8th Asia-Pacific Conference on Plasma Physics, 3-8 Nov, 2024 at Malacca

Self-excited vortical waves in two-dimensional Yukawa solids

Chen-Yu Siao, Wei-Shuo Lo, Hsiang-Ying Chen and Lin I
Department of Physics and Center for Complex Systems,
National Central University, Jhongli 32001, Taiwan
Email (speaker): chenyusiao@g.ncu.edu.tw

The Yukawa system is a model system with strongly coupled particles interacting through Yukawa potential. Dusty plasmas composed of charged particles in low pressure discharges and colloidal systems composed of charged colloids in aqueous background are two common Yukawa systems, for the studies of micro-motion of the solid and liquid, due to their capability of direct optical tracking of individual particle motion. However, the much lower viscous damping of the former than the latter facilitate the study of waves in solid and liquid.

Crystalline solids have an ordered structure with both good translational and orientational order. They can sustain shear stress up to their yield point. Microscopically, ordered lattice structures in solids support longitudinal and transverse phonon propagation [1]. Below the melting point, thermal agitations act as spatiotemporally disordered multiscale sources for exciting and de-exciting multiscale phonons with random phases. This creates a platform of disordered waves, which could be used to reveal the following intriguing unexplored issues: whether coherent waveforms can be excited out of disorder and how they behave spatiotemporally through the propagation and interfering of the stochastically excited waves. Recent methods employing dynamical matrix and Hessian matrices were used to identify eigen-frequencies of the instantaneous modes exhibiting low-frequency swirl-like velocity fields [2, 3], but without paying attention to their spatiotemporal evolution and addressing the above unexplored issues.

In this work, the above issues are numerically addressed in a two-dimension (2D) Yukawa solid through Langevin-type molecular dynamic simulation with periodic boundary condition and experimentally addressed in a monolayer of dusty plasma crystal composed of micro-meter sized dust particles. Multi-dimensional complementary ensemble empirical mode decomposition (MCEEMD) on particle displacement is applied to decompose particle motion into multiscale modes [4]. Both numerical and experimental studies demonstrate for the first time that the disordered thermal phonons can be viewed as a collection of coherent multiscale acoustic vorticity waves, propagating around topological defects with opposite topological charges in the xyt space. Their generic spatiotemporal dynamical behaviors are self-similar over a wide range of scales, and can be extended to other 2D harmonic crystals with different types of interactions.

References

[1] Kittel, Charles, and Paul McEuen. *Introduction to solid state physics*. John Wiley & Sons (2018).
[2] A. Ghosh et al, Phys. Rev. Lett. 104, 248305 (2010).
[3] D. Kaya et al, Science 329, 656 (2010).
[4] P.-C. Lin and L. I, Phys. Rev. Lett. 120, 135004 (2018).