Characterization of Turbulence, Zonal Flow, and Turbulent Transport Against Hydrogen Isotope Ratio in a Torus Plasma Experiment

S. Ohshima[1], H. Okada[1], S. Kobayashi[1], T. Minami[1], S. Kado[1], P. Adulsiriswad[2], D. Qiu[2], M. Luo[2], R. Matoike[2], A. Miyashita[2], Y. Kondo[2], P. Zhang[2], Y. Nakamura[2], S. Konoshima[1], T. Mizuuchi[1] and K. Nagasaki[1]

[1]*Institute of Advanced Energy, Kyoto University, Gokasho, Uji, Kyoto, Japan*

[2]*Graduate School of Energy Science, Kyoto University, Gokasho, Uji, Kyoto, Japan*

Confinement improvement in deuterium (D) plasmas, recognized as the "isotope effect", is still a controversial issue in the study of fusion plasma. The isotope effect contradicts a fundamental understanding of transport, since an increase of characteristic scale (ion Larmor radius or turbulence scale size here) simply leads to the increase of transport, in other words, D plasmas should have a degraded performance compared with the hydrogen(H) plasmas, incompatible with the experimental observations. Although various hypotheses for the isotope effect have been proposed so far, this study focuses on a hypothesis that is attributed to the isotope dependence of turbulence system including a zonal flow activity and we have carried out experiments on the medium-sized helical device Heliotron J.

In this study, turbulence, zonal flow, and the resultant turbulent transport against isotope ratio have been characterized in the steady discharge condition of ECH plasmas. When the H/D gas ratio is varied from the H to the D dominant gas, the zonal flow activity is enhanced increases and is more strongly coupled with turbulence, and the density and potential fluctuation amplitudes reduce. Two-point correlation analysis reveals that the correlation of the fluctuations decreases in D plasmas, although the turbulence scale size increases as the D gas fraction increases. A statistical analysis using a joint probability density function also indicates that the density and potential fluctuations are decoupled in the D plasmas. As a result, the outward particle flux is reduced in D plasmas, which would contribute to the suppression of turbulence transport and the confinement improvement in the D plasmas. Other possible factors to explain the isotope effect, such as plasma impurities and radial electric field, have an insignificant impact on the turbulence behaviour in this experiment. This is the first comprehensive study to exhibit the isotope dependence of a nonlinear turbulence system and its transport characteristic in detail from steady-state turbulence of a torus plasma [1,2], although other factors could act simultaneously and more significantly in higher performance plasmas.

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