LANDAUER TEST
WITH NANOMAGNETS

Nanomagnetism Group
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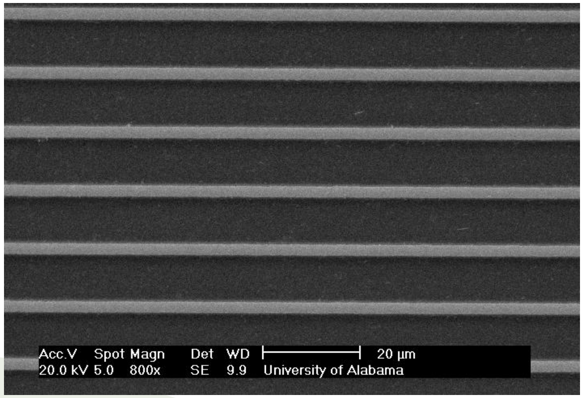
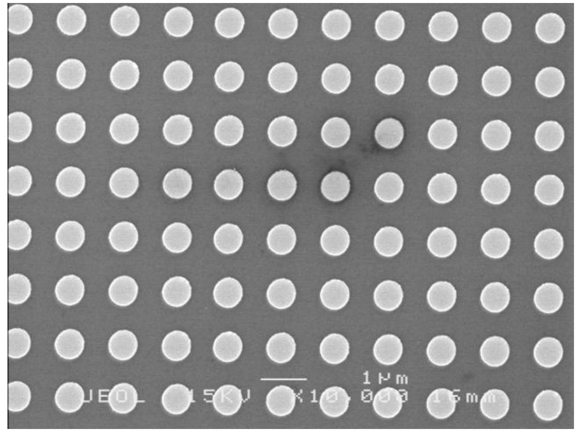
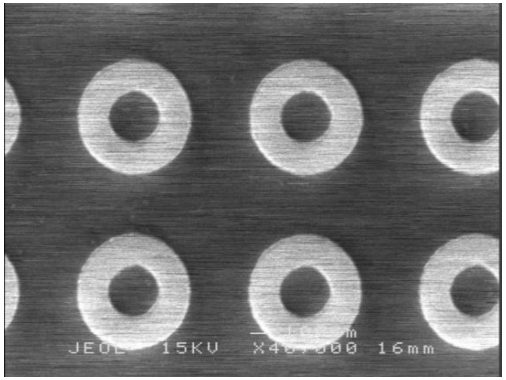
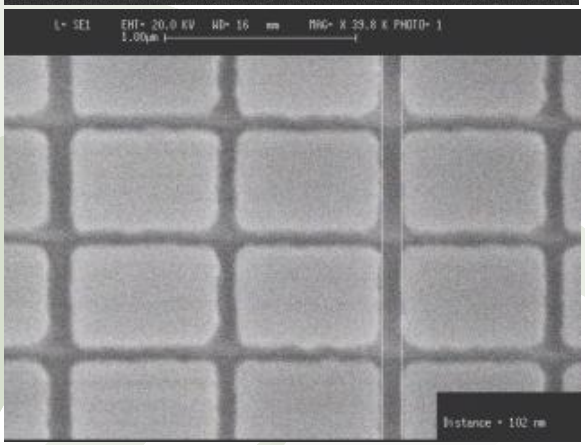
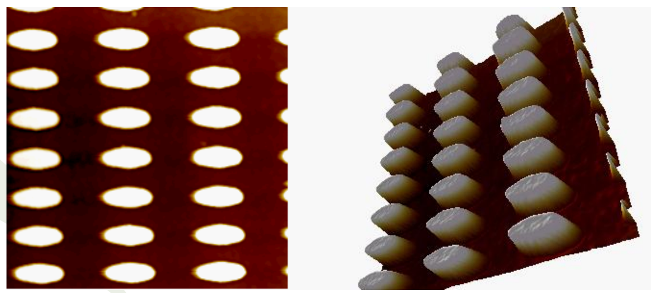
Nanomagnets - Gallery

