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Radiation spectra measurements by using the multi-channel spectroscopic measurement system in the central cell of GAMMA10

多波長同時計測分光器を用いたGAMMA10セントラル部の放射スペクトル測定

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Experiments of molecular gas fueling with Supersonic Molecular Beam Injection (SMBI) device were carried out under the collaboration with Kyoto University. Radiation spectra from a plasma with SMBI were measured by using the multi-channel spectroscopic measurement system in the central cell of GAMMA10. In order to investigate the effects on plasma by SMBI, the density ratio between hydrogen molecular and atoms (n_{H2}/n_H) is calculated with Collision-Radiation model (CR-model). The density ratio between hydrogen molecular and atoms during SMBI were estimated amount about 600 times larger than that without SMBI.

1. Introduction

Experiments of Supersonic Molecular Beam Injection (SMBI) device were carried out under the collaboration with Kyoto University. SMBI device is set for injection hydrogen gas fueling in the central cell of GAMMA10.

We study the effects on spectra during SMBI by using the multi-channel spectroscopic measurement system. Moreover, the density ratio between hydrogen molecular and atoms during SMBI was calculated with Collision-Radiation model (CR-model).

2. Experiment Apparatus

GAMMA 10 is a 27m long tandem mirror plasma confinement device with a thermal barrier. It consists of a 5.6m long axisymmetric central cell, two anchor cells for suppressing magnetohydrodynamics (MHD) instabilities that are located in both ends of the central cell. Two plug/barrier cells are connected to the anchor cells for forming the plug and thermal barrier potentials. In plasmas produced in the core region of the central cell, typical electron density, electron temperature and ion temperature are about 2×10^{12} cm^{-3}, 100 eV and 5 keV, respectively.

SMBI device is set for fueling hydrogen gas into the plasma in the central cell. SMBI device can inject supersonic hydrogen gas squeezing high pressure with pulse-valve. SMBI device can configure the plenum gas pressure with regulator, and regulate pulse width and the injecting timing with pulse control power. The maximum plenum gas pressure of SMBI is 2.5MPa.

The multi-channel spectroscopic measurement system is set to measure 200-700nm spectra with keeping enough wavelength resolution in the central cell. Figure 1 shows schematic of the multi-channel spectroscopic measurement system. The lights collected by the lens lead to the two spectrometers (USB2000, Ocean Optics Inc.) through the optical fiber. One spectrometer measures 200-400nm spectra, and another one measures 400-700nm spectra. The spectrometer has a CCD as a detector and is controlled by WindowsPC through the USB cable. The exposure time of it is typically 50ms.

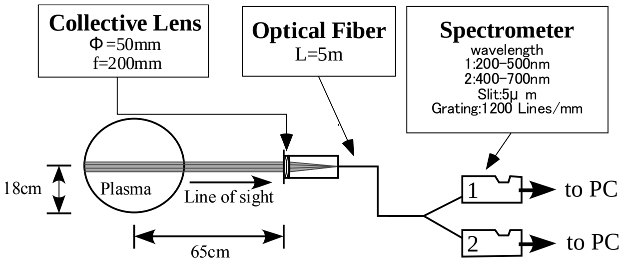

Fig. 1. The multi-channel spectroscopic measurement system.

3. Experimental Results

Figure 2 shows diamagnetism and electron line density (a) and the radiation spectrum during SMBI (b) measured by using multi-channel spectroscopic measurement system. The plasma is the hot ion mode plasma. The Gas-puffing#7 injects the hydrogen gas (250 Torr) at 120-127 ms. SMBI injects the hydrogen gas (1.5 MPa) at 170-171 ms. At 170-175 ms (during SMBI period), the diamagnetism decreases much, and the electron line density adversely increases much.

