DIRECTIONAL MOTION OF FLUXONS IN A PARALLEL JOSEPHSON-JUNCTION CHAIN

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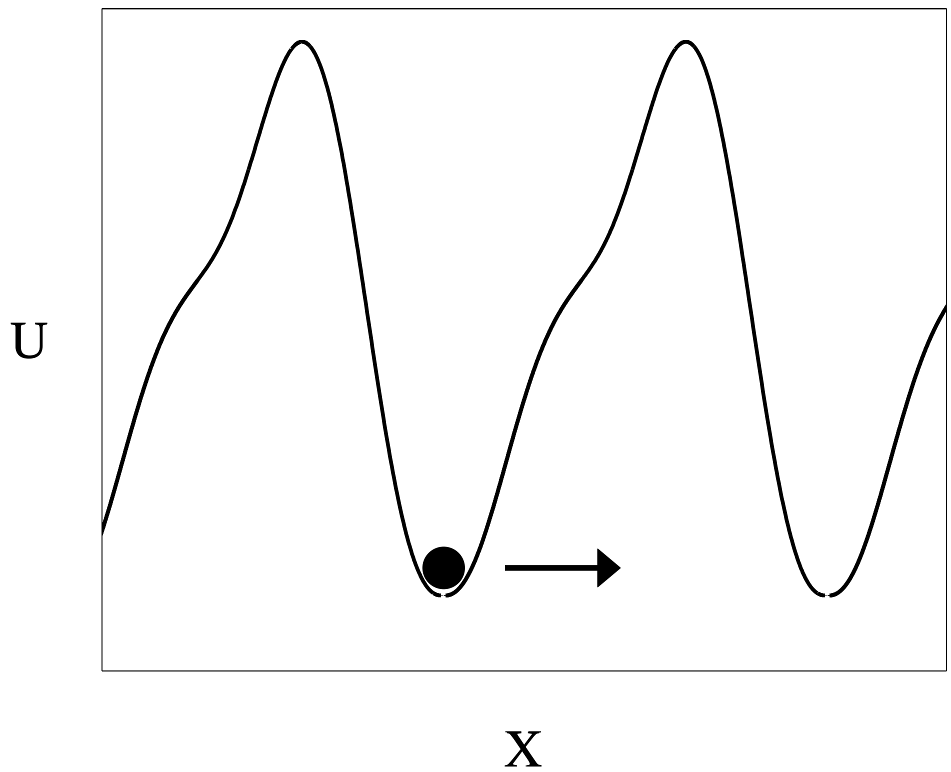
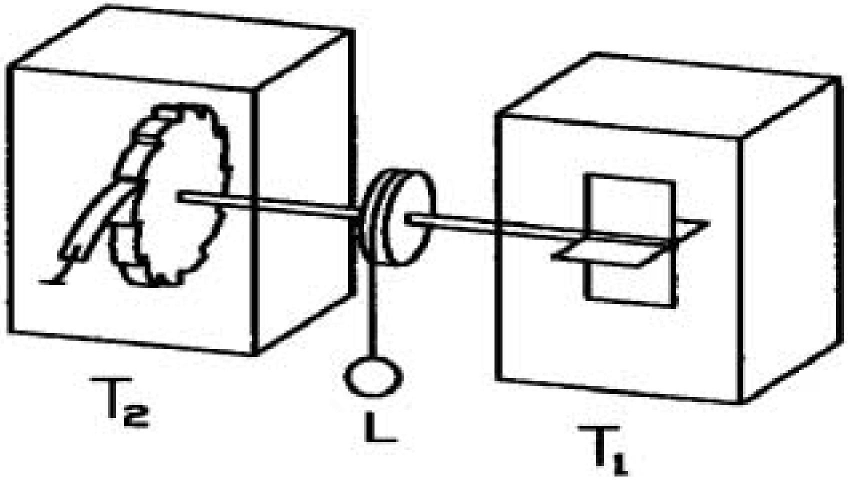
What is a ***ratchet*** potential ? A potential without ***inversion symmetry*** V(x) = V(-x). Thus, it is easier to move a particle in one direction than in the other.



The Feynman´s *“ratchet and pawl”* machine



We can lift the weigth L (**Directional Motion**) if:

* We have an **asymmetric** engine (the ***ratchet***).
* The system is **out of equilibrium** ($T_1 > T_2$ or externally forced).