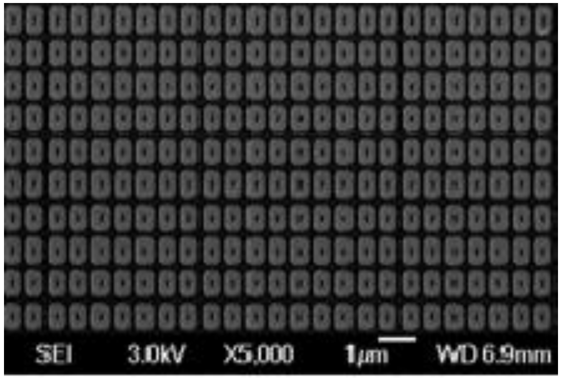


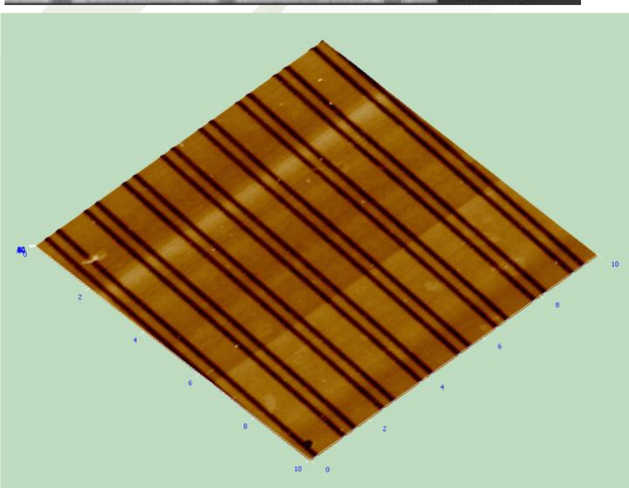


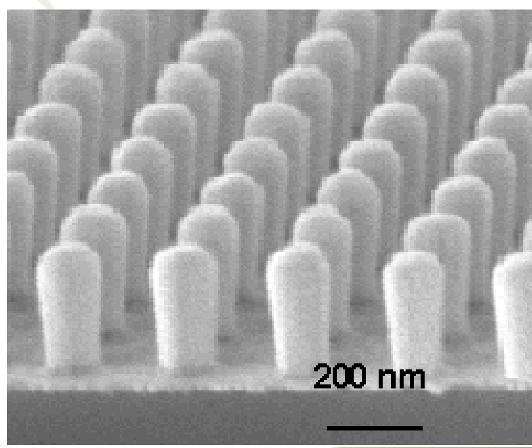


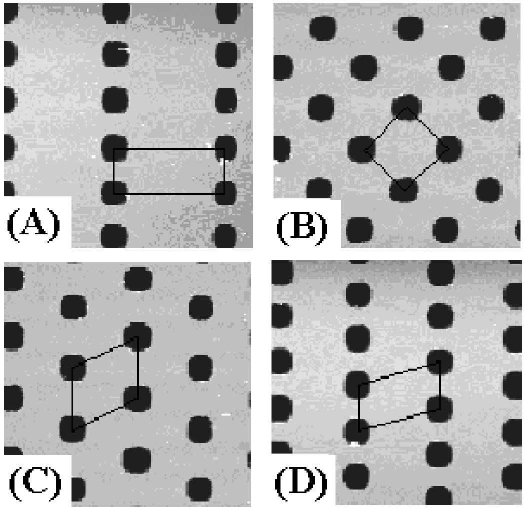






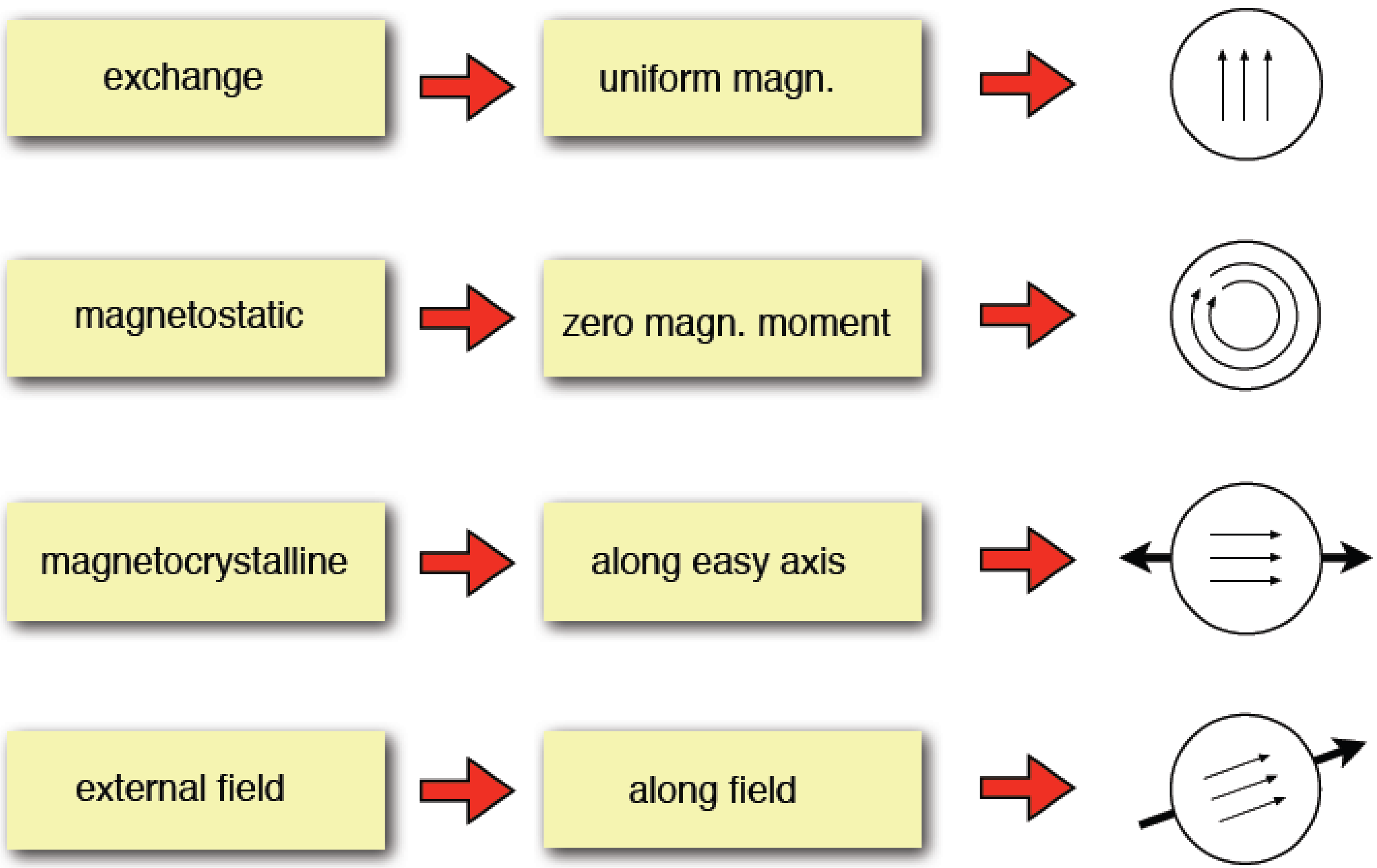






