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Measurement of Anomalous Intensity Distribution on Multiplet Lines in Carbon-Like Oxygen Ion

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Abstract

Anomalous spectral line intensity distribution on the triplet transition 3p $^3D_{1,2,3}$ – 3d $^3F^o_{2,3,4}$ in carbon-like oxygen ion has been observed in the TPD-II plasma. The spectral line intensity of J=2->1 transition in OIII has been observed one of < 3% comparing with one of J=4->3 transition with the strongest intensity in this transition. In the case of the same triplet transition in carbon-like nitrogen ion, this distinctive spectral line intensity ratio has not been observed and has been consistent with the intensity distribution determined by the statistical weight and the radiative transition probability. Therefore, this anomalous spectral line distribution is expected to be characteristics for carbon-like oxygen ion.

1. Introduction

The impurity spectral lines are often measured and used for plasma diagnostics in laboratory plasma. Especially, as a plasma diagnostics in fusion plasma, the spectral line measurement using intrinsic impurities in the plasma provides capabilities of the doppler ion temperature, plasma rotation, impurity density and transport measurements. Recently, a parameter dependence of the spectral line intensity is a noticeable phenomenon for the plasma diagnostics. The characteristics of spectral line intensity distribution of the multiplet transition in impurity spectra are theoretically and experimentally studied, and the comparison the results calculated using the collisional-radiative model (CRM) with one measured in the fusion plasma has been reported for OV spectral lines in ionizing and recombining plasma [1, 2].

Anomalous spectral line intensity distribution on the triplet transition 3p $^3D_{1,2,3}$ – 3d $^3F^o_{2,3,4}$ in carbon-like oxygen ion has been observed. When we make use of an assumption that all J-sublevels of excited states are populated according to their statistical weights and the intensity is determined by the statistical weight times the radiative transition probability, the intensity ratio between the spectral line from the lowest J-sublevel to that from the highest J-sublevel becomes of 0.46. Here, each radial transition probabilities are used one in ref. [3], which are A_{43} = 2.07x10^8 s^{-1}, A_{32} = 1.84x10^8 s^{-1} and A_{21} = 1.73x10^8 s^{-1} in err of 25%, respectively. However, this intensity ratio experimentally measured is taken of under 0.03. For the purpose of being clear the causation for the anomalous intensity distribution on 3p ^3D - 3d $^3F^o$ transition in carbon-like oxygen ion, the intensity distribution of other multiplet lines in carbon-like oxygen ion and that in carbon-like nitrogen ion have been studied using the Test Plasma by Direct current discharge II device (TPD-II) and mixing O_2 and N_2 gases into He working gas. Characteristics of spectral line intensity distribution on neighboring triplet transitions have been studied. These results are reported in this paper.

2. Experimental setup

The experiments were carried out in the Test Plasma produced by Direct current discharge linear plasma second device (TPD-II). Figure 1 shows the setup for the experiments. The

TPD-II produces a steady quiescent state high-density plasma with a discharge current of 50 ~ 120 A, discharge voltages of 120 ~ 150 V, a magnetic field of ~ 2kG. The cathode is composed of Th-W pins and LaB_6 fragments. A discharge runs between the cathode and anode, and plasma flows out through a hole of anode. In case of helium discharge, the velocity of helium ion is 10^3 ~ 10^4 m/s toward the downstream side. The electron temperature T_e and density n_e were found to be several eV and 10^{18} ~ 10^{19} m^{-3}, respectively. The neutral pressure in the plasma region is usually kept at less than 0.1 Pa.

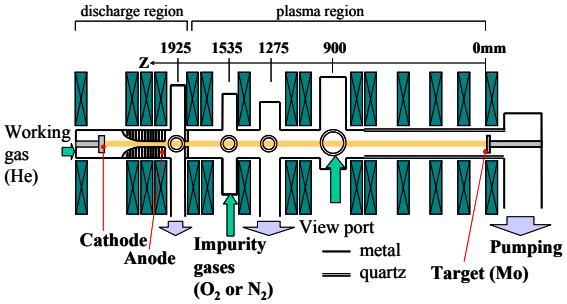

Fig. 1 Schematic diagram of the TPD-II device

Figure 2 shows the spectral line measurement system which is consist of 1m focal length Czerny-Turner UV-Visible spectrometer with 1200 lines/mm grating having the braze wavelength at 1000 nm and ICCD camera with 512 x 512 pixels as a detector, an optical fiber and a lens collected the optical fiber the light. The spectra are measured from perpendicular direction to the plasma column with the optical system is installed at the middle position of the plasma column.

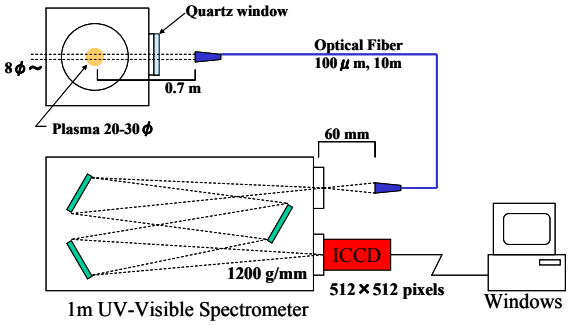

Fig. 2 Spectral line measurement system which is consist of 1m UV-Visible spectrometer with 1200g/mm grating, ICCD(512 x 512 pixels), Optical fiber and Windows PC.