LET DO IT WITH FLUXONS !

THEORY and SIMULATIONS:

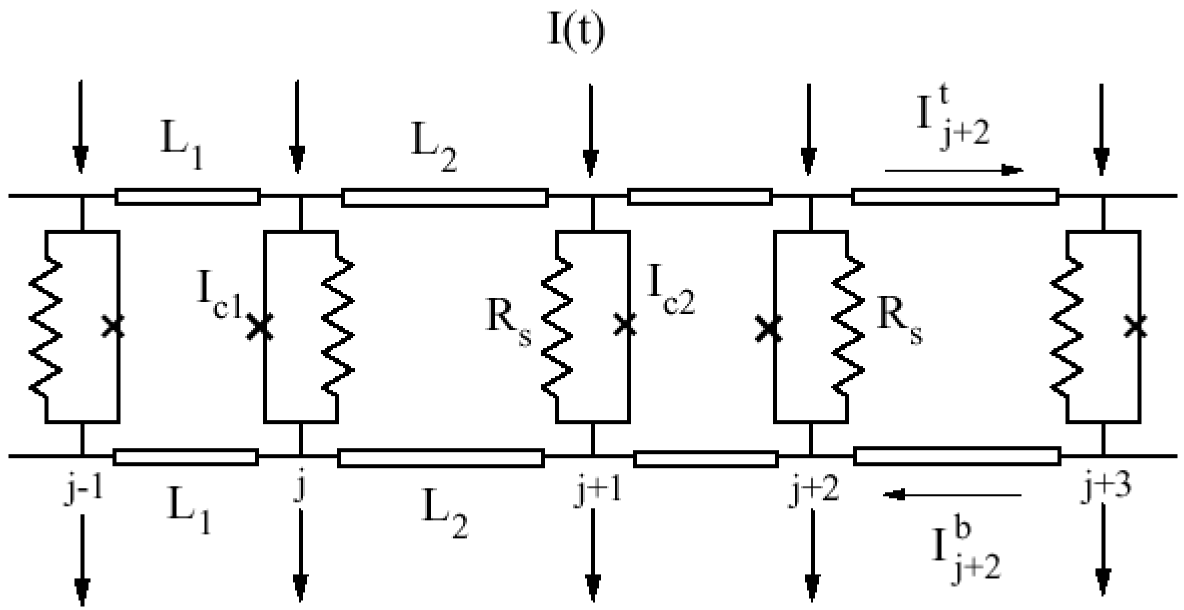
Ratchet potential for fluxons in Josephson-junction arrays.
F. Falo, P. J. Martínez, J. J. Mazo and S. Cilla.
Europhysics Letters **45**, 700-706 (1999).

We design a parallel array in which a fluxon is submited to an effective ***ratchet*** potential.

We calculate the dynamics of the fluxon under ***ac currents***. The ***IV curves*** show ***rectification*** of the current with ***mode-locking steps.***

We also consider ***thermal effects***. A good agreement with ***single particle*** model is found.

THE CIRCUIT MODEL. ALTERNATING CRITICAL CURRENTS AND PLAQUETTE AREAS.



THE EQUATIONS

$$\frac{\Phi_0}{R_s}\dot{x}_j + I_{c1}\sin 2\pi x_j = I(t) + \frac{\Phi_0}{2L_1}(x_{j-1} - x_j) + \frac{\Phi_0}{2L_2}(x_{j+1} - x_j)\,,$$

$$\frac{\Phi_0}{R_s}\dot{x}_{j+1} + I_{c2}\sin 2\pi x_{j+1} = I(t) + \frac{\Phi_0}{2L_2}(x_j - x_{j+1}) + \frac{\Phi_0}{2L_1}(x_{j+2} - x_{j+1})\,.$$

