Details of the mathematical model

For numerical solving of the Vlasov equations, (1), a macro-particle method is used. In the mathematical model, the plasma motion is considered in the plane perpendicular to the magnetic field. The problem is assumed to be two-dimensional, when the distribution functions do not depend on the field-aligned coordinate, while they depend on the field-aligned velocity in the same way as the Maxwell function. The simulation region is a square in the plane orthogonal to the magnetic field. In the mathematical model, in the capacity of macro-particles, hard rods are taken.

For numerical solving of the Poisson equation, (2), a finite-difference method is utilized. At the boundary of the simulation region, the periodical boundary conditions are considered for the distribution functions and the electric field potential. The two-dimensional simulation region, lain in the plane perpendicular to the magnetic field line, is a square and its side length is equal to 128 Debye lengths of the plasma. The quantity of the grid cells is 1024×1024 and the average number of macro-particles in the Debye cell for the model plasma is 2^{15}.

The calculations were performed in a non-dimensional form. For joint solution of the equation of macro-particles motion and the Poisson equation for the electric field potential, the implicit iterative method was used. The velocities and coordinates of macro-particles are calculated at the same time moments, which is convenient for controlling the temperature and hydrodynamic velocity.

The trajectories of macro-particles were calculated using the implicit method of the second order of accuracy with optimal time step automatically chosen at each stage for suppression of the phase error. In order to decrease the discrete noise level, a weighting of the third order over 4 points per measurement was used.

The electric field potential at cell of grid was found as a result of numerical solution of the Poisson equation with periodical boundary conditions. The method of the fourth order of accuracy using fast Fourier transformation was utilized. The electrostatic field strength was calculated on the cell of grid by numerical differentiation of the potential with the fourth order of accuracy.

Computer programs were developed utilizing a programming language Fortran.