Study of Fast Ion Transport using Neutron Emission Profile Measurement on JT-60U

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Abstract

This thesis describes an investigation of fast ion transport using neutron emission profile measurement on JT-60U Tokamak to provide a detailed understanding of the behavior of fast ions by instabilities. This work has been performed at Naka Fusion Research Establishment if Japan Atomic Energy Research Institute in Japan.

In the burning plasma with a high alpha particle pressure gradient, Alfvén eigenmode (AE) can be destabilized by alpha-particles. This destabilized AE can induce the enhanced transport of alpha-particles from the core region and can cause the degradation of the performance of a fusion reactor. Loss of alpha-particles may also damage the first wall. Therefore the understanding of the alpha particle transport when AEs are destabilized is important.

In JT-60U, AE experiments using Negative-ion-based Neutral Beam (N-NB) with energy of $E_{beam} > 360$ keV have been performed. So far, bursting modes with large amplitude called ALEs (Abrupt Large-amplitude Events) in the range of TAE (Toroidlicity-induced Alfvén eigenmode) gap frequency and drop of total neutron emission rate by bursting modes have been observed. Although this suggests transport of fast ion due to bursting mode induced by N-NB injection, it is not clearly understood yet whether this transport is due to loss or redistribution of energetic ions, or both processes are important.

In this thesis, in order to investigate fast ion transport by bursting modes, the development of neutron emission profile measurement has been carried out. Stilbene neutron detector developed by TRINITI laboratory in Russia has been installed on the neutron emission profile monitor in the JT-60U Tokamak to measure the neutron emission profile for the first time. Stilbene neutron detector is a detector which combines Stilbene crystal scintillator with a neutron-gamma pulse shape discrimination circuit, with a very compact size. For the application of this detector to JT-60U experiments, the calibration using neutron and gamma sources and the performance test on Fusion

Neutron Source (FNS) in JAERI Tokai were conducted. In these tests, good gamma-ray suppression of Stilbene neutron detector was verified, and in range of 10^2 ~ 10^5 cps., the operation of the Stilbene neutron detector was demonstrated under existence of background gamma-rays. Also by using Monte Carlo Code for Neutron and Photon Transport (MCNP), the effect of shielding and scattering of neutrons for vacuum vessel and neutron emission profile monitor was estimated. Though the neutron emission profile obtained by Stilbene neutron detectors has error of 30 % in innermost channel with calculation using measured plasma parameters, there is an agreement within 10% error in the other channels.

Then in AE experiments using N-NB, measurements of neutron emission profile were performed for the study of fast ion transport by bursting modes for the first time. The changes of the measured neutron emission profile measurement suggest to the redistribution of fast ions by ALEs. Then fast ion transport from these changes is estimated. The result of the estimation indicates that a large fraction of fast ion population in the center region ($r/a < 0.4$) is expelled to the outer region, that is a radial redistribution, by ALEs, with a part of the expelled fast ions lost to the wall.

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