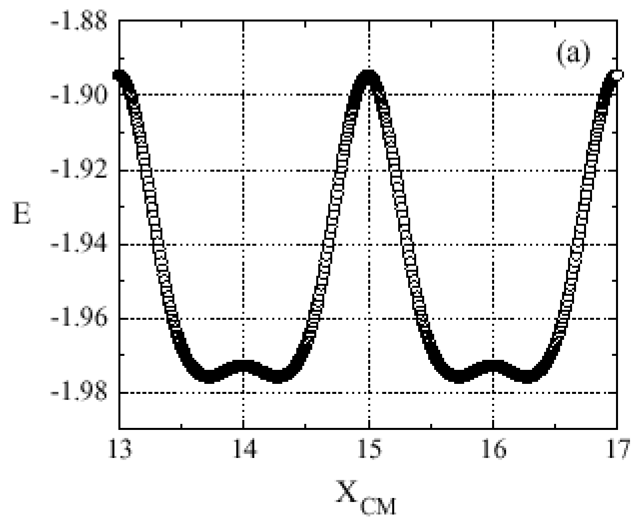
Normalized equations (Frenkel-Kontorova model)

$$\dot{x}_j + \frac{K}{2\pi}\sin 2\pi x_j = \tilde{I}(t) + (x_{j-1} - x_j) + \beta(x_{j+1} - x_j)\,,$$

$$\dot{x}_{j+1} + \alpha\frac{K}{2\pi}\sin 2\pi x_{j+1} = \tilde{I}(t) + \beta(x_j - x_{j+1}) + (x_{j+2} - x_{j+1})\,,$$

Effective Potential for the fluxon.