The spectral lines have been measured in plasma mixing impurity gas, O_2 and N_2, of 0.4-0.5 % into He working gas with B_z = 2 kG at the view port. The intensity has been taken to be accumulated up to 100 s one measured with exposure time of 100 ms.

3. Experimental Results

An anomalous spectral line intensity distribution has been observed on the triplet transition 3p $^3D_{1,2,3}$ - 3d $^3F^o_{2,3,4}$ in carbon-like oxygen in as shown in Fig. 3. The spectral line intensity I(J=j->i) of the transition from j-sublevel to i-sublevel determined by the statistical weight g_j of upper sublevel times the radiative transition probability A_{ji} for transition from j-sublevel to i-sublevel are shown in table 1, and are normalized by the intensity of J=4->3 transition which has the strongest intensity of six spectra of 3p $^3D_{1,2,3}$ - 3d $^3F^o_{2,3,4}$ transition in OIII. The spectral line intensity ratio of three spectra normalized becomes I(4->3) : I(3->2) : I(2->1) = 1 : 0.69 : 0.46.

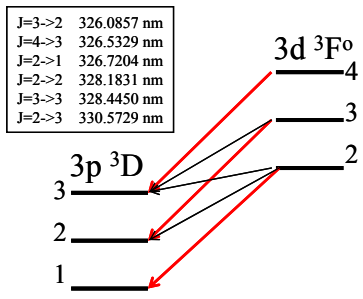

Fig.3 Triplet transition in carbon-like oxygen ion observed an anomalous line intensity distribution and wavelength of all J-sublevel transition.

The spectral lines measured in the TPD-II plasma mixing O_2 gas into He plasma are shown symbol in Fig. 4, and the relative intensity distribution of these spectral lines estimated from

the statistical weight times the radiative transition probability is shown the solid line. The intensity ratio of I(3->2)/I(4->3) is taken one of 0.55 which becomes difference of 80 % to intensity determined by the statistical weight times the radiative transition probability. The difference is expected to be caused by plasma parameter dependence for the spectral line intensity ratio as shown in ref. [1, 2]. The spectral line intensity I(2->1) is more week comparing with one from other J-sublevels. The intensity of that is taken the ratio of below 0.03 to the strongest intensity I(4->3), which is expected of 0.46 by the statistical weight times the radiative transition probability.

In order to confirm the characteristics of this anomalous spectral line intensity distribution observed on the triplet transition 3p $^3D_{1,2,3}$ - 3d $^3F^o_{2,3,4}$ in OIII, carbon-like ion of nitrogen has been studied. Figure 5 shows a relative intensity distribution of three spectra with strong intensity in the triplet transition 3p ^3D - 3d $^3F^o$ in carbon-like nitrogen ion measured on the TPD-II plasma mixing N_2 gas into He plasma and one predicted by the statistical weight times the radiative transition probability, respectively. Here, each radiative transition probabilities are used one of A_{43} = 1.22x10^8 s^{-1}, A_{32} = 1.08x10^8 s^{-1} and A_{21} = 1.02x10^8 s^{-1}, respectively. Symbol in figure expresses the result measured, and color lines show the relative intensity of the radiative transition probability. The black line expresses the inteisty summated one of the all J-sublevels in 3p ^3D - 3d $^3F^o$ transition. The spectral line intensity distribution measured is consistent with one estimated. Therefore, the anomalous spectral line intensity distribution shown on the triplet transition 3p ^3D - 3d $^3F^o$ in carbon-like ion are expected to be characteristics just for oxygen ion.

The spectra with 3d $^3F^o$ state as lower excited state in OIII which is shown the transition (B) in Fig. 6, and that with 3p ^3D state as higher excited state which is shown

Table 1 Spectral line intensity ratio of the triplet transition 3p ^3D – 3d $^3F^o$ state in OIII determined by statistical weight and radial transition probability and measured in the TPD-II plasma

	gj∗Aji	Exp.
I(4−>3)/I(4−>3)	1.00	1.00
I(3−>2)/I(4−>3)	0.69	0.55
I(2−>1)/I(4−>3)	0.46	<0.03

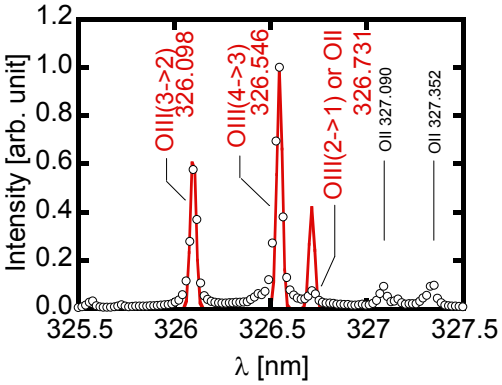

Fig. 4 (symbol) Triplet lines of 3p ^3D – 3d $^3F^0$ transition measured with spectrometer system, (solid line) one determined by g_j times A_{ji}.

