Nonlinear excitations in dusty (complex) plasmas and Debye crystals: a survey of theoretical results

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Dusty Plasmas (DP) (or *Complex Plasmas*), i.e. large ensembles of interacting particles consisting of electrons, ions and massive, strongly charged, mesoscopic-sized defects (*dust* particulates), occur widely in Space and in the laboratory [1]. Due to the presence of the dust component, new charged matter configurations (plasma "states") are possible, including strongly-coupled configurations in the form of quasi-*crystalline* lattice structures. Dust crystals (DCs) occur in a plasma discharge, where the dust grains remain suspended under the combined action of gravity and electric forces. Dust lattices offer an efficient model for microscopic Debye crystals, e.g. occurring in Penning traps and ultra-cold plasmas, and also mimic the generic structure of atomic chains, yet on a different, easily accessible scale.

The general characteristics of dusty plasmas are presented. The nonlinear aspects of dust grain motion in one- (1D) and two-dimensional (2D) (hexagonal, generally) dust lattices are reviewed, from first principles. Electrostatic inter-grain interactions, along with the plasma sheath electric substrate potential and the intrinsic lattice discreteness, provide the necessary ingredients for the formation of localized excitations in Debye lattices.

Horizontal (longitudinal, acoustic) as well as vertical (transverse, optic-like) dust grain motion in a 1D dust monolayer has been studied thoroughly [2]. Excitations in 1D include kink-shaped supersonic solitary excitations (density solitons), related to longitudinal (in-plane) dust grain displacement, and modulated envelope localized modes associated with either longitudinal (in-plane, acoustic) or transverse (off-plane, inverse-optic, backward wave) oscillations. Highly localized excitations (Discrete Breathers), associated with transverse (off-plane) dust-grain motion may also exist, as recently shown from first principles, both in 1D and 2D crystals [3]. Hexagonal (2D) dust lattices sustain modulated envelope structures, formed via modulational instability of in-plane vibrations [4]. A discrete analysis of hexagonal crystals also suggests the occurrence of ultra-localized modes multipole, vortex and soliton type modes [5]. Explicit predictions have been obtained for the stability of such structures, in terms of experimental parameters, via a critical comparison among Klein-Gordon [3] and Discrete Nonlinear Schrodinger [5] theories.

Dusty plasma crystals provide a challenge for experimental investigations, which would confirm the predictions of nonlinear theories. New directions are thus opened, thanks to this novel interface among nonlinear lattice dynamics and plasma physics.

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