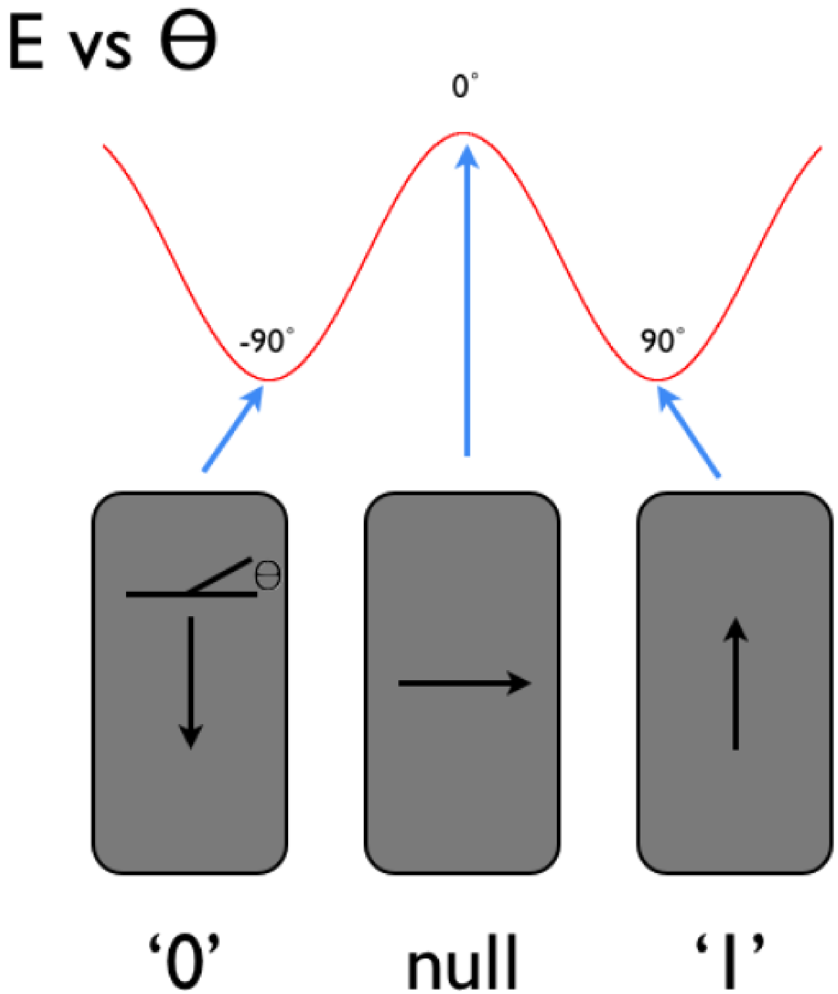
Nanomagnets

Competing energies



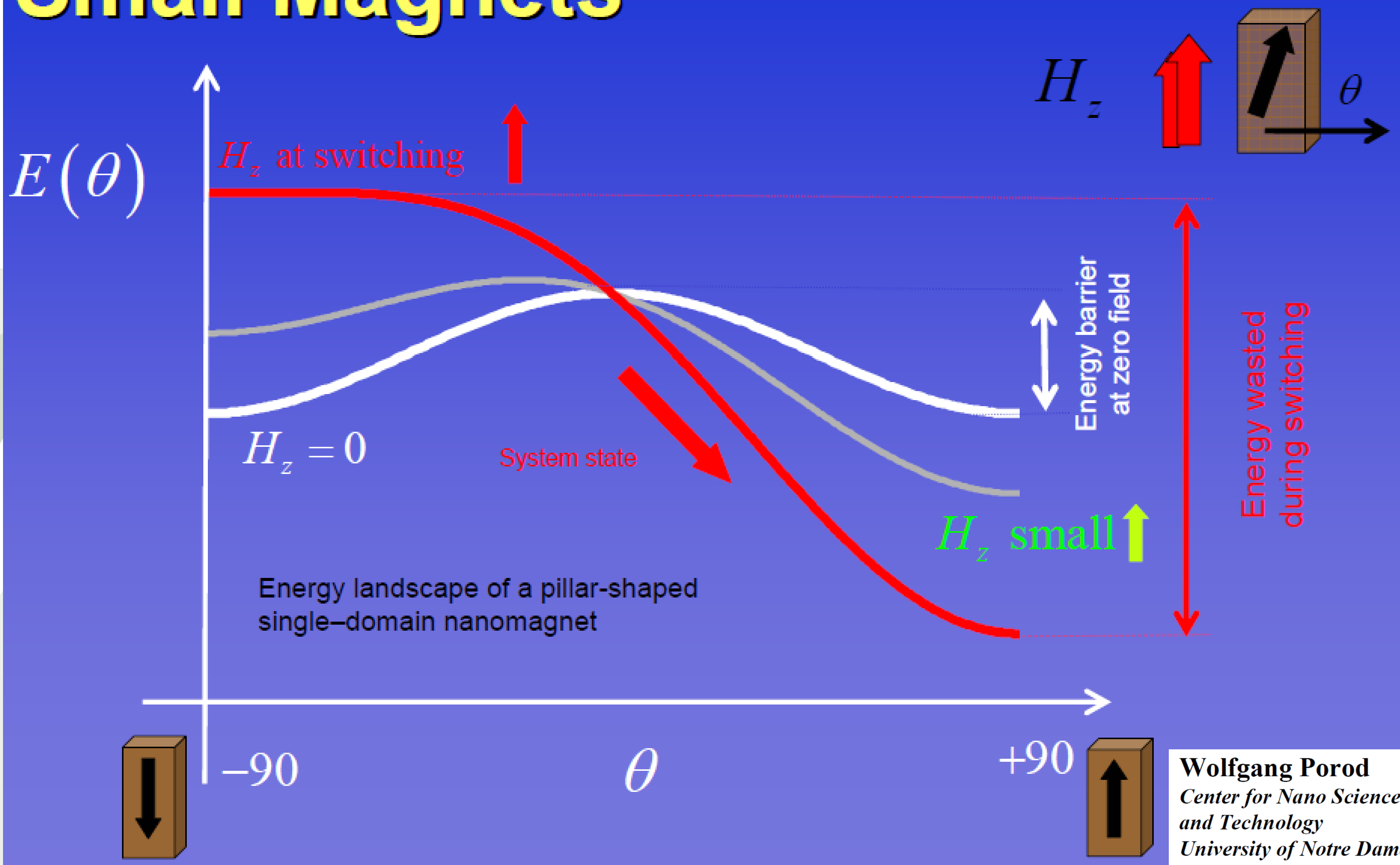
courtesy of G. Bertotti

Rectangular Nanomagnet: bistable system



