§10. Lyman-α Line Profile as a Tool for the Neutral Measurement

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We have measured the Lyman-α line profile for a high density discharge. The spectrometer used for the measurement has a focal length of 3 m and is equipped with a 1200 grooves/mm grating. The second order diffracted light is used for having as high wavelength resolution as possible. The spectrometer is placed at an outboard side port such that its optical axis overlaps with the major radius of the plasma at the toroidal position where the plasma is horizontally elongated. In the present measurement, the field-of-view of the spectrometer is limited by a vertical aperture placed between the plasma and the spectrometer and has the width of 10 mm in the toroidal direction. The vertical width of the field-of-view is also limited to 20 mm by a horizontal aperture placed between the entrance slit and the grating in the spectrometer. The Lyman-α line profile obtained is shown in Fig. 1 with crosses.

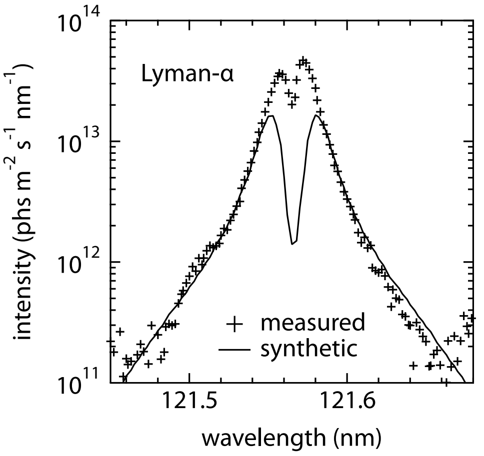

Fig. 1: Lyman-α line profile used for the present analysis. The absolute intensity is scaled so that the Lyman-α line profile fits the synthetic profile evaluated from the Balmer-α line profile analysis.

A salient feature of the spectrum is the dent at the center of the line profile, which is thought to be due to a strong reabsorption effect by low temperature atoms. For a quantitative evaluation of this dent, the so-called "self-reversal", in the line profile, an equation of the radiation transport is solved. We here consider a one-dimensional model which is expressed as

$$\frac{\mathrm{d}}{\mathrm{d}x} I_\lambda(x) = -\kappa_\lambda(x) I_\lambda(x) + \eta_\lambda(x), \qquad (1)$$

where the coordinate x is taken along the line-of-sight, $\eta_\lambda(x)$ is the emission coefficient, and $\kappa_\lambda(x)$ is the absorption coefficient at the wavelength λ and at x. In order to solve this equation, several parameters with respect to hydrogen atoms are required. For the same discharge we have also measured the Balmer-α line and have derived those parameters from the detailed analysis of the line profile[1]. Figure 2 shows $\eta_{\lambda_0}(x)$, $\kappa_{\lambda_0}(x)$, and $I_{\lambda_0}(x)$, where λ_0 is the center wavelength of the line profile. It is observed that $I_{\lambda_0}(x)$ decreases in the edge region due to rapidly increasing $\kappa_{\lambda_0}(x)$.

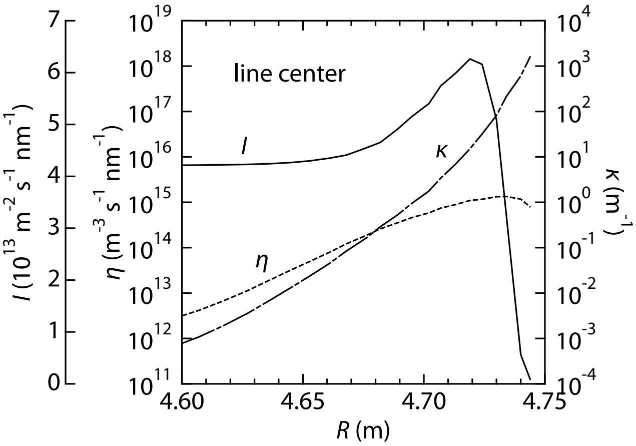

Fig. 2: Radial profiles of the emission coefficient η (dashed line) and absorption coefficient κ (dot-dashed line) at the line center evaluated from the Balmer-α line profile analysis. The resulting line intensity of the Lyman-α line at the line center is given by the solid line.

The complete synthetic line profile is shown in Fig. 1 with the solid line. The absolute intensity of the measured data is normalized to the synthetic profile in the wavelength region $|\lambda - \lambda_0| > 0.04$ nm where an optically thin condition is expected. It is found that the agreement in the tail components of the both profiles is good, which supports our understanding with respect to the penetration of neutral atoms in the core region.

However, a severe discrepancy is observed in the central wavelength region of the profile, which indicates the accuracy of the parameters derived in the analysis of the Balmer-α line profile is insufficient especially in the outermost region. This is understandable because the central wavelength region of the Balmer-α line profile suffers from the Zeeman effect and the assumption of equivalent temperature between atoms and protons would be inappropriate. In other words, the Lyman-α line can be used as a complementary method to the Balmer-α line analysis in determining the neutral density profile.

1) Goto, M.: Nucl. Fusion **51** (2011) 023005.