Low-dimensional structures in a complex cryogenic plasma

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Complex plasma has attracted much attention to the community of plasma physics [1], while recent advances in cryogenic plasma challenge the basic understanding of plasmas [2-6]. The Debye length becomes much smaller than that in a conventional plasma and becomes comparable to the size of a dust particle. Such a short screening length will add unique features to the plasmas like the Coulomb logarithm. The screening length will necessarily affect on the charging state of a dust particle by polarization-induced potential.

Dust particles have been playing an important role to study structures of Coulomb crystals largely due to the fact of easy manipulation in a plasma [7]. Since dust particles levitate in a plane of the sheath-plasma boundary, a complex plasma provides a platform to study low dimensional structures of Coulomb crystals. The interaction energy of dust particles forming a two-dimensional lattice structure is used to describe the dynamical matrix to find dispersion relation for the low dimensional lattice.

In the experiments, ultracold plasmas was produced by photoionizing laser-cooled atoms [2]. A hot-filament discharge plasma was created in a vacuum chamber with an inner wall cooled by liquid nitrogen [6]. We produced a cryogenic plasma by applying high voltage between needles in liquid helium [3], or in a gas cooled by liquid helium [4], where the plasma disappeared in a few milliseconds in a gas with 4K electron temperature. Recently we have succeeded to produce a steady plasma by an rf discharge in a vapour of liquid helium. The plasma is characterized by the ion temperature of a few tens of K, while electrons are on the order of a few eV [5]. Some of the collective modes of dust particles have been observed.

References