Conformal vortex structures induced by nonuniform magnetic textures

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Quite generally, interacting particle systems under nonuniform strain reorganize in a disordered configuration characterized by a certain distribution of topological defects. In superconductors, a well-known example is the critical state, where the distribution of edge dislocations was observed to fully account for the linear vortex density profile [1]. Topologically ordered nonuniform crystals are much more rare. An example is the so-called “gravity rainbow, a topologically ordered 2D configuration of magnetic spheres compressed by gravity [2]. This particular structure resembles the conformal logarithmic transformation of a triangular lattice into a structure that is periodic in the x direction and has an exponentially decaying density profile in the y direction. Mathematically, this conformal lattice can be constructed hierarchically by mapping concentric hexagons of the original triangular lattice into the z(x, y)-pane. However, the physical realization of conformal lattices has shown to be elusive. Even the stability of the configuration observed in [2] has been questioned.

In a recent paper [3], we have shown theoretically that conformal vortex crystals can be thermodynamically stabilized in superconductors under suitable conditions and that such structures are stable with respect to the thermal excitation of topological defects below a certain threshold temperature. Here, using a series of molecular dynamics and Ginzburg-Landau simulations and analytical modeling, we study in detail the nucleation and growth of quasi-conformal vortex crystals in finite superconducting thin films. The inhomogeneous magnetic texture necessary to induce the quasi-conformal vortex distribution is produced by current-carrying nanowires placed nearby the film edges, which provides a high degree of controllability over the number of vortices in the film. As the current through the wires increases, the existing vortex configurations go through a series of buckling instabilities as more vortices enter the sample, each time resulting in a new hierarchy of the conformal structure. Our results also suggest that the topological order of the conformal vortex structure near the sample edges is enhanced when the local field approaches the second critical field.