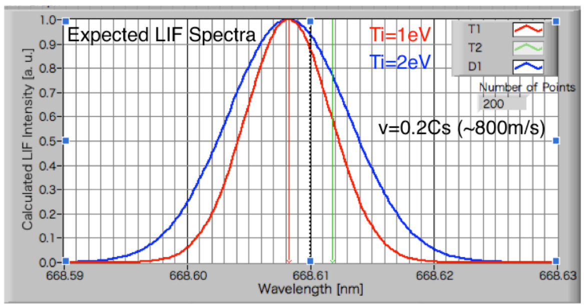

Fig. 4. Expected LIF spectra for Ti=1eV and 2eV

We will report the results of investigation for ion temperature using ISP and LIF in recombining plasmas in CTP-HC at our presentation.

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