D. Carlton, PhD thesis «Nanomagnetic Logic», Berkley 2012

Non – Adiabatic Switching of Small Magnets



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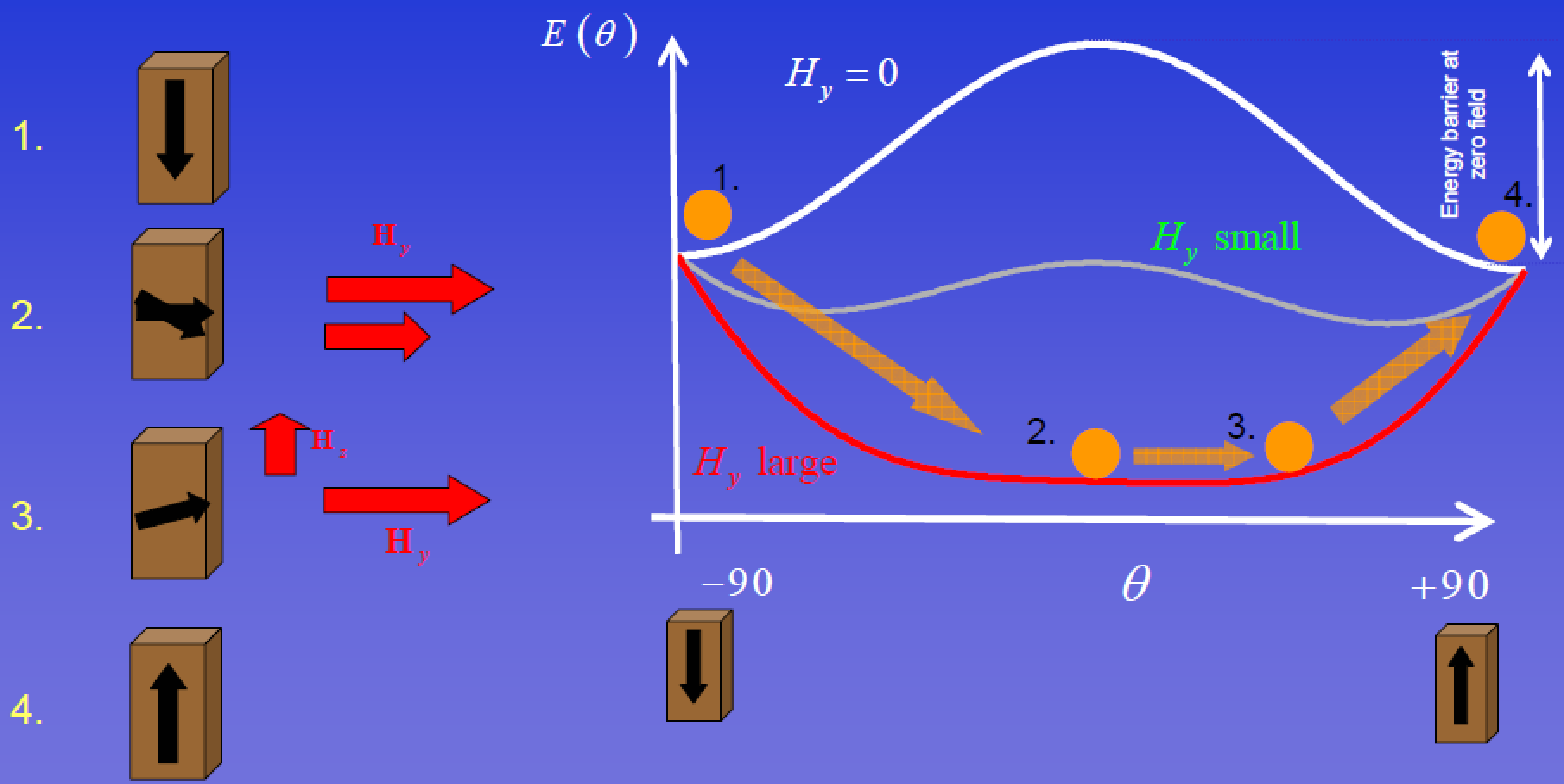
Adiabatic Switching