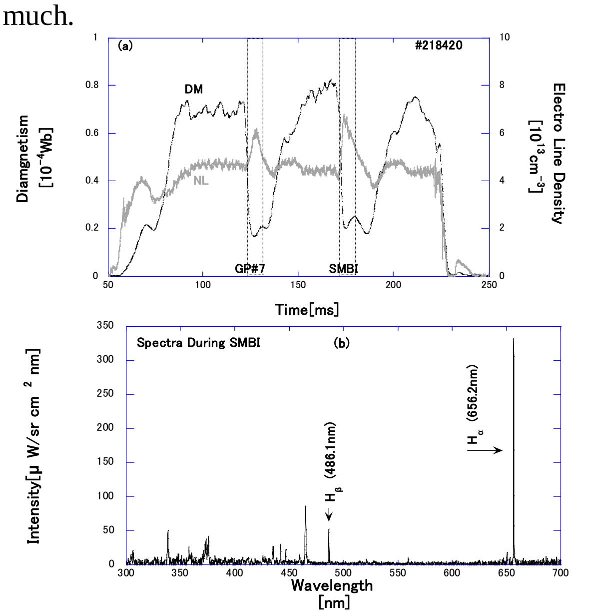

Fig. 2. Diamagnetism, Electron line density, radiation spectra during SMBI

H_α (656.2nm) and H_β (486.1nm) spectra increase by SMBI. Table 1 shows the radiation intensities and plasma parameters during SMBI. The density ratio between hydrogen molecular and atoms were calculated with CR-model. CR-model uses the radiation intensity, n_e (from the microwave interferometer) and T_e (from the Thomson scattering measurement). The expression of the radiation intensity ratio is shown in eq.(1),

$$\frac{I(i,k)}{I(j,k)} = \frac{\{R_1(i)n_e n(1) + R_2(i)n_e n_i\}A(i,k)}{\{R_1(j)n_e n(1) + R_2(j)n_e n_i\}A(j,k)} \qquad (1)$$

.

Then, the expression of the intensity ratio between H_α and H_β is shown in eq.(2),

$$\frac{I_{H_\beta}}{I_{H_\alpha}} = \frac{\lambda_{H_\alpha}}{\lambda_{H_\beta}} \frac{A_{H_\beta}}{A_{H_\alpha}} \frac{R_1(4)}{R_1(3)} \frac{1+(\frac{R_2(4)}{R_1(4)})(\frac{n_{H_2}}{n_H})}{1+(\frac{R_2(3)}{R_1(3)})(\frac{n_{H_2}}{n_H})} \qquad (2)$$

.

Here, *I*, *A*,and *R* are radiation intensity, the radiative transition probability, and the population coefficient, respectively. The population coefficient depends on both n_e and T_e.

H_β [a.u.]	H_α [a.u.]	H_β/H_α	N_e [10^{12} cm^{-3}]	T_e [eV]
51.7	**331.4**	**0.16**	**2.3**	**23.6±3**

Table 1 Itensity and Parameters

Figure 3 shows the calculated result of CR-model. This figure plots n_{H_2}/n_H (the density ratio between hydrogen molecular and atoms) as a function of T_e. We apply T_e (T_e=23.6±3eV) to the function in this figure, and get $n_{H_2}/n_H = 60\sim75$. The evaluation of $n_{H2}/n_H = 1/10$ in ordinary plasma. The density ratio increase about 600 times as large as that of ordinary plasma.

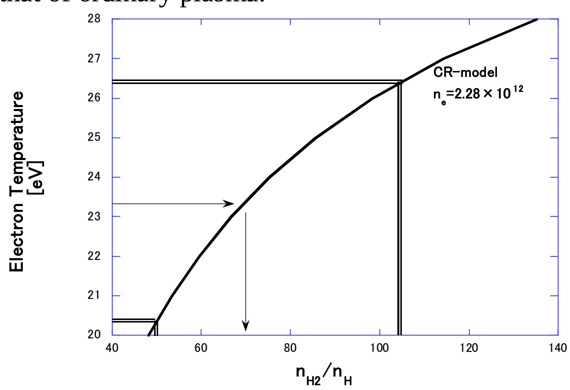

Fig. 3. The result of CR-model

4. Summary

We measured the changes of the radiation spectra during SMBI by using the spectroscopic measurement system. H_α and H_β spectra increase much by SMBI.

The density ratio of atomic and molecular hydrogen was calculated with CR-model.

5. Reference

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