(3) Diagnostic Systems

The Large Helical Device is equipped with several diagnostics for the precise measurements of plasma parameters. The integration of the diagnostics data has been developed as well as the improvement of each diagnostics. 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. 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. The relation between the temperature gradient and turbulence intensity measured with "Microwave reflectometer" is also studied. Further integration of the diagnostics data is desirable for deeper understanding of transport and MHD stability in LHD plasmas.

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 "mapping" and the other is "combination with numerical calculation". The "mapping" is the conversion from real coordinate (R, z, ϕ) to the effective minor radius ($r_{\rm eff}$) as a flux coordinate, which is crucial to compare the plasma quantities (temperature, density, rotation, radiation, fluctuation, etc.) measured at different poloidal cross section with different line of sight and different timing. In LHD, there are equilibrium data base with various configuration, current, beta, based on the VMEC calculation. Then the best equilibrium is selected by minimizing the in-out symmetry of electron temperature profiles measured with YAG Thomson. The mapping to the flux coordinate at each time slices of T_e measurement with YAG Thomson is done between shot intervals. The other issue is combination with numerical calculation. This is important in the transport analysis. The transport analysis requires detailed profiles of plasma parameters such as temperature, density, radial electric field, radiation, etc., and deposition profiles of heating power (ECH and NBI and ICRF) which is calculated by numerical code based on the measured radial profiles of plasma parameters. Therefore the combination between the measured data and calculated data is important. In LHD,the measured data and calculated data are unified to one analyzed database. Using this analyzed database, the transport analysis is done for all time slices of YAG Thomson measurements.

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). More recently beam emission spectroscopy (BES) has been developed to investigate the density fluctuation with long range correlation due to mezo- or macro-scale turbulence. The potential fluctuations due to the instability driven high energy particle is measured with HIBP, which is much larger potential fluctuations driven by drift wave. MHD instability driven by high energy particles injected by neutral beam injection (NBI) or ICRF heating are observed in the particle loss directed by the neutral particle analyzer (NPA), fast ion beam probe.

The mechanism of edge localized mode (ELM) suppression by perturbation magnetic field is still not well understood in torodidal plasmas, although this is one of the most important issue in ITER. There are possible mechanism for the ELM suppression, one is the decrease of pressure gradient of the pedestal due to the stochastization and the other is the stabilization of MHD instability due to the magnetic topology change by perturbation field. Therefore the effect of magnetic topology (magnetic island, stochastization) on fluctuation and transport has been recognized to be important in toroidal plasmas. The precise measurements and correlation study between the density/temperature fluctuation driven by the electro static turbulence and magnetic field oscillations driven by MHD instability will be urgent issue in the diagnostics system in LHD in understanding the three dimensional effect on transport and MHD instability in toroidal plasmas.

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