$\alpha = 1, \beta = 1$



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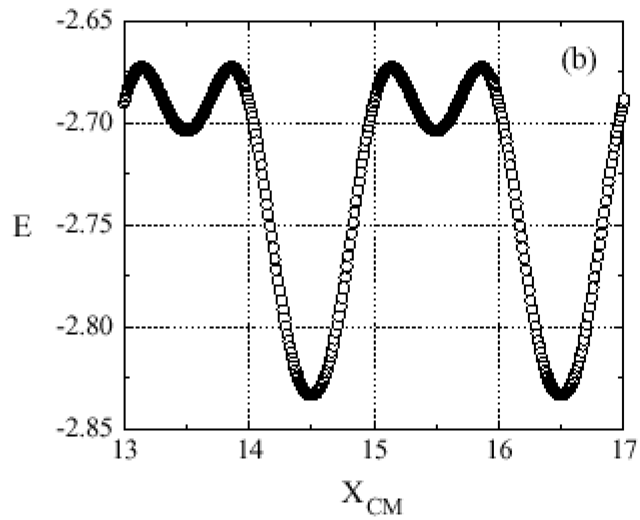
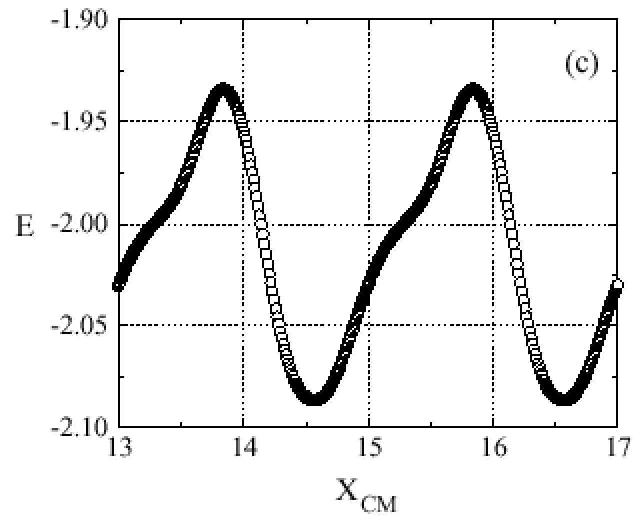
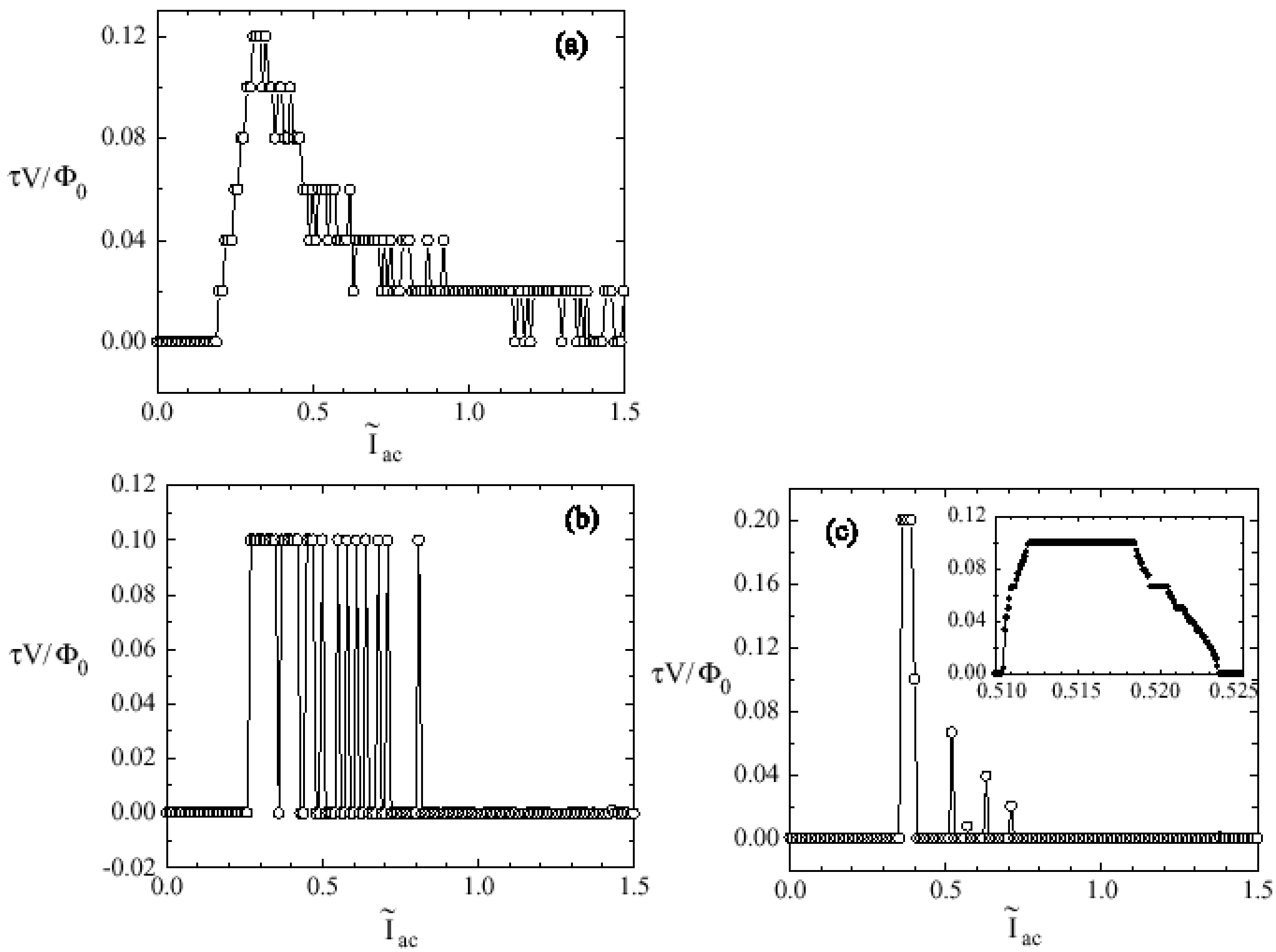
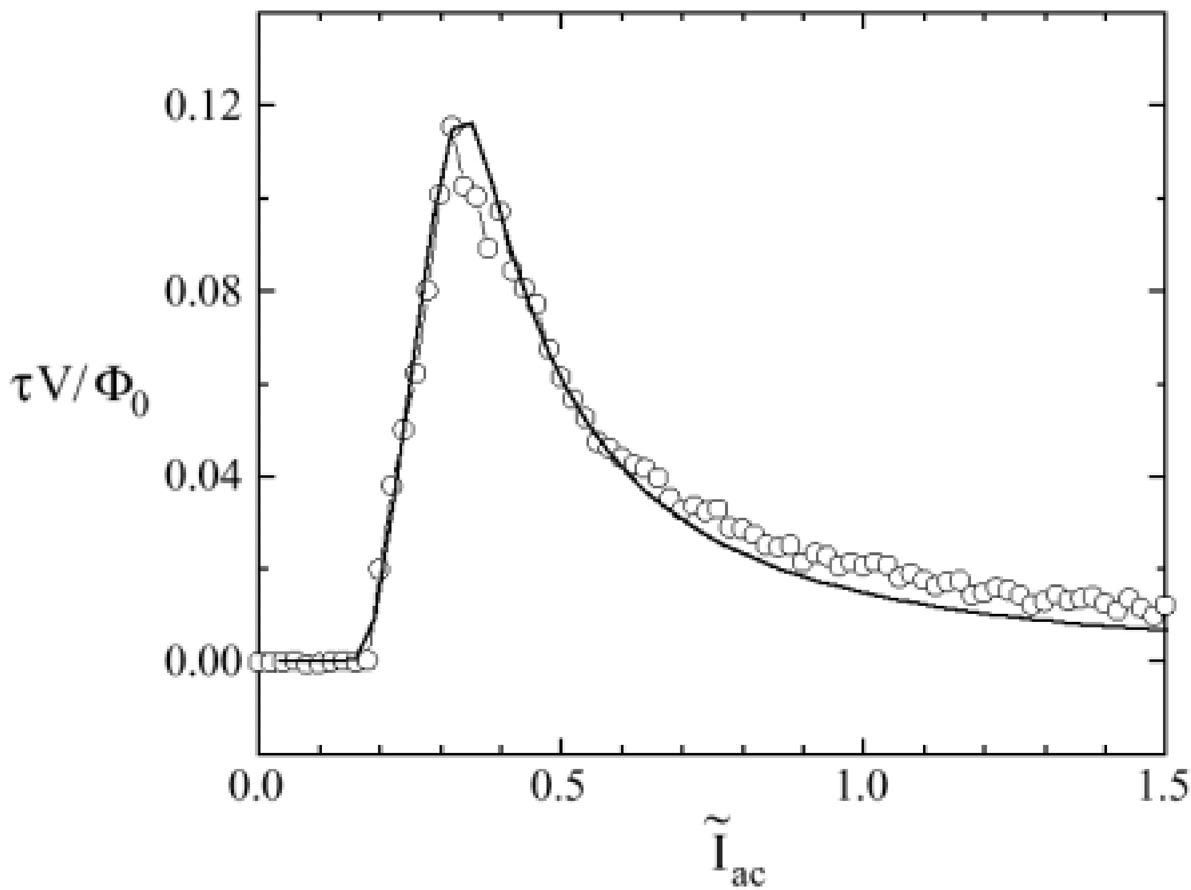