By adiabatic clocking, the system can be switched with almost no dissipation, but at the expense of slower operation.

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Exploring the Thermodynamic Limits of Computation in Integrated Systems: Magnetic Memory, Nanomagnetic Logic, and the Landauer Limit

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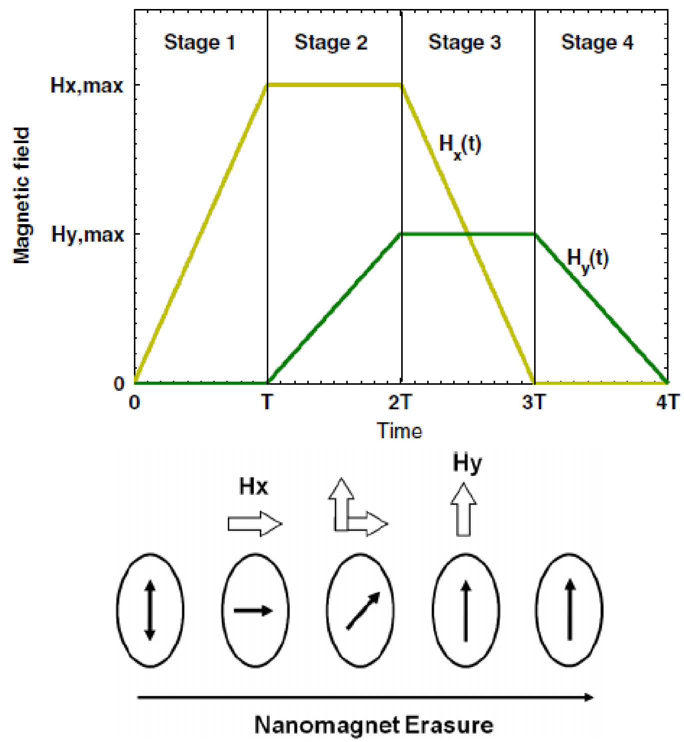
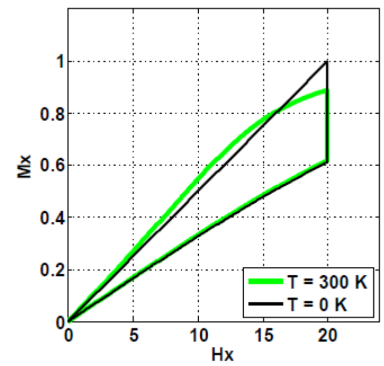
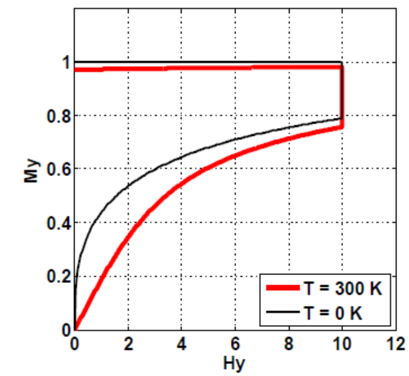
(Received 21 March 2011; revised manuscript received 23 May 2011; published 1 July 2011)

