6th Asia-Pacific Conference on Plasma Physics, 9-14 Oct, 2022, Remote e-conference

Alternating Screening And Higher Harmonics In Complex Plasmas

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Modeling properties of strongly correlated many-particle systems are of both fundamental and practical importance. At the same time, generating and probing these properties is challenging. To this end, laboratory model systems play a central role in studying correlated many-particle phenomena. Therefore, a number of laboratory model systems serves as a practical surrogate for studying highly correlated many-particle structures under controlled conditions. Model systems such as ultracold atoms provide insights into the inherent dynamics of purely quantum phenomena. Likewise, dusty plasmas and colloidal suspensions are used in the context of classical strong-correlation phenomena. These model systems probe otherwise inaccessible quantities and create states difficult to observe in nature.

Dusty plasmas have also been successfully used as a laboratory model system for investigating non-ideal 2D systems. In experiments, charged dust particles are observed in terms of a few isolated dust grains or as an ensemble of grains interacting with each other. Under the influence of external electric and magnetic fields, they exhibit a myriad of physical phenomena. Additionally, the physics of non-Hamiltonian and self-organizing open systems has been investigated with the aid of 2D dusty plasmas [1].

In this presentation, we focus on a specific laboratory model system – dusty plasmas – to model collective particle behavior under controlled conditions. Thereby, we push the frontier of dusty plasma physics by predicting the generation of high harmonics in dusty plasmas with alternating screening length [2]. The spectrum of the generated multiple high harmonics in a 2D dusty plasma is illustrated in figure 1. We also obtain a simple phenomenological expression that accurately represents these high harmonics.

We demonstrate all this for dusty plasmas in capacitively coupled radio-frequency (RF) argon discharges. Our results are based on multi-scale and multi-physics simulations approach. The RF discharge simulation is based on the combination of the self-consistent particle-in-cell technique with the Monte Carlo method (PIC/MCC) [3]. The time evolution of the dust particles is obtained from molecular dynamics (MD) simulations that are driven self-consistently by the numerical data generated from the PIC/MCC calculations.

An interesting property of the found dispersion relation is that the group and phase velocities are directed opposite to each other. In this way, it is shown that the periodically alternating screening causes a self-conjugate state with negative refraction. As the application, we speculate that our findings can serve as a test bed for studying the fundamental physics of a self-conjugate state with negative refraction in strongly correlated systems on the kinetic level.

References

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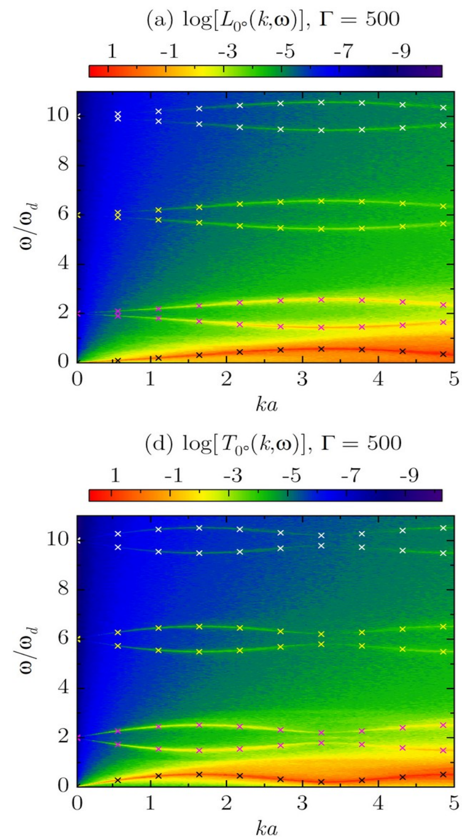

Figure 1. Higher harmonics in the 2D system of charged microparticles emerge in the spectrum of the longitudinal (top panel) and transverse (bottom panel) current fluctuations for liquid. Crosses correspond to the analytical result presented in Ref. [2].