IV Curves (at different frequencies)



Thermal Effects (Langevin Dynamics)



EXPERIMENTS:

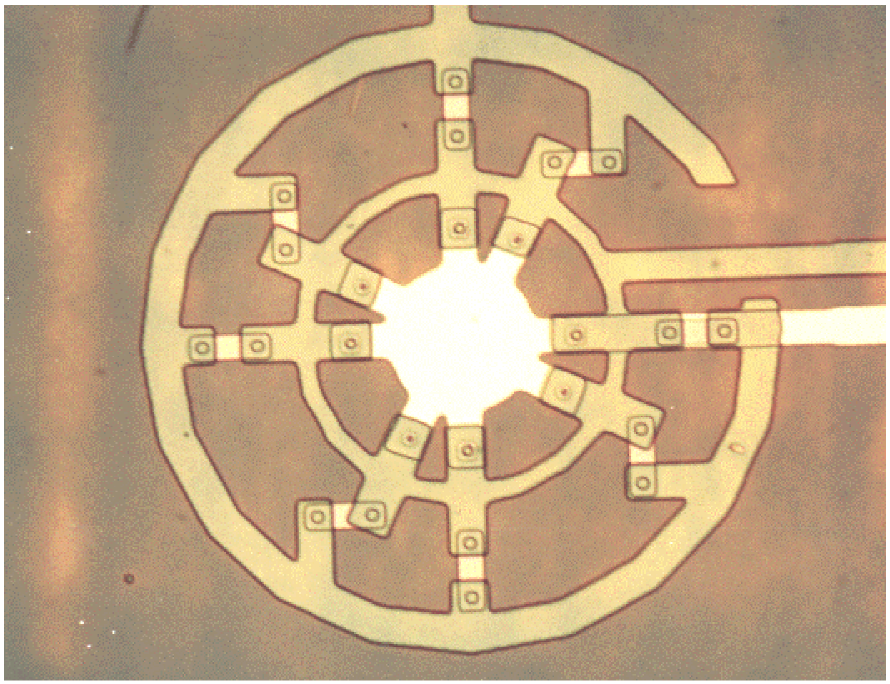
Depinning of kinks in a Josephson-junction ratchet array.
E. Trías, J. J. Mazo, F. Falo and T. P. Orlando
Physical Review E 61, 2257-2265 (2000).

