Structural and Dynamical Properties and Melting of a Classical Quasi-one-dimensional Wigner Crystal

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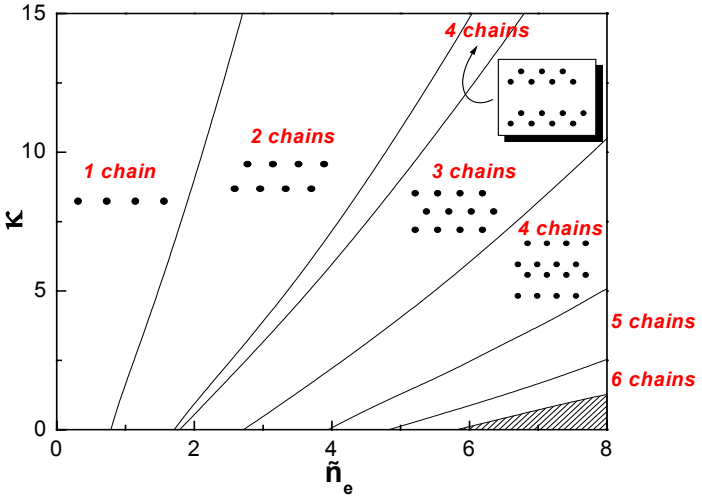
We study the properties of a quasi-one-dimensional classical Wigner crystal where the particles move in a plane and interact with a repulsive Yukawa-type potential (the screening length is an external parameter; if taken zero it gives the usual Coulomb potential between electrons). The particles are confined by a parabolic potential in one direction. Long range order is not allowed in the thermodynamic limit according to the Mermin-Wagner theorem, but short range order is still possible.

Neglecting temperature fluctuations we obtain the phase diagram in the space of inverse screening length κ and density n_e (see figure). The particles are ordered in chains the number of which increases with the density through structural phase transitions. But surprisingly enough they follow the pattern 1→2→4→3→4-chains… at low densities as shown in the figure. Those results were obtained using analytical calculations as well as Monte Carlo simulations [1]. All these structural transitions are of first order except for the 1→2 transition which is a 'zig-zag' transition induced by the softening of one of the phonon modes. The phonon spectrum was calculated for the different phases of the 'electron' solid. The magnetic field dependence of this phonon spectrum was obtained which can be compared with experiments.



Including the thermal fluctuations we studied, using Monte Carlo simulations, the melting of the chain structures. A remarkable reentrant behavior is found as a function of the density and furthermore the melting temperature drops to zero for those densities at

which the structural transitions occur. Due to the anisotropic nature of the system, we observe that the order can be maintained in the direction of confinement while it is lost in the unconfined direction. Therefore, it is possible to assign two different melting temperatures : parallel to the chains (T_x) and perpendicular to them (T_y).
Possible experimental realization of the findings will be discussed. We show that the relevant particle densities and melting temperatures which are calculated, are consistent with typical values for the system of electrons floating above liquid helium. Quasi-one-dimensional structures were recently realized in this system [2].

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