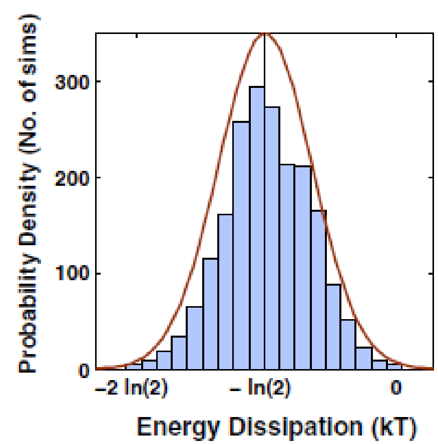




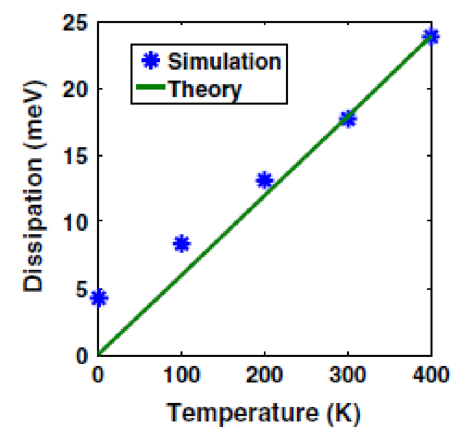
(a)X-axis hysteresis loop



(b)Y-axis hysteresis loop



(c)Probability density function



(d)Energy dissipation vs. temperature

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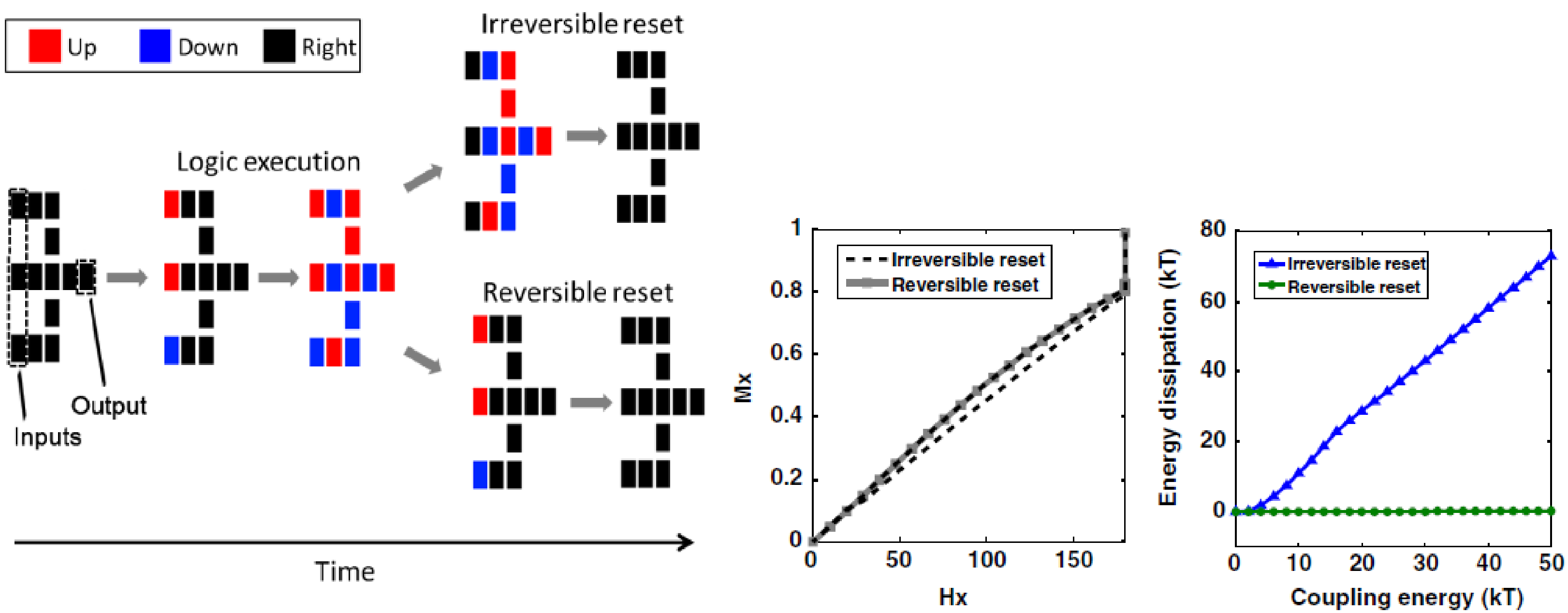


(a)Logic execution cycle (b)X-axis hysteresis loop (c)Energy dissipation vs. coupling energy

FIG. 3 (color online). (a) Two possible computation cycles for a nanomagnetic logic circuit containing a single majority logic gate (MLG) and (b),(c) their corresponding hysteresis loops and energy dissipation. In (a), the circuit computes the majority vote of three inputs (leftmost nanomagnets) and passes the result to an output (rightmost nanomagnet). After logic execution, the circuit is reset to its initial state irreversibly (top branch) or reversibly (lower branch). In (b), the hysteresis loops for the magnetic field applied to the nanomagnets to the right of the inputs is plotted. The nearest neighbor coupling energy was set to $50kT$ in this simulation. In (c), the energy dissipation of both computation cycles is plotted as a function of the nearest neighbor coupling energy between nanomagnets.

