4th Asia-Pacific Conference on Plasma Physics, 26-31Oct, 2020, Remote e-conference

Lane formation in driven pair-ion plasmas

Upasha Sarma[1], Swati Baruah[1], and R. Ganesh[2]
[1] Department of physics, School of Basic Sciences, Kaziranga University
[2]Institute for Plasma Research
e-mail (speaker):baruah.s1@gmail.com

There are a number of physical systems, where the particle dynamics can be varied from under-damped to overdamped dynamics, for example, dusty plasma or multi-ion plasmas[1]. One of the novel sub-classes of multi-ion plasmas is pair-ion (PI) plasmas, that is, plasmas that contain only positive and negative ions (no electrons) with the same mass and opposite charges[2]. Pattern formation is found on many different length scales and time scales. However, the fundamental understanding of such non-equilibrium phenomena requires the study of non-equilibrium phase transition phenomena from the 'first-principle' approach.

We have investigated Lane formation dynamics of driven two dimensional (2D) PI Plasmas in underdamped case using Brownian Dynamics (BD) simulation[3]. Our study is based on a plasma model where the ion-ion interaction is described with a screened electrostatic potential characterized by a screening parameter, and the ion-neutral background interaction is described using an overall friction force characterized by a damping factor and a zero-average stochastic collisional term that enables describing the diffusion effect. This model is used to describe the dynamic of a set of N ions submitted to stationary or time-varying electric field in a 2D domain. More specifically, the authors focused on a self-organization effect where the 'plasma' is structured as a set of lanes that alternatively contain positive and negative ions. This effect is quantitatively characterized in terms of an order parameter. This work brings new and interesting information as far as the self-organization effect is concerned. As shown in Fig.1, for a stationary electric field case, a critical value of the electric field strength is required above which self-organization exist for the underdamped case. This critical value is determined by the value of the lane order parameter, i.e. ϕ=0.5, further increasing the external field gives values of ϕ close to unity as can be seen in Fig.1(b). Our study also reveals that this critical value is larger than the one obtained for overdamped plasma and increases with the screening strength.

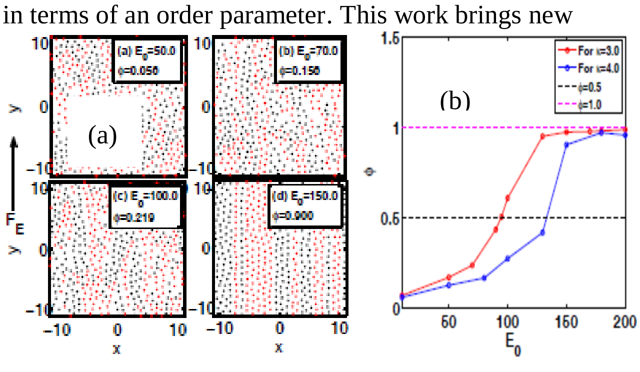

Fig.1: (a) Typical simulation snapshots showing lane formation dynamics in the underdamped case with different electric field strengths in the presence of a constant electric field (b) Variation of order parameter with electric field strength plot.

To consider the dynamical mechanism of the lane formation starting from an initial mixed state, the long-time self-diffusion coefficient is studied, and it is revealed that the self-organization is correlated to a strong decrease of the transverse diffusion coefficient.

As shown in Fig.2, the 'plasma' shows a non-stationary lane like self-organization behavior, with oscillation between self-organized and random states for the small frequency values, when submitted to time-varying electric field. For each electric field there exists a critical frequency above which the system cannot reach the self-organized state and it is an increasing function of field strength. A comparative study with the overdamped case has been performed, which suggests that the critical field strength corresponding to the phase transition point is higher for the underdamped case as compared to the overdamped one. Our simulation results may help to understand the key parameters that determined the existence and the order of lane formation phases in PI plasma system.

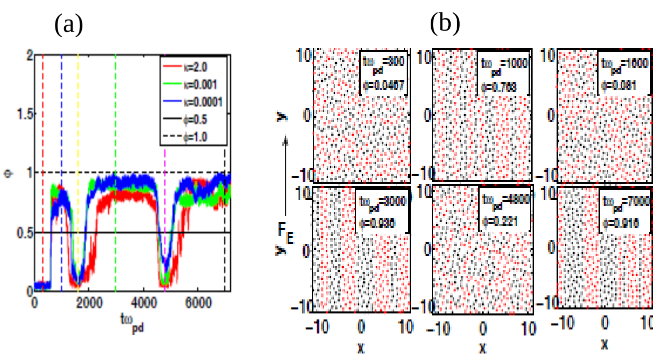

Fig.2: (a) Time varying order parameter plot for the under-damped system with an oscillatory electric field. (b) Typical simulation snapshots showing instantaneous particle positions.

This research work is supported by the Board of Research in Nuclear Sciences (BRNS), DAE, Project sanctioned No. 39/14/25/2016-BRNS/34428, date: 20/01/2017.The authors U. Sarma and S. Baruah would like to acknowledge Institute for Plasma Research, for allowing to use the Uday cluster.

References

[1] C. R. Du *et al*. Europhys. Lett. **99**, 45001 (2012).
[2] S. Baruah *et al*. Phys. Plasmas **22**, 082116 (2015).
[3] U. Sarma *et al*. Phys. Plasmas **27**, 012106 (2020).