Three-dimensional Kinetic Effects on Plasma Filament Dynamics

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Recently, the intermittent filamentary plasma structures called “blob” or “hole” have been observed in the boundary layer plasmas in the experiments of various magnetic confinement devices. Such structures are thought to bring the radial non-diffusive transport in the boundary layer plasmas. Motivated by such observations, many theoretical and numerical works regarding the plasma filament dynamics have been performed on the basis of two-dimensional reduced fluid models [1, 2]. However, the size of such structures on the poloidal cross-section is considered to be slightly larger than the ion gyro radius in many situations. In such situations, the kinetic dynamics must be playing an important role in the phenomena. Therefore, we have developed the three-dimensional (3D) electrostatic particle-in-cell (PIC) simulation code called “p3bd” [3-5] and investigated the kinetic dynamics on the filament phenomena.

The p3bd code has shown the self-consistent current system and the temperature structure in a blob [6]. Furthermore, the code has revealed that a filament transports impurity ions with the large effective radial diffusivity which is comparable to the Bohm diffusion coefficient [7]. Also, numbers of simulations have shown the correlations of the effective diffusivity with the filament size, the ion temperature, and the impurity ion mass [8, 9]. On the other hand, we have revealed that the poloidal symmetry breaking of filament propagation is caused by the particle gyro motion [10] and that such an effect appears three-dimensionally [11]. However, it is difficult to apply the p3bd code to the system long enough to analyze the kinetic dynamics parallel to the magnetic field. Thus, we have upgraded the code with the domain decomposition method in order to perform huge-scale 3D-PIC simulations. In this paper, we study the parallel kinetic dynamics in filament phenomena with the upgraded code called “up3bd”. We analyze the details of the parallel particle dynamics and the influence of the parallel density gradient by using the up3bd code and discuss the effects of them on the filament dynamics.