cnr.it
Highlights 2009 | 2010

Consiglio Nazionale delle Ricerche

STATISTICAL PHYSICS

Dynamics and ordering process in artificial spin ice

A central concept in physics is equilibrium. Normally, systems can get to equilibrium, although possibly only over very long time scales. Two features contribute to these long times and therefore merit special attention. The first is large energy barriers that block and freeze the system. And it may be useful for example to stabilize magnetic recording. The second is competition between different couplings so that they cannot both be satisfied, like when we try to be friends with two people who hate each other.
Nanomagnets, which allow manipulation of magnetic units and visualization of their state, are an ideal playground for these fundamental concepts. An artificial spin ice (see Fig. 1) is an ordered two-dimensional array of units, each one magnetized along its longitudinal axis. Since the energy barrier to switch the magnetization is so large that the system is thermally stable, even if not in equilibrium, dynamics can only be induced by an external magnetic field. A key question is to understand the response of the system to the driving field, in much the same way as a granular material in a cylinder responds to its rotation, or a flock responds to a predator. In all these cases, the response depends both on the driving force and on the interaction among constituents (magnetic units, grains, birds). In spin-ice, the interaction is the magnetostatic coupling among units, which is frustrated.
We described the system in terms of 'vertex dynamics': the magnetic states of units converging to a vertex define the vertex type (see Fig. 2, top) and spin switching correponds to vertex processes. We find that a rotating field of suitable amplitude can be very effective to drive the system towards low energy states (Fig. 2, bottom). In a perfect system, effective dynamics are determined by edges and are well-ordered processes. In a real system, disorder is important for the ordering process!

Z. Budrikis, P. Politi, R.L. Stamps, "Vertex Dynamics in Finite Two-Dimensional Square Spin Ices", *Phys. Rev. Lett.*, 105 (2010), 017201.

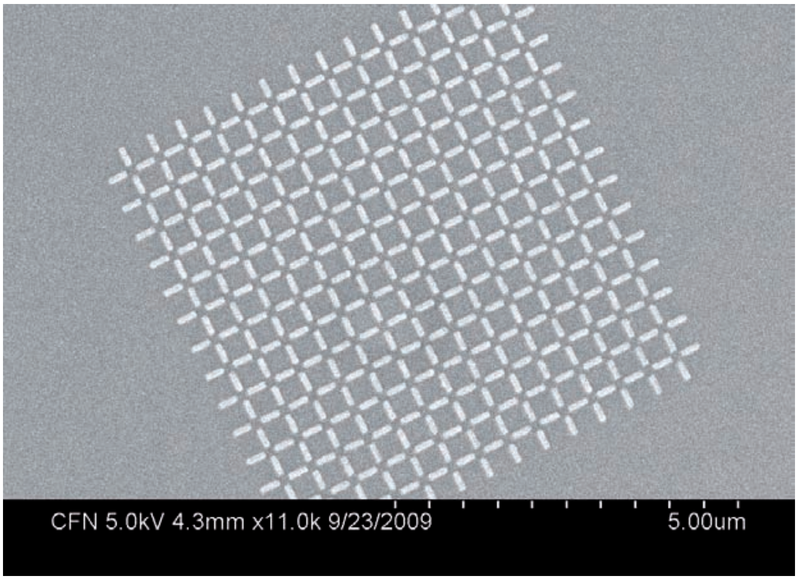

Figure 1 A scanning electron microscopy image of an artificial spin ice pattern (Courtesy of Jason Morgan and Chris Marrows, University of Leeds).

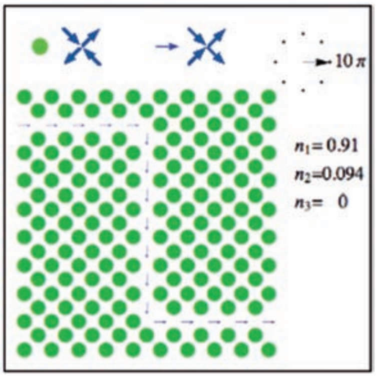

Figure 2 A representation of a low-energy state obtained in our simulations of a rotating field. Green circles represent low energy type 1 vertices and arrows represent higher energy type 2 vertices.