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Observation and analysis on poloidal distribution of impurity spectral emissions in ergodic layer of LHD

LHDのエルゴディック層における不純物スペクトル放射のポロイダル分布に関する観測と解析

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Two-dimensional (2-D) distributions of edge impurity line emissions have been measured using a space-resolved extreme ultraviolet (EUV) spectrometer in Large Helical Device (LHD). A strong emission along the plasma boundary is observed at the top and the bottom edges in the 2-D distribution. At first the CIV 2-D distribution is analyzed, and the poloidal distribution is estimated from edge emissions. The result clearly indicates a non-uniform poloidal distribution reflecting the 3-D magnetic field structure in the ergodic layer. The poloidal distribution is also analyzed for CVI emissions.

1. Introduction

The 2-D distribution of impurity emissions has been measured in EUV range for various impurity species to study the impurity transport in the ergodic layer with 3-D magnetic field structure [1,2]. Since the LHD plasma toroidally rotates, the poloidal distribution of edge impurity emissions can be estimated by analyzing the 2-D distribution. At first, in the present study, the poloidal distribution of CIV and CVI emissions is analyzed from the top and bottom edge intensities in the 2-D distribution. The result is discussed with magnetic field structure in the ergodic layer.

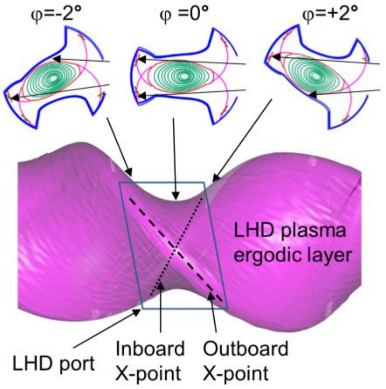

Fig.1 Schematic view of observation range in 2-D measurement .

2. 2-D distribution measurement of CIV

A 2-D space-resolved EUV spectrometer working in the wavelength range of 60 – 400 Å has been developed to measure the 2-D distribution of impurity line emissions in the ergodic layer. As shown in Fig.1, the observation range in vertical and horizontal directions at the 2-D measurement is 120cm and 90cm, respectively [2]. A typical image of the 2-D distribution is shown in Fig.1 for CIV (384.174 Å) measured at R_{ax}=3.60m configuration. Strong CIV emissions are observed at the top and the bottom edges in the 2-D distribution which is enhanced by a relatively long chord length passing through the edge plasma. The image shows the CIV emission at the bottom edge is stronger than that at the top edge. It indicates a vertical asymmetric profile.

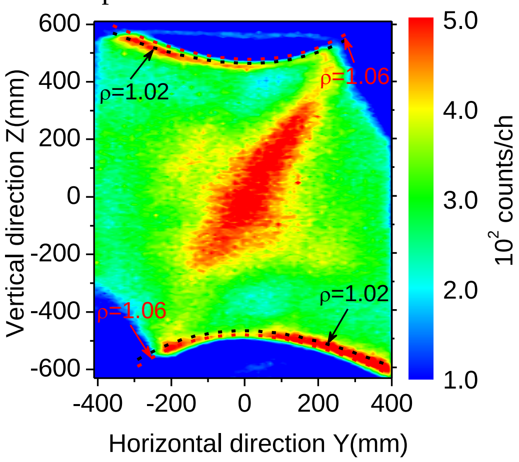

Fig.2. 2-D distribution of CIV (384.174 Å).

3. Analysis of poloidal distribution

The poloidal distribution of radial thickness for C^{3+} ions in the ergodic layer can be also estimated by analyzing each vertical profile at different toroidal positions. The magnetic flux surface of LHD is calculated with 3-D equilibrium code, VMEC, as a function of plasma pressure profile. The magnetic flux surface outside $\rho \geq 1$ can be estimated by extrapolating the magnetic flux surface at last closed flux surface (LCFS). By matching vertical positions of the strong CIV emission trajectories and the magnetic flux surface calculated with VMEC, Then, the inner and outer boundaries of CIV line emissions in the radial direction can be estimated by analyzing the CIV vertical profile against the extrapolated magnetic surface. The radial position of ρ = 1.02 and ρ = 1.06 is obtained for the inner and outer positions, respectively. The vertical position of magnetic flux surfaces of ρ = 1.02 and ρ = 1.06 is denoted with black dashed lines and red dashed lines in Fig. 2, respectively. The observation chord length passing through an impurity emission contour is calculated based on the radial thickness of C^{3+} location. The poloidal distribution of CIV emission is thus reconstructed from the 2-D distribution.

4. Results

The emissivity distribution of CIV is shown in Fig.3 (a) as a function of poloidal angle. Due to the limit of observation range of EUV spectrometer, the data are obtained in the range of $55° \leq \theta_{\_Top} \leq 110°$ and $255° \leq \theta_{\_Bottom} \leq 320°$. Here, $\theta_{\_Top}$ and $\theta_{\_Bottom}$ are the poloidal angle at the top and the bottom edges, respectively. As shown in Fig.3 (b), the emissivity distribution of CVI ((2 × 33.73 Å) is also obtained with same method. The poloidal intensity distribution of CIV is also plotted at the horizontally elongated plasma cross section, as shown in Fig.4. The CIV emissivity is expressed with different colors. It is clear from the figure that the CIV emission is strong as the location is close to the X-point, while it is weak at both the top and bottom O-points. The CIV emissivity near the bottom O-point is also stronger than that near the top O-point.

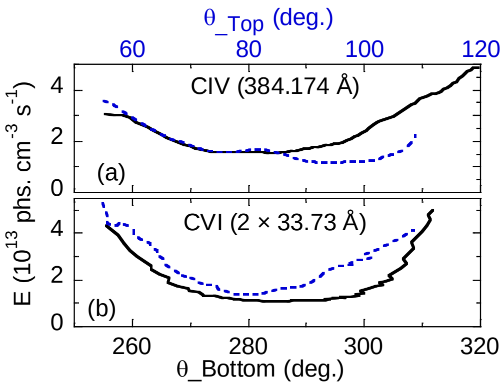

Fig.3 Poloidal distribution of (a) CIV and (b) CVI emissivity as functions of poloidal angles of $\theta_{\_Top}$ and $\theta_{\_Bottom}$.

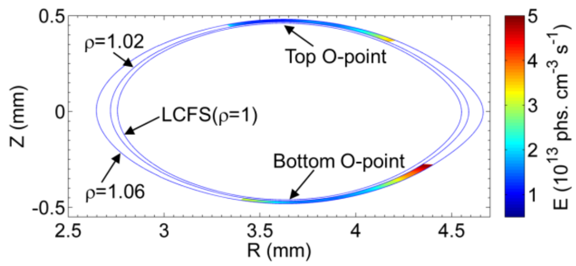

Fig.4. Poloidal distribution of CIV emissivity at horizontally elongated plasma cross section.

5. Summary

2-D distribution of edge impurity emissions has been observed in LHD. The poloidal distribution of CIV and CVI is clarified by analyzing the 2-D distribution. A non-uniform poloidal distribution is clearly observed and discussed with magnetic field structure in the ergodic layer.

Acknowledgments

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