Out-of-equilibrium annealing of travelling colloidal carpets

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Paramagnetic colloids can be assembled into two-dimensional colloidal clusters (carpets) by using an in-plane rotating magnetic field [1]. The applied field induces a finite magnetic torque on the particles, which sets them in rotation at a given angular speed and forces the colloids to assemble into clusters [2, 3, 4]. These structures can be steered in any direction of the plane by adding a perpendicular component to the in-plane rotating field.

We studied the stability and the structures of these carpets for different parameters of the actuating magnetic field and compared the corresponding experimental phase diagram with a theoretical one. The latter was obtained by balancing hydrodynamic with magnetic torque and performing a linear stability analysis. We find that for certain parameters, when the carpet is propelling, the particles in the back can jump on top of the two-dimensional colloidal structure and travel through the carpet's lattice to the opposite side. These particles either fill out existing holes in the carpet or deposit on the other side following the lattice order. This provides a new out-of-equilibrium way to anneal colloidal structures, by transforming initial disordered clusters of particles with defects to perfect crystalline lattices. We study the dynamics of this process. We see that, counter-intuitively, the faster the dynamics of the carpet, the sooner a monocrystal is formed.

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