Logic Gates with Nanomagnets

a)

i_1 $\overline{i_2}$ i_3	out
000	0
001	0
010	0
100	0
011	1
101	1
110	1
111	1

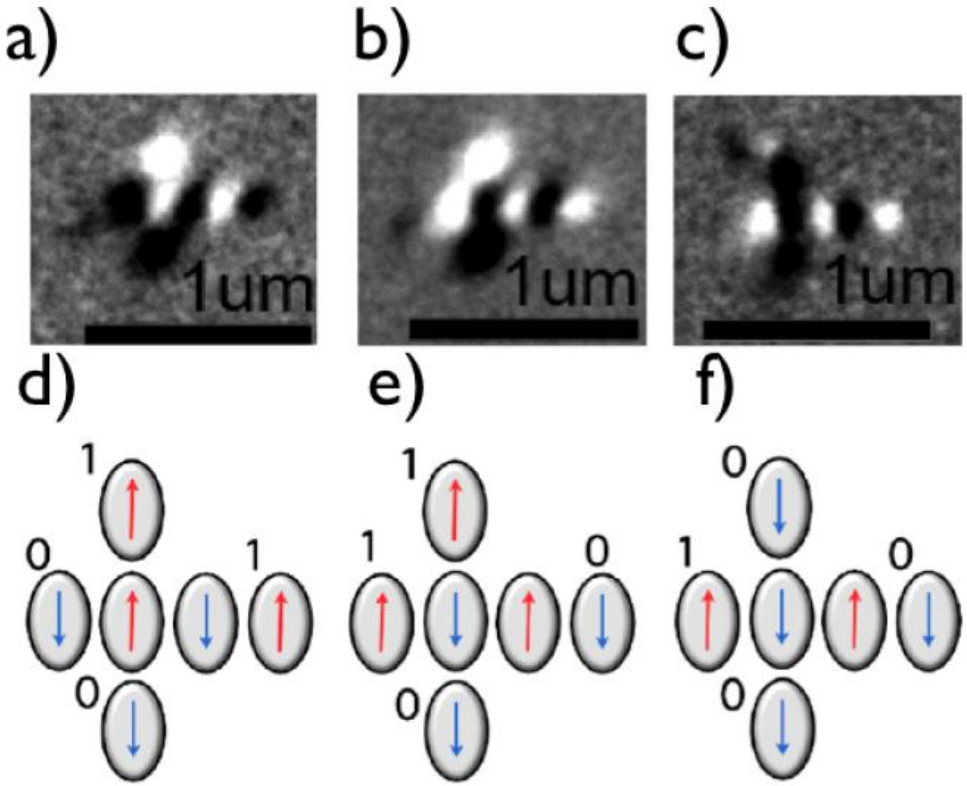
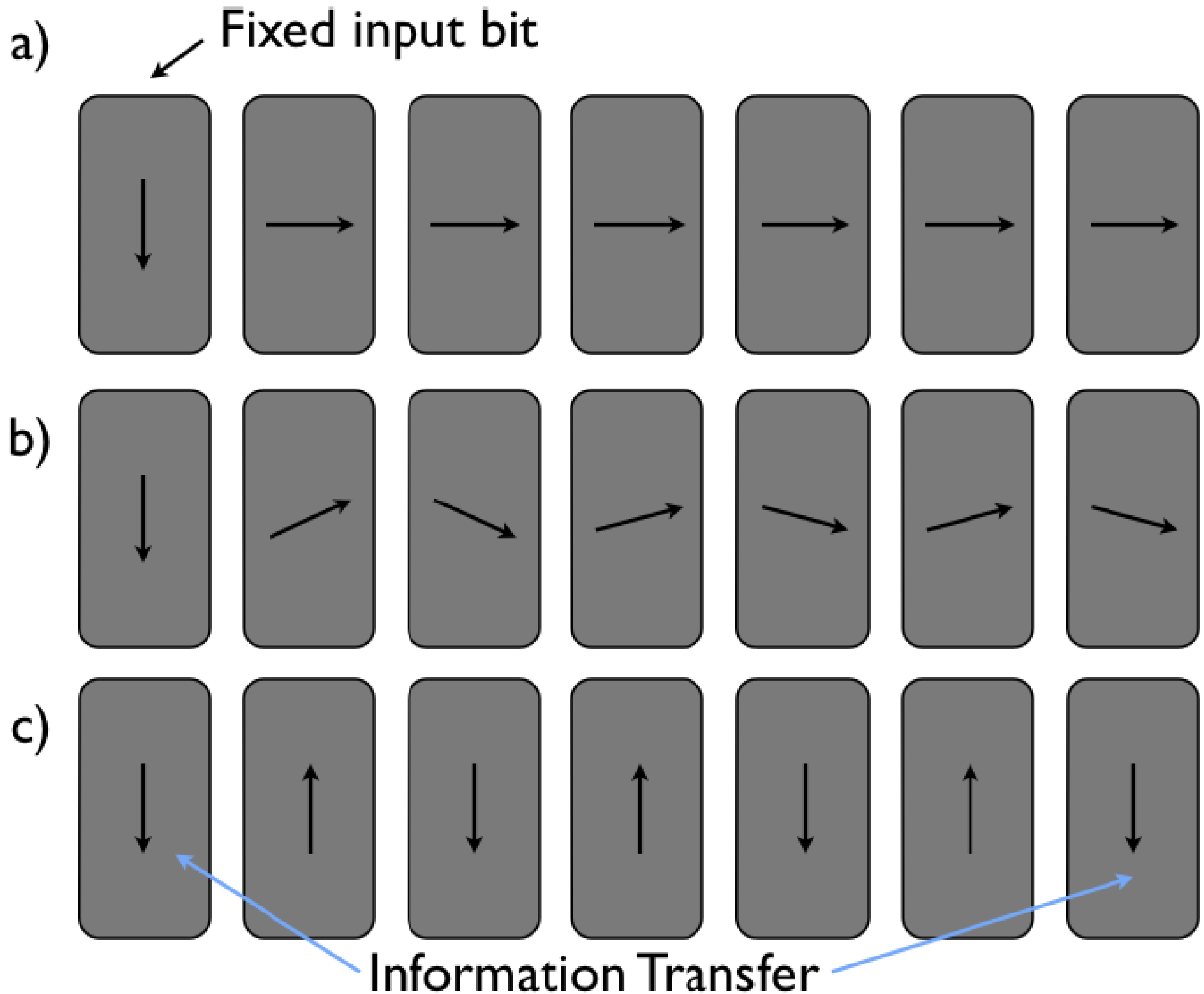