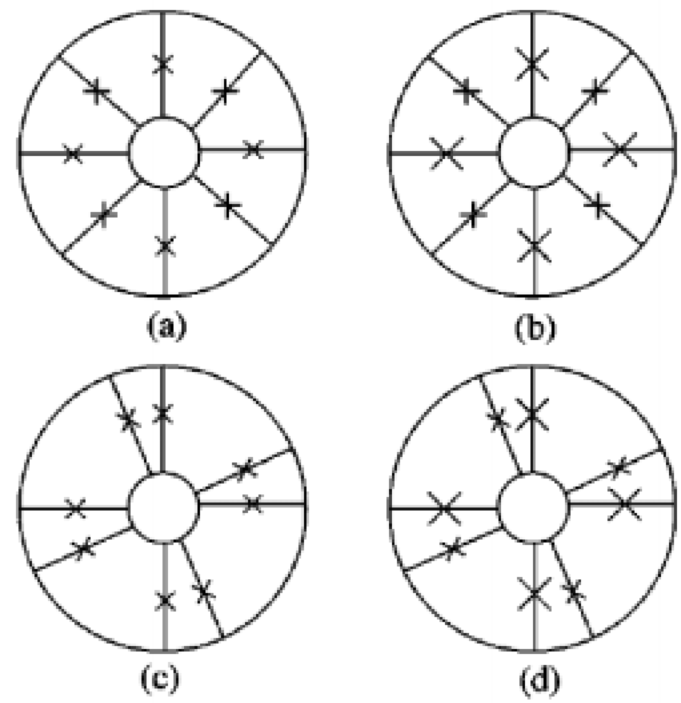
We have ***built*** circular arrays with different ***ratios*** of ***critical currents*** and ***area plaquettes***.

We have measured the ***IV curves*** under ***dc currents***. They show ***different depinning*** current of the fluxons depending on the ***current direction***.

The dependence of the ***depinning currents*** versus ***magnetic field*** is a function of the area ratio.

