Metastable States in Shaped Long Josephson Junctions

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The Goal

The goal of this work is to show the existence of metastable static fluxon states in a double-well potential created by shaping a long Josephson junction and applying an external magnetic field.

This requires to

- control the height and width of the potential features by controlling the field and shaping the junction.
- prepare the junction in one of two states by applying a combination of bias current and external magnetic field.
- determine the state of the junction by measuring the critical current.

We plan to use this techniques to measure activation rates in the thermal and quantum regime. [1]

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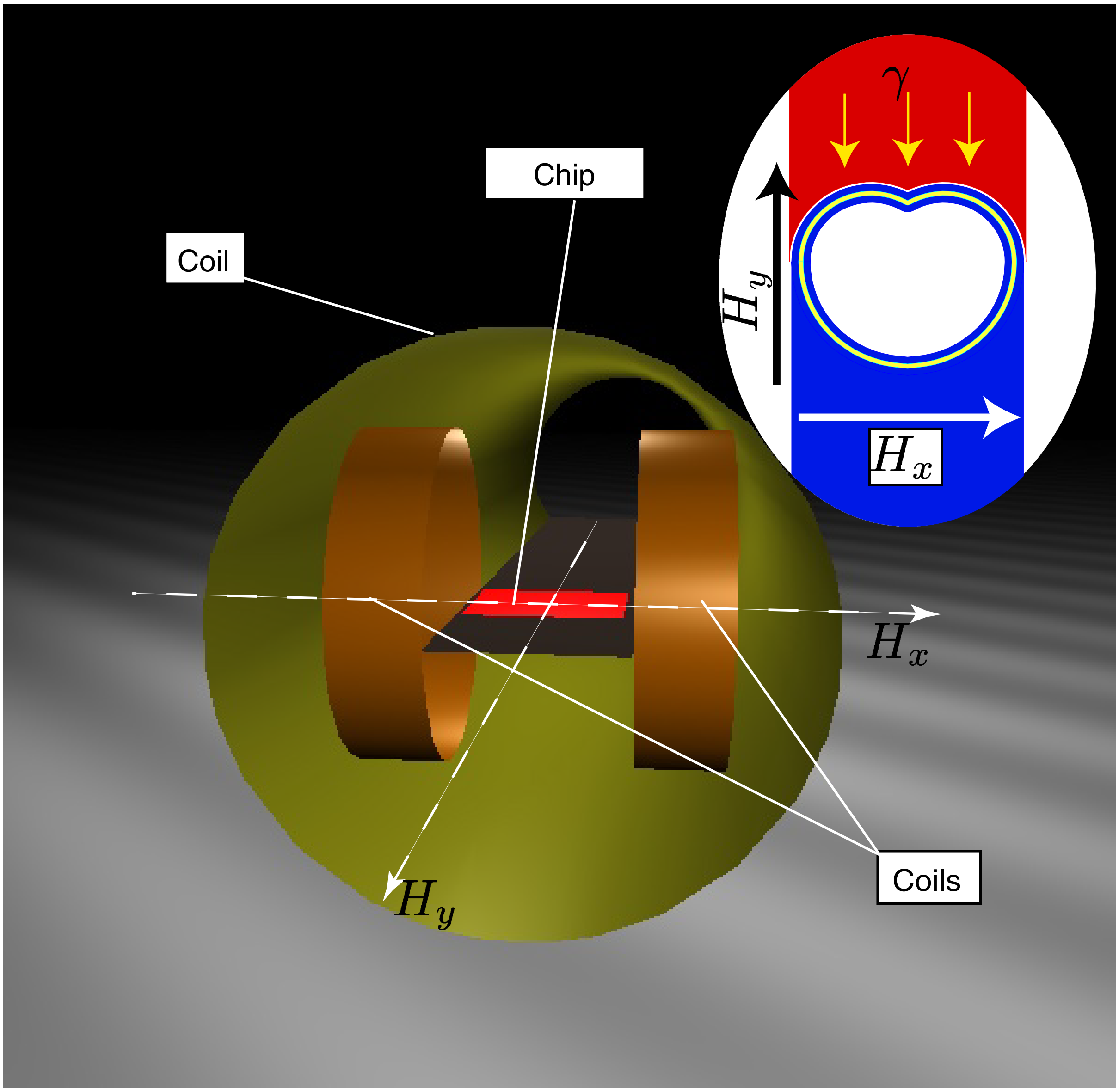
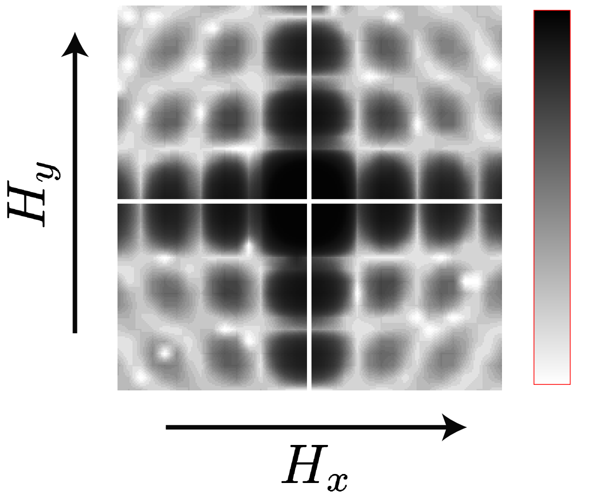
[1] Annular Long Josephson Junctions in a Magnetic Field: Engineering and Probing the Fluxon Interaction Potential, A. Wallraff, Yu. Koval, M. Levitchev, M.V. Fistul, A.V. Ustinov, JLTP Vol. 118

The Setup

For controlling the field direction in the plane of the junction we use 2 coils.





