2nd Asia-Pacific Conference on Plasma Physics, 12-17,11.2018, Kanazawa, Japan

Estimating the emission spectra of $W^{23+} - W^{30+}$ by the numerical decomposition of multiple spectra observed from LHD plasmas

Takehiko Esaka[1], Izumi Murakami[2], Shigeru Morita[2],
Masahiro Hasuo[1], Keisuke Fujii[1],
[1] Graduate school of Engineering Kyoto University, [2] National Institute for Fusion Science
e-mail (speaker): esaka.takehiko.86a@st.kyoto-u.ac.jp

1 Introduction

A diagnostic method to monitor tungsten (W) transport in high temperature plasmas has been demanded because W will be used as a divertor material of ITER. Almost only available approach for this purpose is the spectroscopic observation. Figure 1 shows two examples of W spectra y_m measured for LHD plasmas in different two conditions. m is an index along wavelength direction. Each spectrum is modeled as follows.

$$y_m = \sum_q n_q \phi_{q,m} + \varepsilon \qquad (1)$$

where n_q is the density of W^{q+}, $\phi_{q,m}$ is its emission spectrum and ε is the noise of the measurement. The variation of n_q results in the spectral profile difference. As Eq. 1 is a linear, The evaluation of n_q is possible by numerical inversion of y_m, if the exact profiles of $\phi_{q,m}$ are known.

Atomic structure theory has been developed to predict exact $\phi_{q,m}$. Blue curves in Fig. 2 (a) show three results $\phi^{\mathrm{ref}}_{q,m}$ (q = 26, 27 and 28) from one calculation model [1, 2]. Conventionally, with the assumption that tungsten ions in a particular range of charged states q exist in plasmas, n_q has been estimated so that it optimizes the following equation.

$$\mathrm{argmin}_{n_q} \sum_m D(y_m | \sum_q n_q \phi^{\mathrm{ref}}_{q,m}) \qquad (2)$$

where $D(a|b)$ is a distance measure between a and b. The squared distance $(a-b)^2$, has been frequently used. Blue curve in Fig. 2 (b) shows the reconstructed result $\sum_q n_q \phi^{\mathrm{ref}}_{q,m}$ with the best n_q, where q = 23-30 is assumed. As shown in the figure, it is still difficult to reconstruct the experimental data exact enough due to the accuracy limitation of the atomic structure calculation of $\phi^{\mathrm{ref}}_{q,m}$. In this work, we also evaluate $\phi_{q,m}$ as well as n_q by decomposing the observed spectra based on its profile variation, considering theoretically predicted spectra.

2 Method

We use multiple spectra $y^{(k)}_{\mathrm{m}}$ observed with various experimental conditions, where k = (1, 2, …, 4580) is the experimental data index. We consider to estimate both $\phi_{q,m}$ and $n^{(k)}_q$ from the following optimization problem,

$$\mathrm{argmin}_{n^{(k)}_q, \phi_{p,m}} \left\{ \sum_k D\left(y^{(k)}_m | \sum_q n^{(k)}_q \phi_{q,m}\right) + \sum_{q,m} D\left(\phi^{\mathrm{ref}}_{p,m} | \phi_{p,m}\right) \right\} \qquad (3)$$

The first term represents the goodness of reconstruction, while the second term represents the closeness between $\phi_{q,m}$ to be estimated and $\phi^{\mathrm{ref}}_{q,m}$. α is a hyperparameter, which controls the relative importance of the second term. We use 250 for α. In this work, we use Kullback-Leibler divergence for D. Since this equation has the same form to the non-negative matrix factorization (NMF) problem, it is optimized efficiently [3].

3 Results and Discussion

Figure 2 (a) shows three of the decomposed results of $\phi_{q,m}$ (q = 26, 27 and 28, red curves). Although the overall shapes of $\phi_{q,m}$ and $\phi^{\mathrm{ref}}_{q,m}$ are similar to each other, their detailed shapes are different. In Figure 2 (b), our reconstructed result $\sum_q n^{(k)}_q \phi_{q,m}$ is also shown (red curve). It is suggested that the use of $\phi_{q,m}$ instead of $\phi^{\mathrm{ref}}_{q,m}$ increases the accuracy of the density estimation.

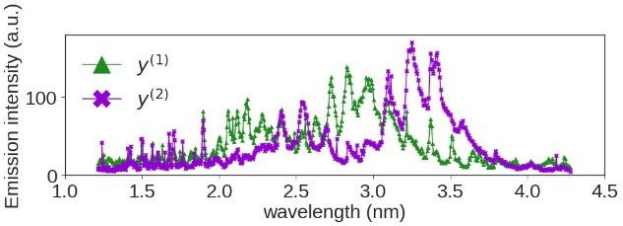

Fig. 1 Two examples of the observed W spectra.

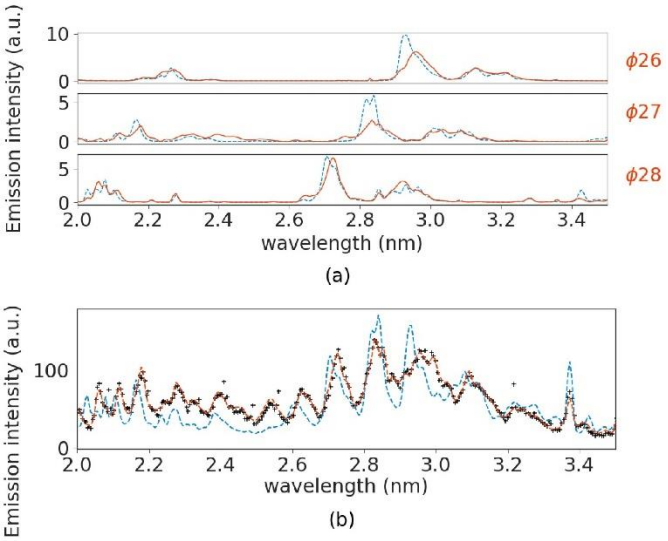

Fig. 2 (a) Three examples of $\phi^{\mathrm{ref}}_{q,m}$ (blue curve) and decomposed $\phi_{q,m}$ (red curve) for q = 26, 27, and 28. (b) One example of the observed spectrum $y_m{}^{(k)}$ (markers), reconstruction from the atomic structure calculation $\phi^{\mathrm{ref}}_{q,m}$ (blue curve) and that from our decomposition (red curve).

References

[1] I. Murakami, et al. , 2015, *Nucl. Fusion*, vol. 55, 093016.
[2] A. Bar-Shalom, et al. ,2001, *J. Quant. Spectrosc. Radiat. Transfer*, vol. 71, pp. 169-188.
[3] D. Lee and H. Seung, 2000, *Neural Information Processing Systems (NIPS)*, pp. 556-562.