Figure 2.6: Thermal switching of a majority logic gate. a)-c), PEEM images show the final magnetization state of a single majority logic gate structure performing computations for several input combinations using only thermal energy. d)-f), Schematics show the direction each nanomagnet in the gate is magnetized. The nanomagnets were randomized by raising the temperature over the Curie point. As the gate is cooled through the critical point, random fluctuations allow the nanomagnets to find their correct ground state orientation containing the answer to the computation.

D. Carlton, PhD thesis «Nanomagnetic Logic», Berkley 2012

Transfer of information in a chain of coupled Nanomagnets



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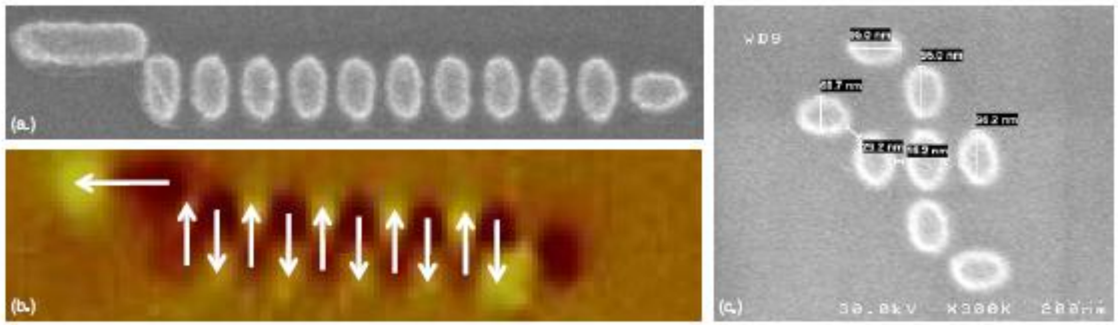

Figure 1. (a) SEM image of AF-ordered line; (b) MFM image of AF-line in logically correct state; (c) SEM image of majority voting gate.

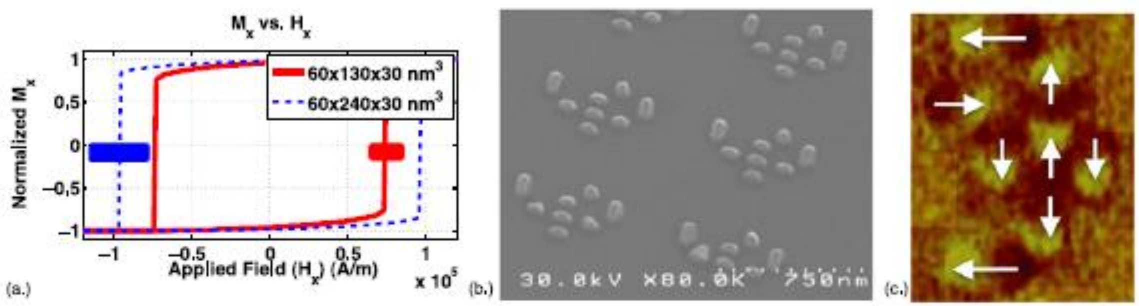

Figure 2. (a) Hysteresis loops for different aspect ratio magnets; (b) majority gate design where top and bottom inputs are larger than the middle input; (c) when subjected to two fields of opposite sign and magnitude, a strong field sets the magnetization state of all inputs, while a weaker field only reverses the magnetization state of the shorter input magnet. Note that the gate is in a logically correct state. Also, more fine-grained, quantitative data is presented in section 6.

Grazie per l’attenzione!