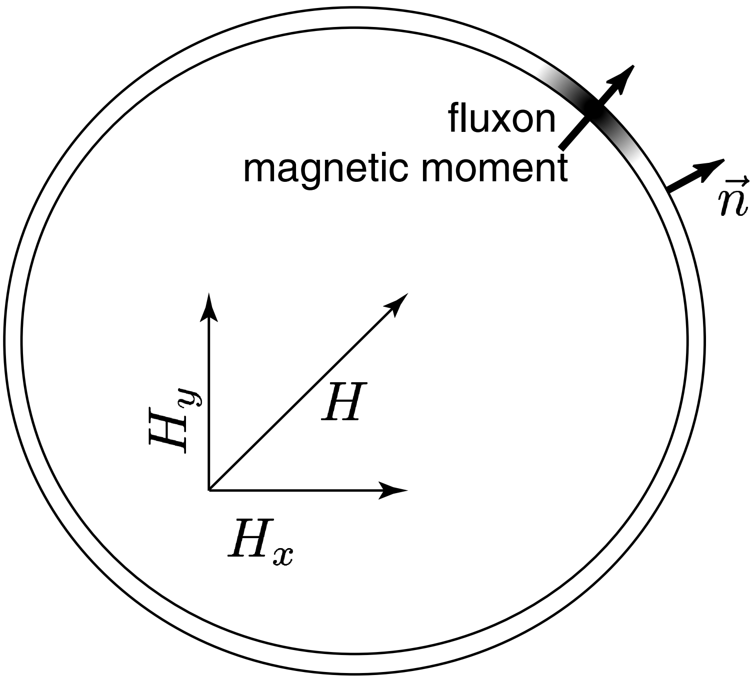
$I_c(H_x, H_y)$ pattern of a small square junction

The Potential for a Fluxon in an External Magnetic Field

Applying a magnetic field to a shaped long Josephson junction creates a potential for the fluxon[2].

$$U_{ext}(x_0) \propto \int_0^l \frac{\partial \phi_f(x - x_0)}{\partial x} \vec{H} \cdot \vec{n}(x) dx$$

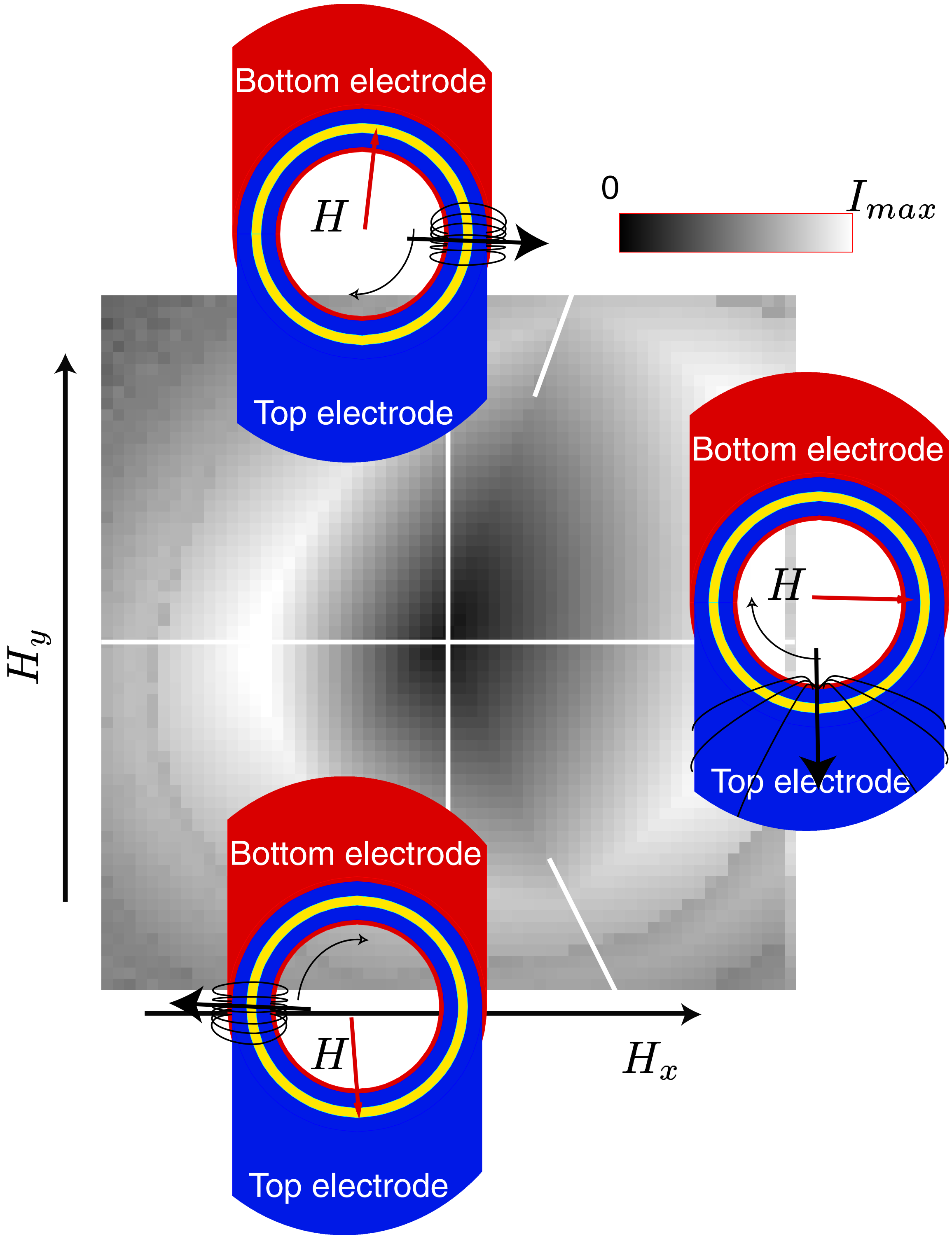
- $\vec{H} = \begin{pmatrix} H_x \\ H_y \end{pmatrix}$
- l is the length of the junction
- x_0 designates the normalised coordinate of the fluxon
- ϕ_f is the phase distribution of a fluxon



