(3) Diagnostic Systems

The profile measurements of plasma parameters in the Large Helical Device have high quality (high accuracy with high time and space resolution). The measurements of radial profiles of ion and electron temperature and density are important for the transport study. The radial profiles of electron temperature and density are measured with "YAG Thomson scattering system", where the electron density is calibrated by "Far InfraRed (FIR) laser interferometer". The radial profiles of ion temperature and poloidal and toroidal rotation velocity are measured with "Charge Exchange Spectroscopy (CXS)". The radial profiles of radial electric field is measured with the CXS near the periphery and with "Heavy Ion Beam Probe (HIBP)" in the core. The deuterium experiment is planned to start in 2016. Then the diagnostics, that will be damaged by neutron, is planned to be uninstalled or to be shielded in 2014 and 2015. Especially the diagnostics with semiconductor detector located neat the LHD should be uninstalled. Also neutron detector diagnostics will be essential in the deuterium experiment. The planning of the re-arrangement of the diagnostics in LHD started.

The important issue of LHD diagnostics system is that how to integrate the experimental data from various diagnostics. There are two important issue, one is "quick look" and the other is "comparison with the data from other diagnostics". The "quick look" is the plotting the data in the time evolution and radial profiles in a flux coordinate using a effective minor radius ($r_{\rm eff}$) as well as a real coordinate (R, z, ϕ) between shots. The conversion from real coordinate (R, z, ϕ) to the effective minor radius ($r_{\rm eff}$), which is crucial to compare the plasma quantities (temperature, density, rotation, radiation, fluctuation, etc.) can be done within 1 min after the discharge. The "comparison with the data from other diagnostics" is also important issue to understand the physics mechanism causing various interesting phenomena in LHD. For example, the relation between the temperature gradient, fluctuation amplitude, heat flux are important in the transport analysis and hysteresis between them in the perturbation experiment gives us valuable insight of transport mechanism. In order to integrate the data from various diagnostics, the data viewer based on Python program "MyView" has been developed.

Studies for plasma response to the perturbation is recognized to be important in understanding the transport and MHD stability in the plasma. Therefore the instruments that give the perturbation to the plasma are categorized to a part of diagnostics tool by combining the other diagnostics. "Tracer-Encapsulated Solid pellet (TESPEL)" is originally used for impurity transport study, but it becomes to be used in the cold pulse propagation experiment for non-local transport study by combining temperature measurements with 'Heterodyne radio meter of electron cyclotron emission (ECE)". The study on magnetic topology (stachastization) is done by combining the magnetic shear measured with "Motional Stark Effect (MSE) spectroscopy" and heat pulse propagation speed measured with ECE in the modulation electron cyclotron heating (MECH) experiment. By using the conditioning averaging, the characteristics of the heat pulse propagation has been investigated in details and fast front propagation has been identified. The relation between the temperature gradient and turbulence intensity measured with "Microwave reflectometer" is also studied. The improvement of analysis of the data is found to be as important as the improvement of diagnostics. The recent progress of the analysis technique has contributed to the deep understanding of the physics mechanism of the transport and topology of magnetic field.

The radial profiles of basic plasma parameters such as temperature, density, potential (radial electric field), magnetic shear, in LHD has high quality both in spatial and time resolution, although the magnetic configuration is complicated due to three dimensional magnetic configuration. However, the measurements of turbulence still needs development to understand the physics mechanism of turbulence transport. There are several diagnostics for turbulence study in LHD. The density fluctuations due to micro turbulence are measured with phase contrast imaging (PCI) of CO_2 laser, multichannel reflectometer. In contrast, temperature fluctuation with long range correlation due to mezo- or macro-scale turbulence is measured with electron cyclotron emission (ECE). Beam emission spectroscopy (BES) has been developed to investigate the density fluctuation and the edge harmonic oscillation has been observed.

In LHD, the highest ion temperature is achieved after the wall conditioning for low recycling with helium ICH discharges. It is an important study how the edge neutral density is reduced by the low recycling wall conditions and how is the core transport coupled with edge parameters. Therefore the measurement of neutral density is found to be indispensable to understand the transport and contribute the achievement of high performance plasmas. The radial profile of neutral density is evaluated from H-alpha spectrum measured with high dynamic range spectrometer by the de-convolution analysis using the detailed ion temperature profile measured with charge exchange spectroscopy. Significant reduction of neutral density in the core as well as edge is observed in the discharge after the low recycling wall conditions. The precise measurements and correlation study between the neutral density and the density/temperature fluctuation driven by the electro static turbulence will be key diagnostics in understanding the transport improvement and achievement of high performance in LHD in future.

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