5. Theoretical and Simulation Researches

Variety of theoretical and simulation studies have been performed in the NIFS collaborative research programs. Fusion plasma, space plasma, related basic plasma phenomena, and other material physics have been investigated by using fluid, particle, composed, integrated and other various models. 3D visualization such as Virtual Reality (VR) System study has also been performed.

Fluid models are widely used in variety of fields. In particular, magnetohydordynamics (MHD) model is commonly used in fusion, space and astrophysical plasma researches. Self-organization in a low-aspect-ratio Reversed Faield Pinch (RFP) plasma has been investigated and a helical deformation is observed. Zonal flow generation has been shown by MHD dynamo simulation. Coronal mass ejection, plasmoid ejection and magnetic reconnection in magnetosphere plasma have also been investigated. The study of next generation high-resolution scheme for MHD has also been performed. Electron MHD model where ions are treated as a background has been applied to the investigation of core heating in Fast Ignition (FI).

Various simulation models have been developed to investigate macroscopic spatial and time scale phenomena which cannot be explained by conventional MHD model. Gyrokinetic PIC code has been developed for this purpose. Extension and optimization were done to apply to wide range of parameter region. Conventioal Gyro-fluid code was applied to investigate multi-scale plasma turbulent transport and roles of voltex flows.

Heat transport associated with turbulence has been investigated by using various models. Voltex structures and transport levels in toroidal electron temperature gradient (ETG) turbulence have been explored by means of the 5-dimensional gyrokinetic fluxtube code. Comparative study of experiment and PIC simulation of ETG has been also discussed. Ion temperature gradient instabilities have been investigated by means of Landau fluid model.

Particle-in-Cell (PIC) simulation is a powerful tool to investigate kinetic plasma phenomena. Relativistic laser interaction with thin foils has been investigated by 2d relativistic electromagnetic PIC simulations and ion acceleration mechanism has been investigated. Particle acceleration due to large amplitude MHD waves has been investigated and a role of parallel electric field was unveiled.

Turbulence in neutral fluid and MHD plasma are extensively investigated by direct simulations. The energy cascade process in developed turbulent flow has been investigated. Comparative studies of MHD and hydrodynamic turbulence have been extensively performed by 2D and 3D direct simulations.

Spatiotemporal chaos, stochasticity and transport in toroidal plasma have been analyzed by using gyrokinetic Vlasov simulation data. Integrate modeling of magnetic confinement devices is useful tool to understand the phenomena appeared in experiment. A series of transient behaviors of an edge localized mode H-mode plasma is successfully simulated by an integrated code.

Molecular dynamics (MD) simulation is a powerful tool to investigate elementary material physics. Interaction of incident ions and grapheme plays an important role in divetor operation. The energy dependence and incident angle dependence of the reactions between a hydrogen atom and a graphen sheet have been investigated. Molecular dynamics simulation of micelle formation in amphipilic solution has been performed and the effect of molecular rigidity on the micelle formation process has been investigated. The simulation indicates that the micellar shape changes from a cylinder into a disc as the intensity of the molecular rigidity increases.

Field-reversed configuration plasma and two-fluid model for non-neutral plasma have been discussed. Thermoelectric effects in a psude-one-dimensional electron gas with a spin-orbit interaction and analysis on time evolution of shielding current density in high-temperature superconductor have also investigated.

VR system is a powerful tool to analyze 3D (4D) complicated simulation results. Extension of VR software VFIVE to visualize time-developing data has been performed. (Ishiguro, S.)