[2]Phase-locking of long annular Josephson junctions coupled to an external rf magnetic field, N. Grønbach-Jensen, P.S. Lomdahl, Phys. Lett. A, Vol 154

Pinning at the Bias-Leads

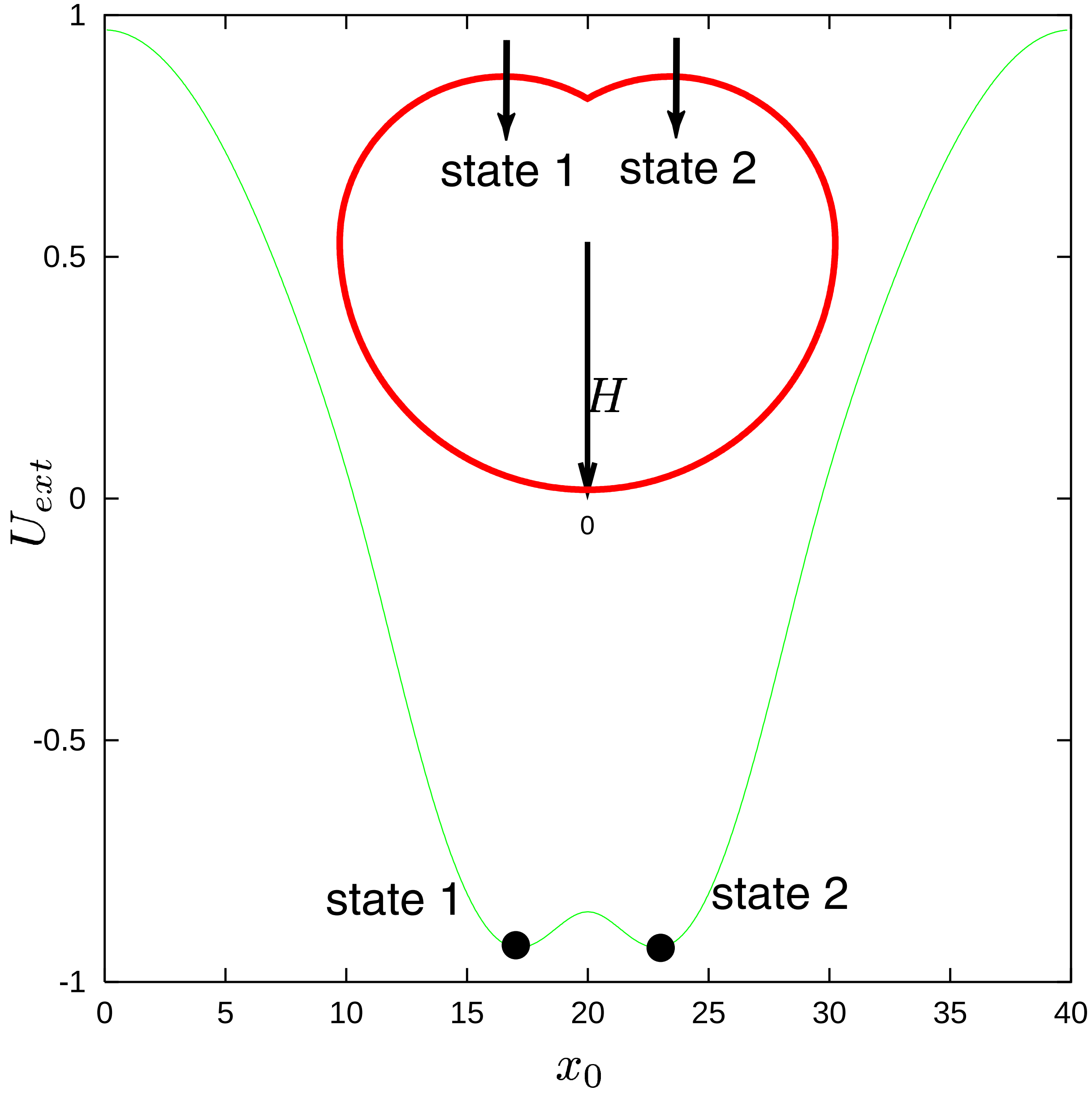
The single-fluxon-state critical current diffraction pattern for an annular junction shows pinning at the bias leads, as observed before[3]