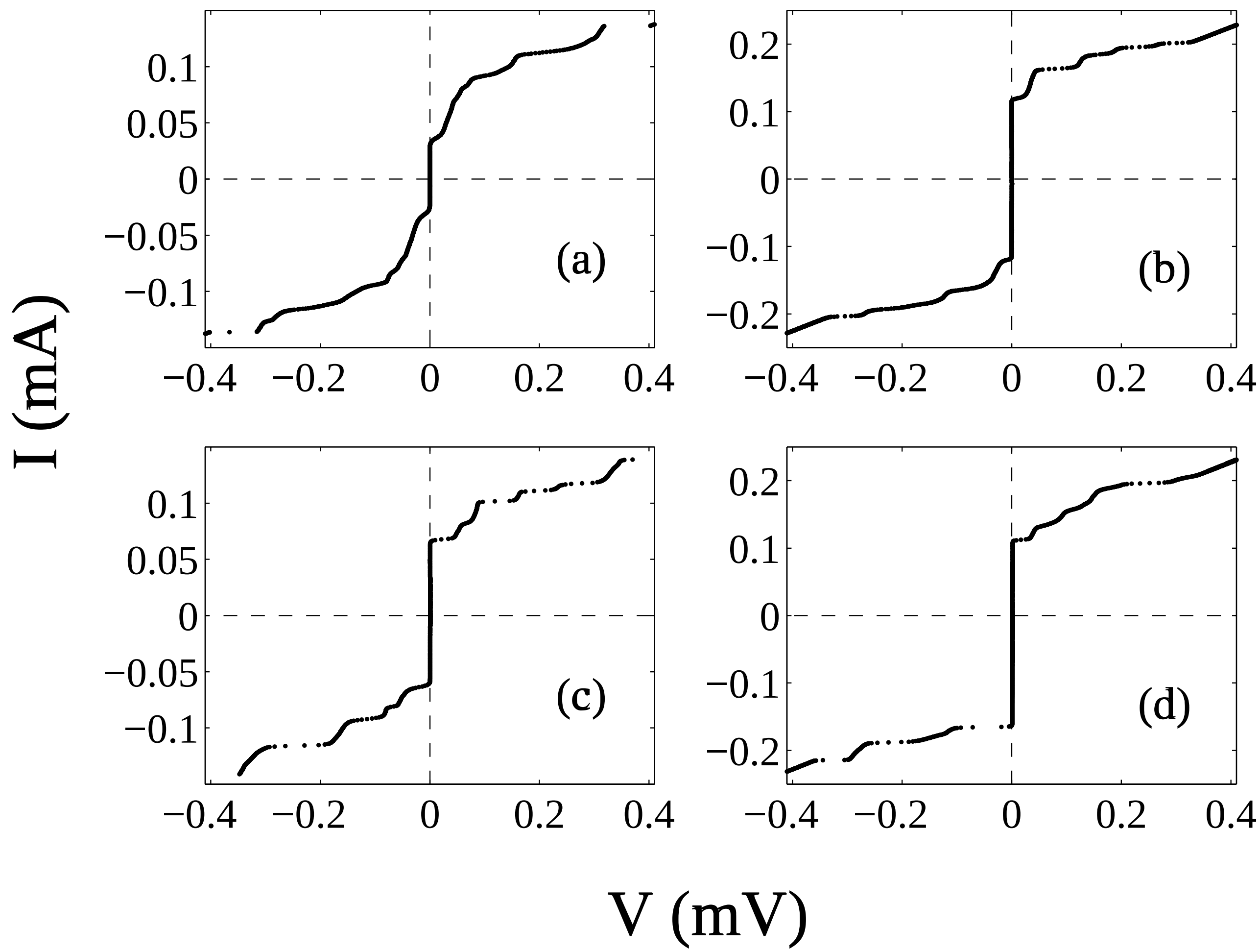
CIRCULAR PARALLEL ARRAYS



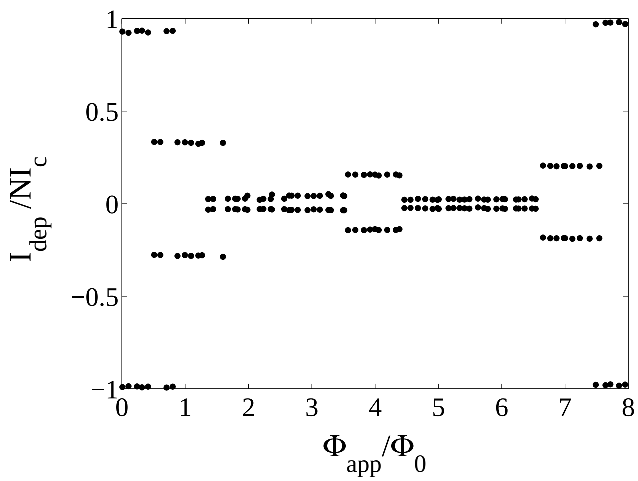


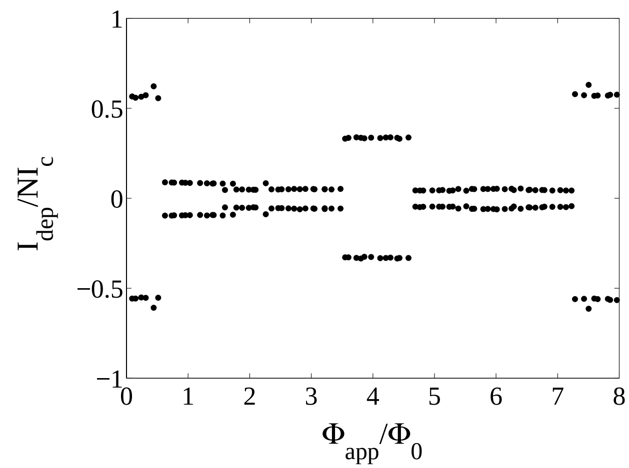
Four different arrays

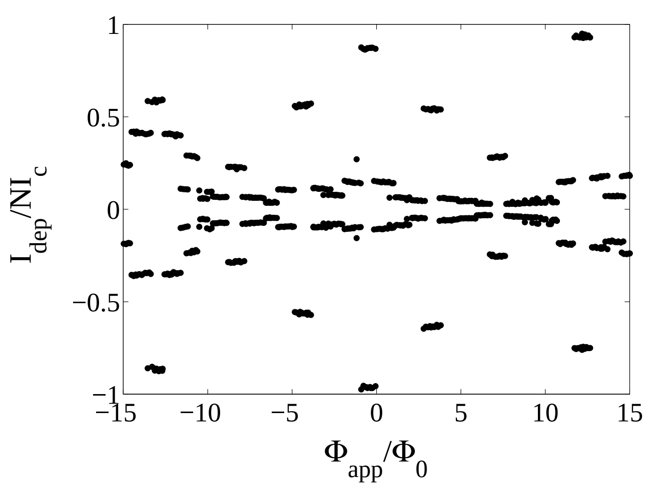
IV CURVES (DC Currents)