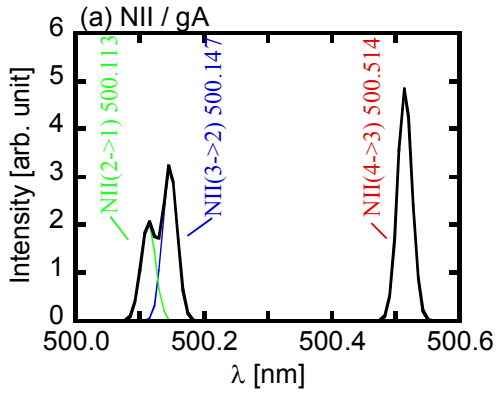

Fig.5 Spectral lines of the triplet transition 3p ^3D – 3d $^3F^o$ in carbon-like nitrogen ion. Symbol shows the line intensities observed in TPD-II plasma mixing N_2 gas into He plasma, color lines show the intensity of J-sublevel determined by the statistical weights and the radiative transition probability, respectively, and black line expresses the intensity summated one of all J-sublevel.

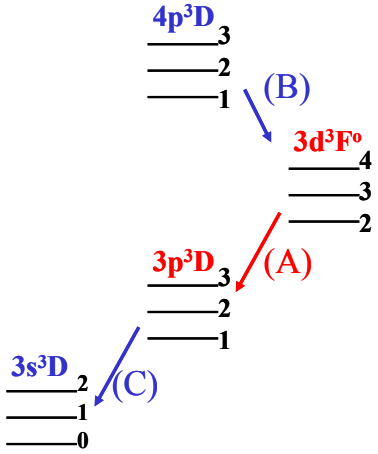

Fig. 6 Grotrian diagram of triplet transition neighboring 3p ^{3}D – 3d ^{3}F^o transition in carbon-line ion.

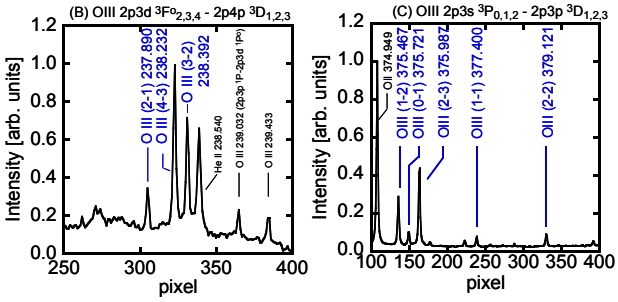

Fig. 7 Spectral line intensity distribution of triplet transition neighboring 3p ^{3}D – 3d ^{3}F^o transition in OIII measured in TPD-II.

the transition (C) in Fig. 6, have been measured to study the characteristics of the spectral line intensity distribution on neighboring triplet transitions to the transition 3p ^{3}D - 3d ^{3}F^o with the anomalous spectral line intensity distribution. Figure 7(B) and (C) show the two spectra expressed above measured in the TPD-II plasma, respectively. In the case of (B) transition, the intensity of two spectral lines of J=3->4 and J=2->3 in 4p ^{3}D – 3d ^{3}F^o transition are consistent with one determined by the statistical weights times the radiative transition probability, however, the spectrum with J=1->2 has just intensity of 40 % to one determined. This result expresses that the anomalous population distribution for 3d ^{3}F^o states causes by a cascade from upper states. On the other hand, the intensity of the spectral lines from two higher J-sublevels are consistent with the difference under of 0.5 % to one estimated. The intensity from the lowest J-sublevel is one of about 65 % to one estimated. This result also shows same property with one of above transition.

4. Summary

The anomalous spectral line intensity distribution to the triplet transition 3p ^{3}D$_{1,2,3}$ - 3d ^{3}F$^o_{2,3,4}$ in carbon-like oxygen ion has been observed in the TPD-II plasma. Since this distinctive phenomenon has not been identified for carbon-like nitrogen ion, one is expected to be inherence for the carbon-like oxygen ion. The multiplet transition which has 3d ^{3}F$^o_{2,3,4}$ levels as lower states and one which have 3p ^{3}D$_{1,2,3}$ levels as upper states have been observed at the wavelength shown in the wavelength list, respectively. Since anomalous line intensity distribution for the triplet transition which is higher than the triplet transition 3p ^{3}D - 3d ^{3}F^o in OIII also have been observed in the TPD-II plasma mixing O_2 gas into He discharge, the distinctive population distribution is expected to be contribution factor for the anomalous spectral line intensity distribution. However, the spectral line intensity from the lowest J-sublevel of 3d ^{3}F^o states is too week. This result is suggested that there is a stronger transition process.

References

[1] T. Kato *et al*., J. Phys. B **29**, 4241 (1996)

[2] I. Murakami *et al*., J. Plasma Fusion Res. SERIES **5**, 171 (2002)

[3] W. L. Wiese, M. W. Smith and B. M. Glennon, *Atomic Transition Probabilities Volume I Hydrogen Through Neon* (U.S. Government Printing office Washington, D.C., 1966)