[3]Fluxon pinning through interaction with the superconducting wiring of long annular Josephson junctions, D. Münter, T. Doderer, H. Preßler, S. Keil and R. P. Huebener, Phys. Rev. B, Vol 58, Number 21

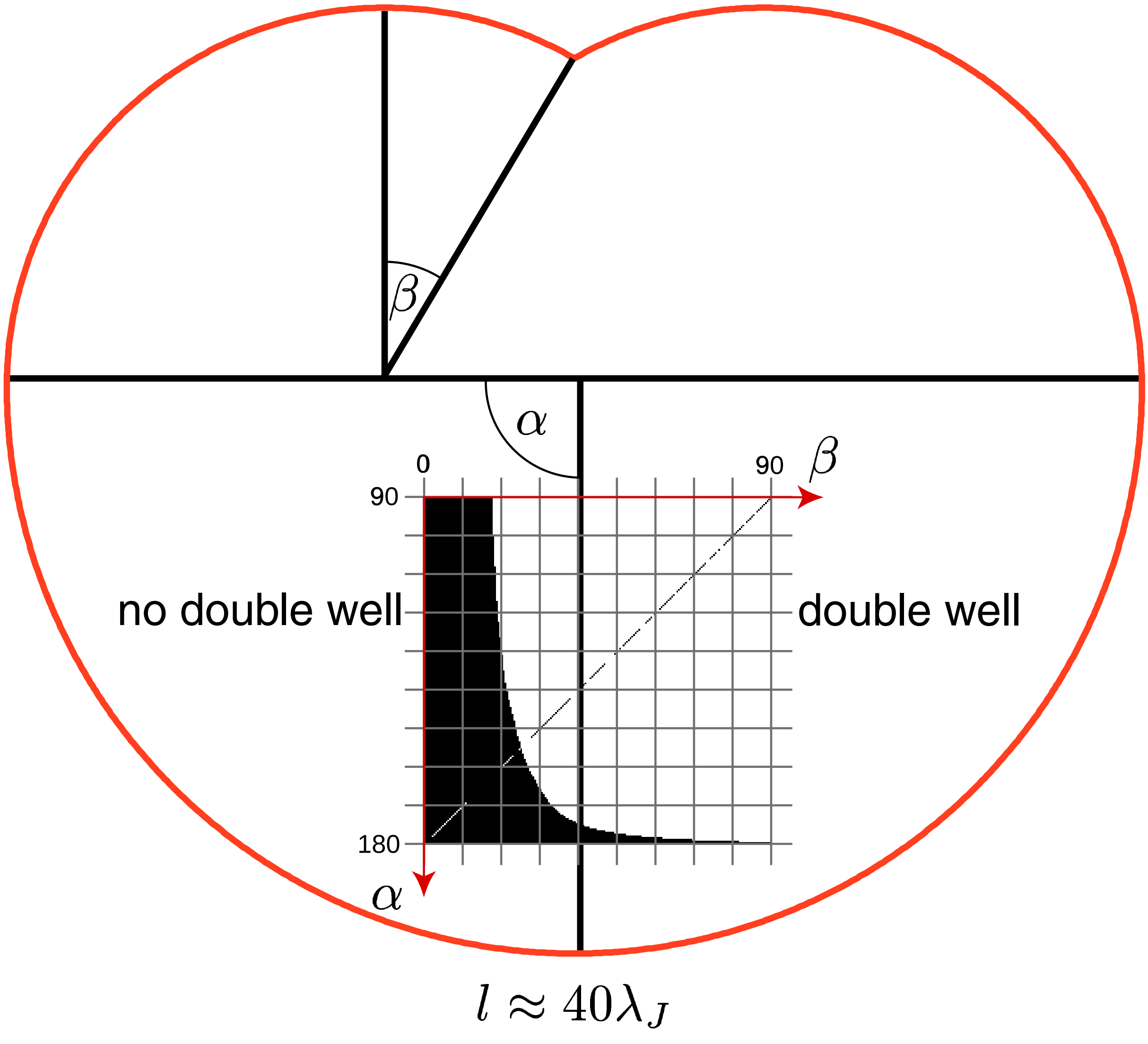
Heart-Shaped Junctions

Applying a field to a heart-shaped junction can result in a double-well potential: Here local minima correspond to metastable states.



The Junction Geometry

Due to the convolution of the potential with the fluxon form there are, for a given length of the junction, limitations to the construction parameters α and β, which determine if a double-well-potential can be formed.