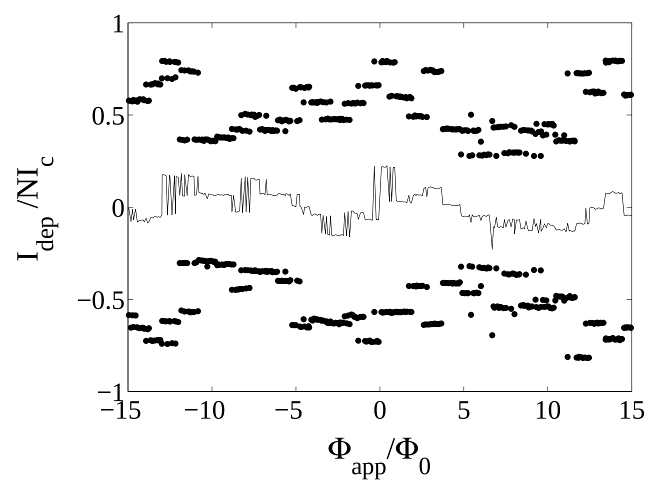


Deppinning currents vs applied magnetic field

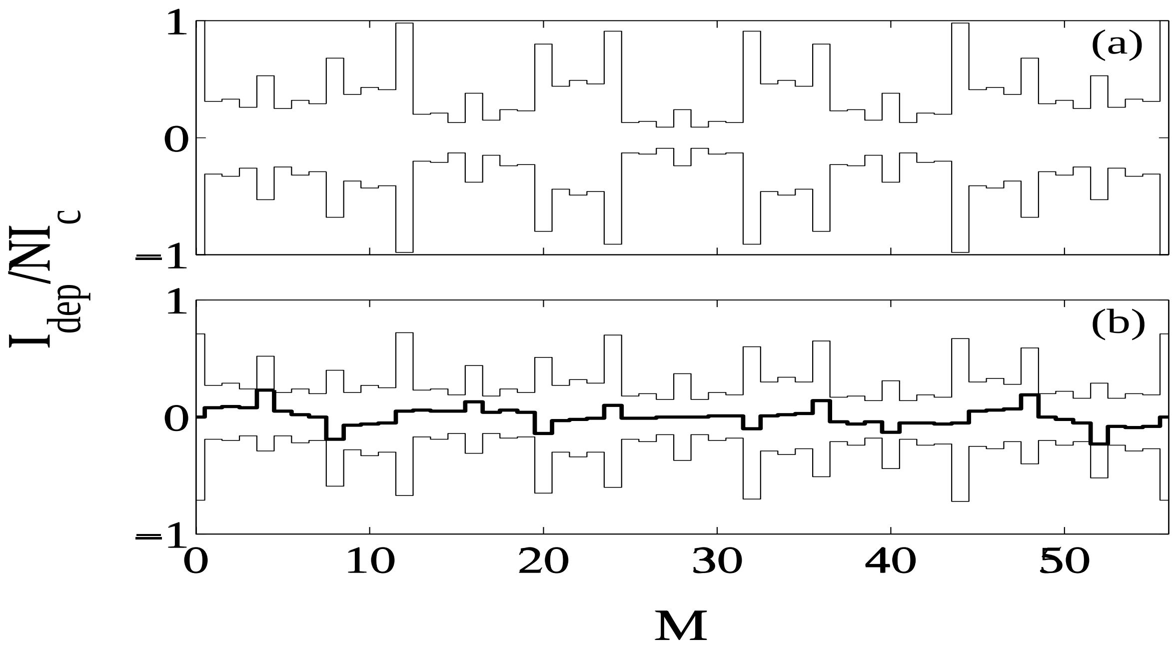








Simulated dependence of a ring of N=8 vs applied magnetic field



Different areas

Ratchet

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