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Laser absorption spectroscopy for argon atoms in inhomogeneous ECR plasma
不均一ECRプラズマ中のアルゴン原子のレーザー吸収分光

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Neutral density profiles in the linear device HYPER-I were measured by the laser absorption spectroscopy (LAS). The Abel inversion technique was utilized to derive radial profiles from multi-path data. In an inhomogeneous plasma with a quite bright core region, it was found that the neutral density shows hollow profile, which agrees with that observed by the emission spectroscopy.

1. Introduction

It has been found that there is a close relationship between plasma distributions and neutral particle distributions not only in the large high temperature torus plasma but also in the low temperature plasma in the small linear devices.

In the HYPER-I device, the electron cyclotron resonance (ECR) plasma with the inhomogeneous structure has been investigated to clarify the influence of neutrals on the plasma structure formation [1]. It is considered that the gradient of the neutral density profile plays an important role to form such a stationary inhomogeneous plasma. In that study, neutral density distributions were obtained by the conventional emission spectroscopy with some appropriate assumptions. Therefore the precise measurement for neutral density is urgently required.

In this study, radial neutral density profiles in such inhomogeneous plasmas were directly measured by the laser absorption spectroscopy (LAS). Comparison of the neutral density profiles between the emission spectroscopy and the LAS is presented at the conference.

2. Experimental Setup

Experiments were performed in the HYPER-I device in National Institute for Fusion Science. The HYPER-I is a liner electron cyclotron resonance (ECR) plasma producing/heating device of which diameter and axial length are 0.3 m and 2 m, respectively [2]. The port through power of the microwave was approximately 5 kW, and the pressure of the argon gas was 10mTorr.

Schematic diagram of the LAS experimental setup is shown in Fig. 1. An external cavity diode laser (ECDL) tuned at 772.633 nm was employed for the LAS. The ECDL can vary its wavelength within 0.015 nm. The laser light injected into plasma is absorbed by metastable argon atoms (Ar*).

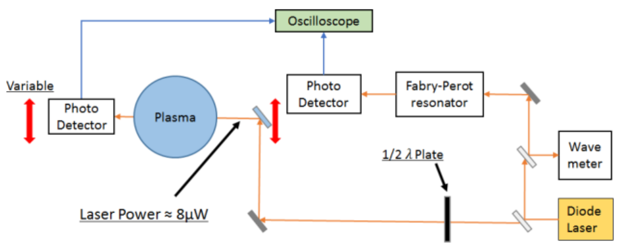

Fig. 1. Schematic of the experimental setup.

3. Data analysis

From the absorbance measured with different line of sights, the neutral density profile is obtained by the Lambert-Beer Law and the Abel inversion.

The LAS can derive the neutral particle density from the ratio of the transmitted light intensity to the incident light intensity, changing the wavelength or oscillation frequency of the laser. The relationship between the incident light intensity I_0 and the transmitted light intensity I can be described with the Lambert-Beer Law, which is

$$I = I_0 \exp(-\alpha z) \quad (\alpha = \sigma_{ik}[N_i - (g_i/g_k)N_k]) \quad (1),$$

where z is the effective optical path-length, σ_{ik} the absorption cross section of atoms with the transition energy level of i → k, N the density of the certain state, and g the statistical weights [3]. It can be modified, as follows,

$$A = \alpha z = -\ln(I/I_0) \quad (2).$$

Since the value A in Eq. (2) is a line-integrated value with the optical path-length z, the local value A were derived by the Abel inversion.

4. Experimental Results

Neutral density profiles of the counter $E\times B$ plasma were measured by LAS, changing the laser and the photo detector positions y from -2.0 cm to +6.0 cm, with the interval of 0.5 cm.

A visible light image taken by a CCD camera and a typical absorption profile obtained by LAS in the argon counter $E\times B$ plasma are shown in Fig. 2.

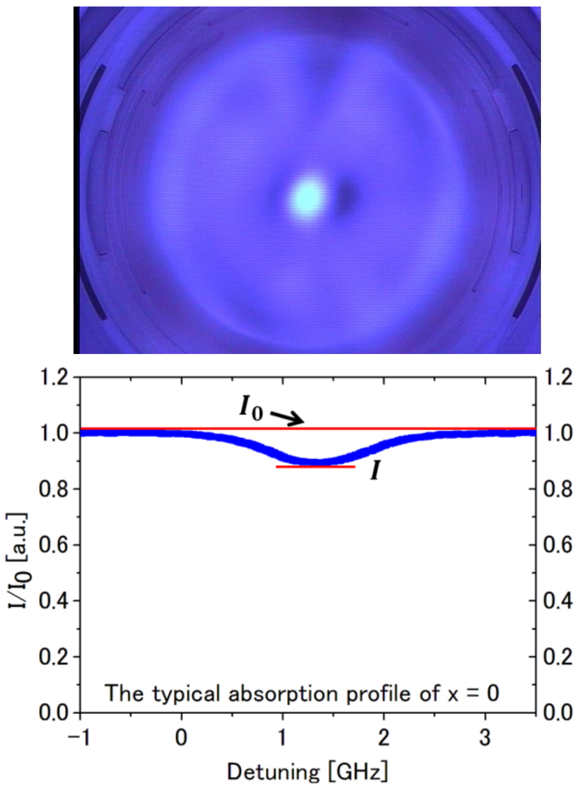

Fig.2 A CCD image and the typical absorption profile of the Ar* in counter E×B plasma.

I and I_0 in Fig. 2 (bottom) correspond to those in the Lambert-Beer Law, i.e., in Eqs. (1) and (2).

Using those equations, the Ar* density profile in the counter $E\times B$ plasma is determined by the Abel inversion [4].

Argon atom profiles measured with the conventional emission spectroscopy and the LAS were compared. Assuming the constant electron temperature, σ_{ex} should be constant. In addition, $n_i = n_e$ from the quasi-neutrality of the plasma. Thus, the following equation for emission spectroscopy can be derived; $n_i \propto \sqrt{I_i}$ and, $n_n \propto I_n/\sqrt{I_i}$ where I_i and I_n are emission light intensity from ion and neutral. By measuring I_i and I_n in above equations, one can evaluate the neutral density profile. The radial profiles of neutral atom density measured with the emission spectroscopy [5] and the LAS are shown in Fig. 3. It is found that both profiles have similar hollow shapes.

At the conference, experimental results with the plasma hole [6] will also be presented.

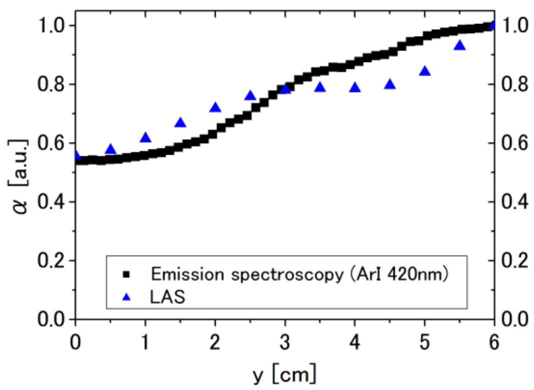

Fig.3 Radial profiles of neutral atom density measured with the emission spectroscopy and LAS.

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