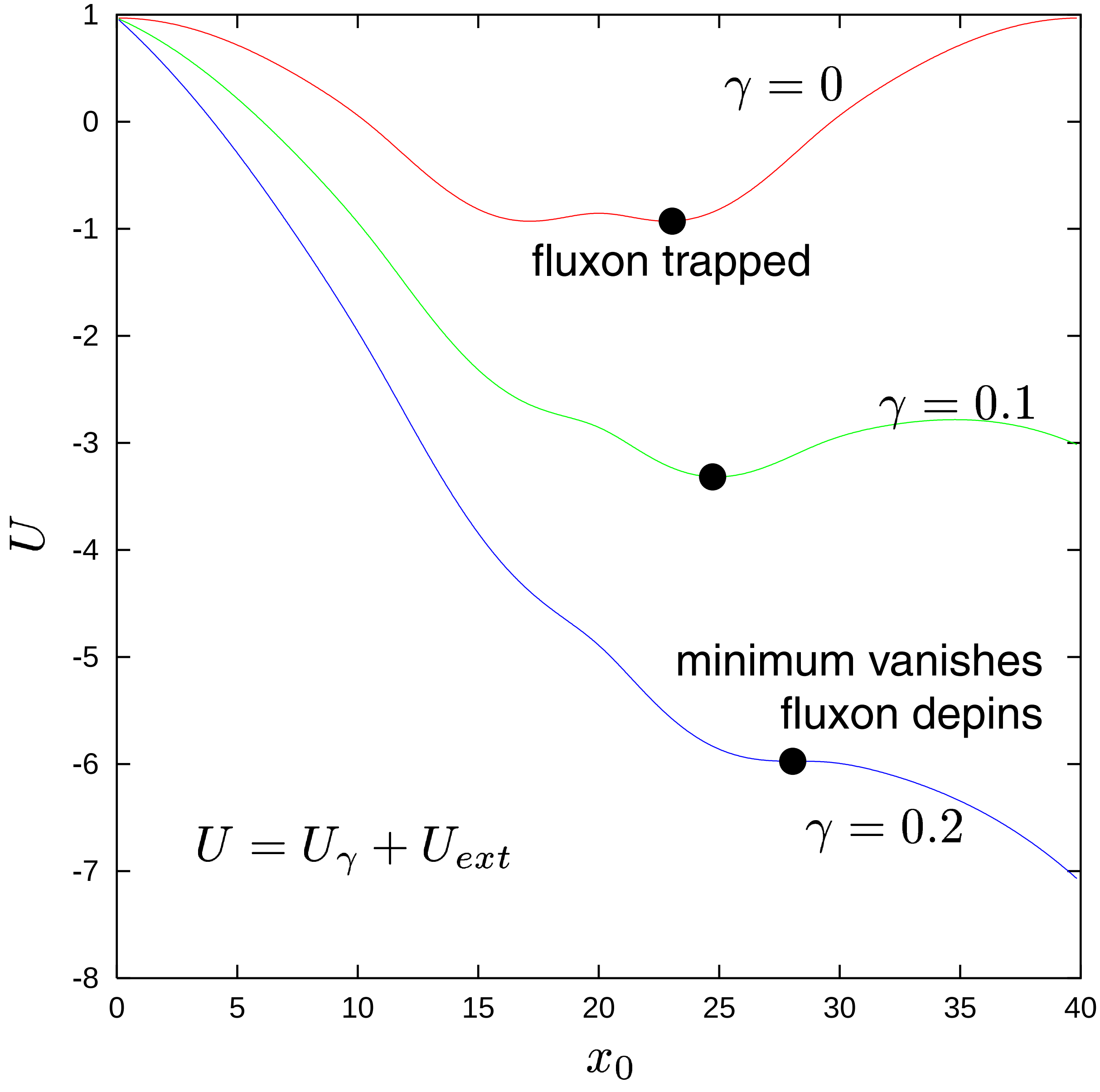


$l \approx 40\lambda_J$

The Depinning Current

The bias current $\gamma = \frac{I_{bias}}{I_c}$ produces an additional potential

