Research of basic plasma physics toward nuclear fusion in LHD

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The plasma parameter in the large helical device (LHD) has been extended to high density (electron density, $n_e(0) = 1.2\times10^{21}m^{-3}$) or high temperature (central ion temperature of 5.6 keV at $n_e(0) = 1.6\times10^{19}m^{-3}$, central electron temperature 10 keV at t $n_e(0) = 5.0 \times10^{18}m^{-3}$) or high beta ($\beta$ = 5.1%). Because of the wide range of plasma parameters, there are various physics issues which the LHD can explore in the research field of transport study in high temperature plasma, research for MHD stability in high density and high beta plasma, that are crucial for future device aiming nuclear fusion.

Physics of confinement improved mode is discussed with a new paradigm of non-linearity, non-diffusivity and non-locality of the transport. The non-locality appears as a non-local temperature rise, in which the central temperature increases associated with the drop of temperature triggered by the impurity pellet injection. The non-locality is also observed in the formation of an internal transport barrier (ITB). The ion temperature near the periphery slightly decreases when the central ion temperature increases.

A strong outward convection velocity of impurity is observed in the plasma with impurity hole, where the impurity density profile becomes extremely hollow after the formation ITB. This observation strongly supports the simultaneous achievement of good energy confinement and low impurity concentration, which is necessary for a fusion plasma. Spontaneous rotation is one of the important issue in toroidal plasma, because the plasma rotation is expected to contribute to suppression of MHD mode, for example resistive wall mode, which is a serious problem in tokamak. In this plasma, a clear toroidal spontaneous rotation is also observed and rotation driven by the ion temperature gradient is comparable to ones driven bu tangential NBI. These phenomena demonstrate that there are clear non-diffusive terms in the plasma.

Various MHD modes are observed such as an interchange mode and high energy particle driven modes. The magnetic island physics are intensively studied by applying the perturbation field with local island divertor (LID) coil or by controlling the magnetic shear with NBCD. One of the advantages in LHD is that there is no disruption, which is typically a problem in tokamak. Disruption does not take place even though dynamical response in transport suggests that the magnetic field becomes stochastic in the area of more than one-third of the plasma minor radius.

LHD gives the excellent profile measurements for density, electron and ion temperature, rotation velocity, radial electric field and rotational transform. Precise profile measurements enable us to study fine plasma physics on transport and MHD stability in high temperature plasma discussed above. The LHD also gives opportunity to extend the research beyond plasma physics, material physics are also done by analyzing the plasma facing component. Researches concerning the atomic process such as test of collisional-radiative model and energy levels of highly charged heavy ions are also investigated using the plasma in LHD.