

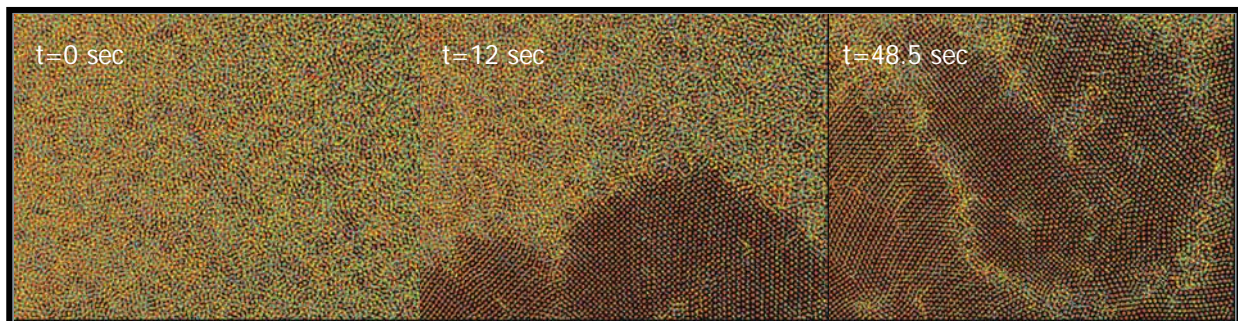


Study of the Crystallisation Process of Complex Plasmas



We present new laboratory experiments with complex plasmas consisting of small particles of $1.28 \mu\text{m}$ in diameter, where we studied the dynamics of the crystallisation process in detail.

The experiments were performed in a plasma chamber similar to PKE-Nefedov. We first created a large cylindrically shaped plasma crystal ($r \times h = 4 \times 2.5 \text{ cm}$, $80 \mu\text{m}$ particle distance) and then melted the system by a short variation in the radio frequency amplitude. Already after a few seconds the complex plasma started to recrystallise. An upward moving crystal wave front was observed. The vertical extension of the front was 2-3 particle distances broad. Within this interface the particles were quickly cooled - the mean particle velocity was 2.5 times in the disturbed zone. The crystal front decreased with height from 0.25 mm/sec at bottom and stopped after approx. 45 sec. Different structural domains were build up, with transitional interfaces in between with considerably higher disorder.



Each of the images displays a superposition of all particles at ten subsequent time steps (1 sec in total). This colour-coding provides a direct qualitative view of the kinetic energy of the particles.

Detailed investigations showed that the randomly vibrating particles from the disturbed phase loose their kinetic energy through Coulomb collisions. Numerical simulations predict that this dissipated energy is transferred out of the crystal via shock waves or compressional waves. During the crystallisation process the complex plasma became vertically compressed. In simulations we find in the beginning of the sedimentation many metastable crystalline states (hcp) together with fcc. The particles rearrange to the state with lowest potential energy which is a very slow process (comparable to the observations) and is driven by thermal motion.

Additional experiments showed that beside such nonequilibrium crystallisation processes also a crystallisation close to the local thermal equilibrium can occur. The crystal formation starts mostly from bottom, because there the compression is higher (due to gravity) than on top. The growth velocity decreased with height (max. 0.25 mm/sec at bottom), since at smaller compression it is easier to melt the crystal and to slow down the process. The crystal is build up with particles from the liquid-like state located above. During crystallisation the particles in the "liquid" state lose energy through collisions with neighbours. The energy is dissipated by waves, which are propagating through the crystal medium (numerical results).

In future experiments we will repeat the measurement with CCD cameras of higher temporal and spatial resolution. In addition fast 3D scans will be performed during crystallisation to identify structure changes during the crystal growth.

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