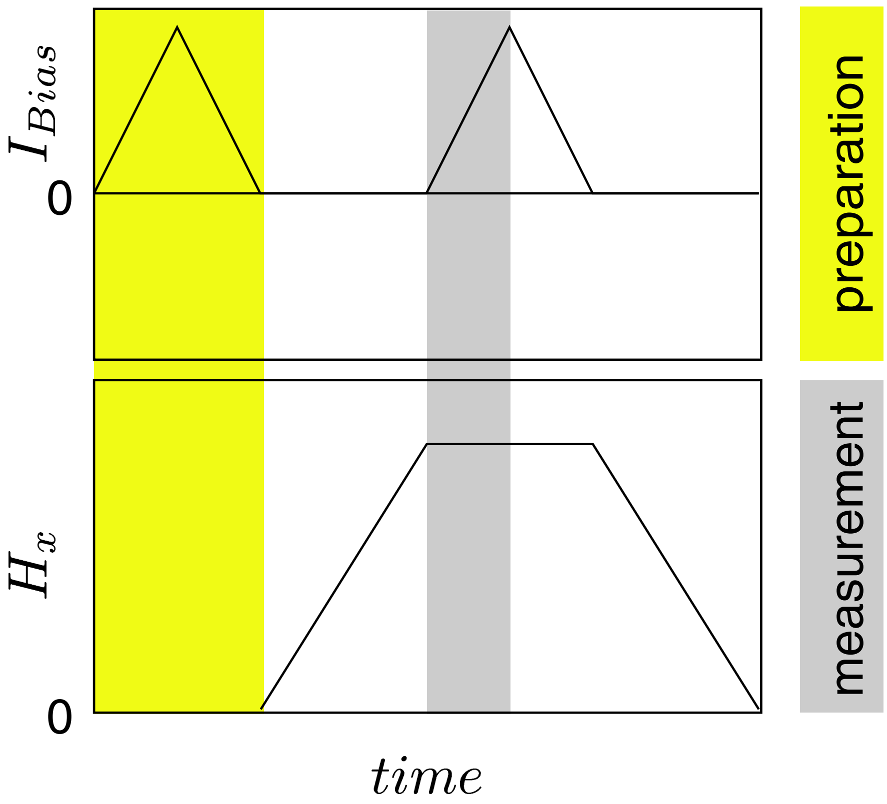
$$U_\gamma = -2\pi\gamma x_0$$



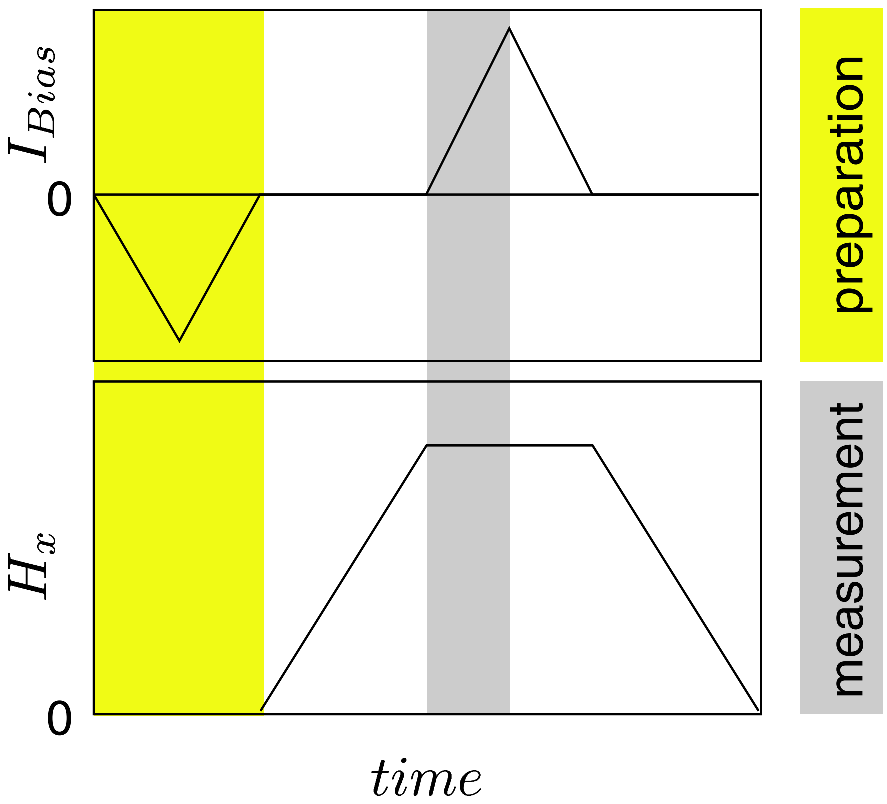
Preparation and Measurement

Two ways of preparation:

