Nonlinear effects in complex plasmas

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Mixtures of ion-electron plasmas with micron-sized particles or grains are called complex (dusty) plasmas. These highly charged grains can be levitated and confined in a gas discharge. They strongly interact with each other, form liquid- or solid-like structures, and exhibit a range of collective effects such as phase transitions, waves, solitons, shocks, etc. Complex plasmas are similar to colloids where the liquid medium is replaced with gaseous. Since the damping rate is many orders of magnitude lower in gases than in liquids, particle-mediated dynamic effects can be observed. Individual traceability of the grains makes complex plasmas a very useful tool for studying general phenomena in solids and liquids at a microscopic level.

We performed complex plasma experiments in a radio-frequency gas discharge, where a monolayer of monodispersed microspheres was levitated and confined. The particles were illuminated with a sheet of laser light and imaged with a high speed video camera. The monolayer was excited with electrostatic pulses applied to wires stretched at or below the layer.

The dynamic phenomena that we have studied include shock waves, solitons, their interaction with each other, with the medium and with the lattice defects. As a dispersive and nonlinear medium, crystalline complex plasmas sustain Korteveg-de Vries solitons [1]. It was shown that the soliton parameter is conserved in the presence of weak damping. We demonstrated that after two counter-propagating solitons collide, they do not change their shape but get delayed. It was observed also that the soliton amplitude grows when it propagates in a medium with decreasing density [2]. Lattice defects were affected by solitons. We found that the defects jumped across the lattice preferentially in the direction of their Burger's vectors. Shock waves were observed to melt and compress the lattice and to induce phase transitions [3].

Complex plasma as a collection of microparticles is used for test and development of fast three-dimensional particle diagnostics. We are working on three methods, the first is based on a laser sheet scanner synchronized with the recording camera [4], the second on a gradient illumination, the third on a color coded illumination. Potential applications include flow visualization, pollution and aerosol particle tracing, and monitoring of contamination in fusion reactors. We are also developing particle tracing algorithms based on an Extended Kalman Filter with the goal of maximizing the tracking accuracy.

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