1. by positive bias current pulse

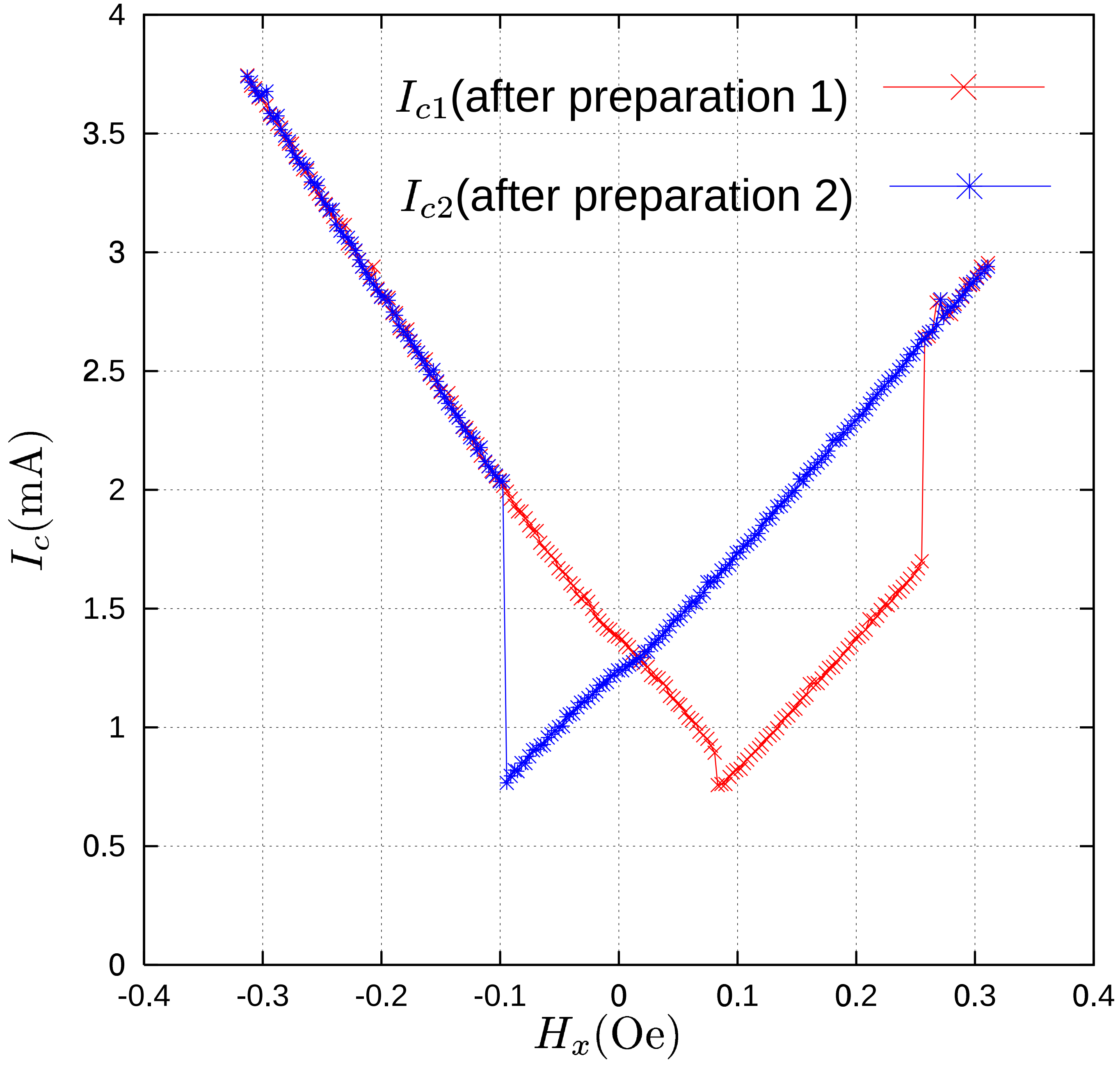


2. by negative bias current pulse



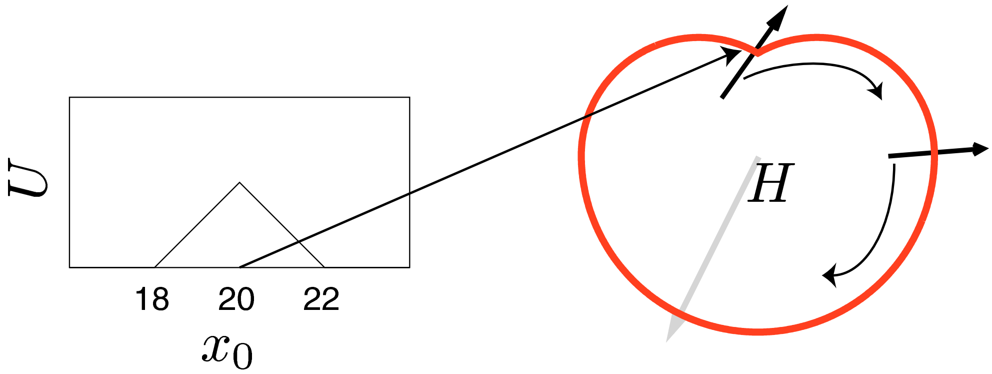
Measured Critical Currents

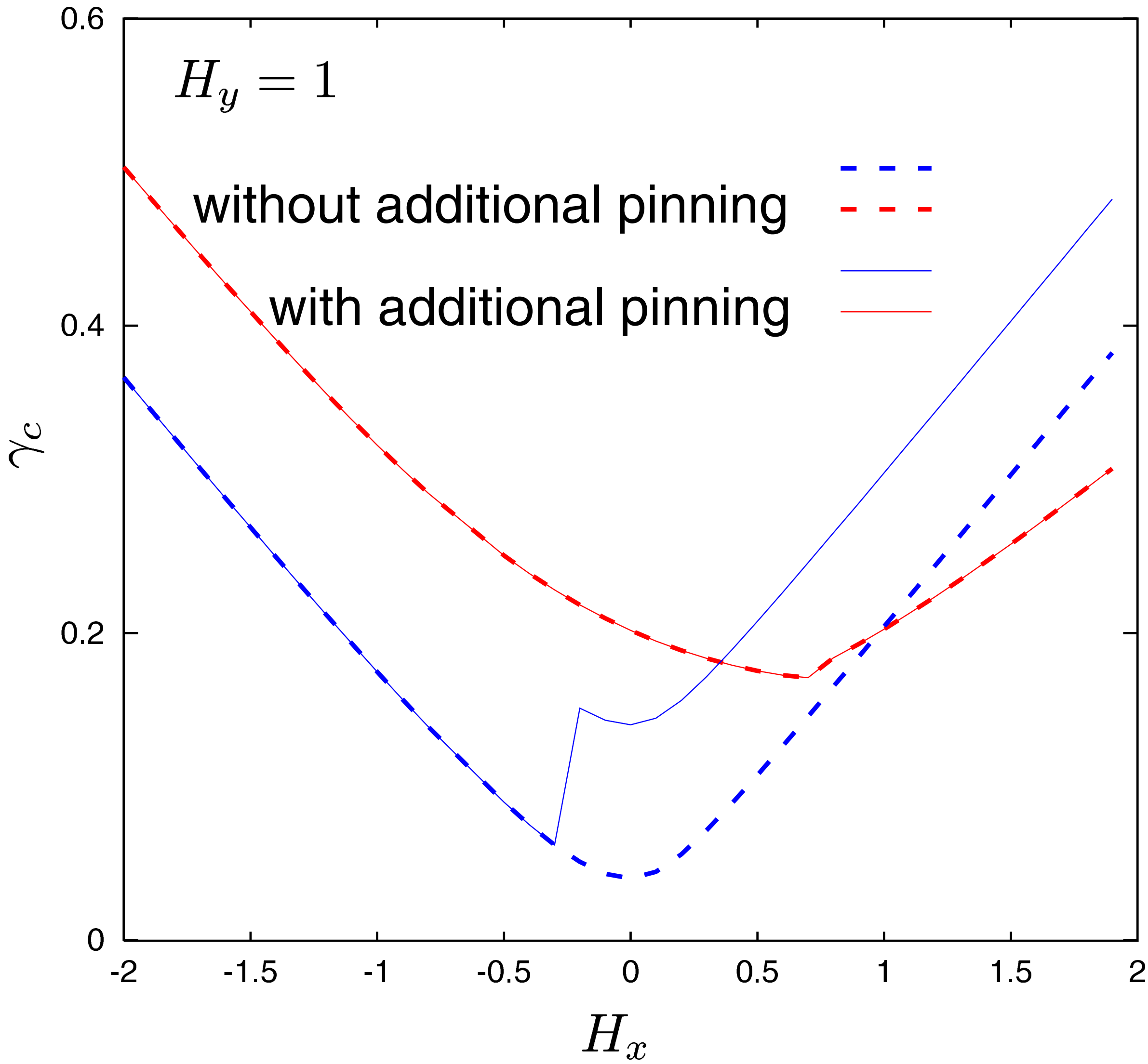
Critical currents are measured for constant $H_y \approx 0.14$ Oe against H_x.



Calculated Critical Currents

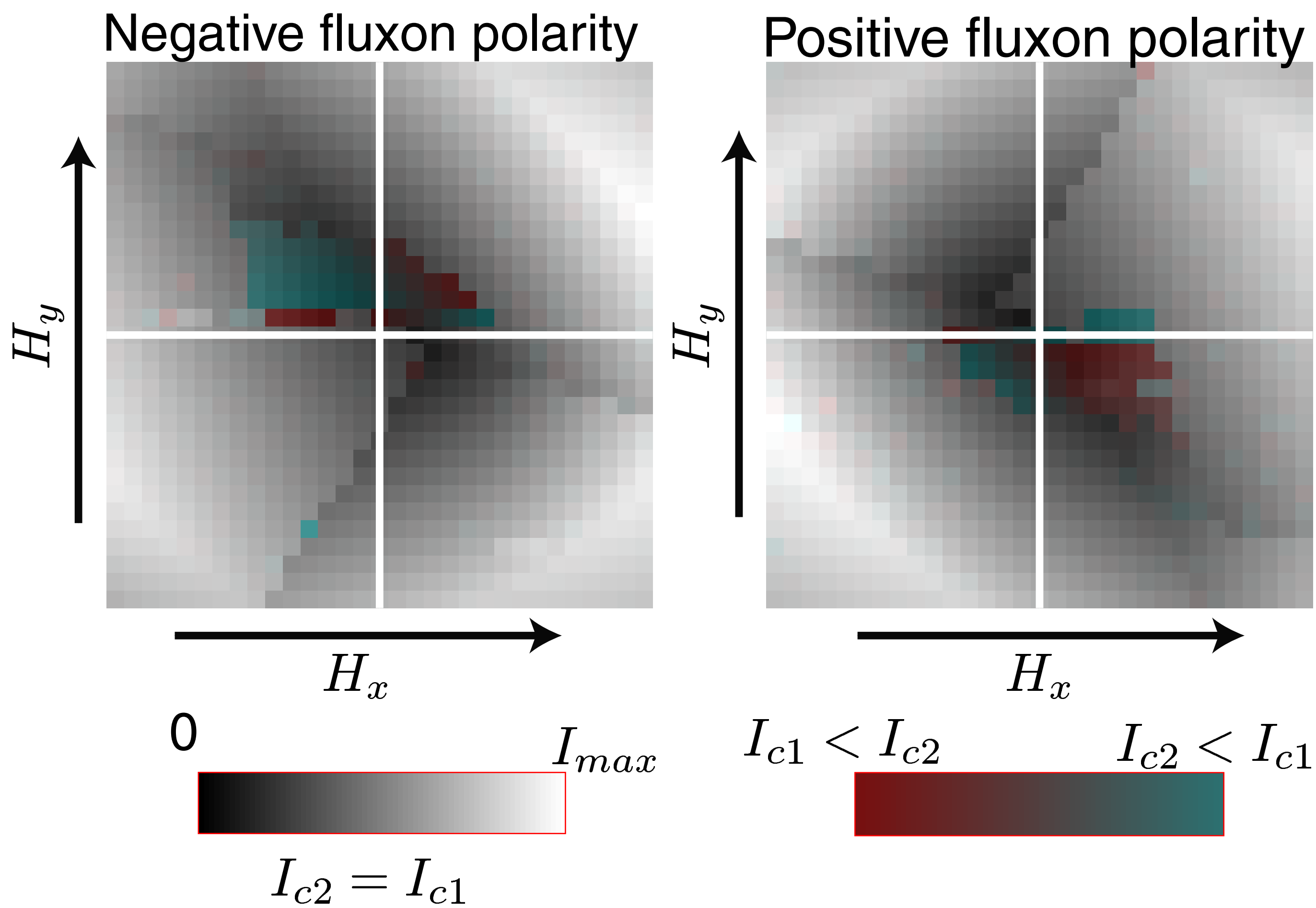
Adding a pinning potential at the shown position in the heart results in a better match with the experimental result.

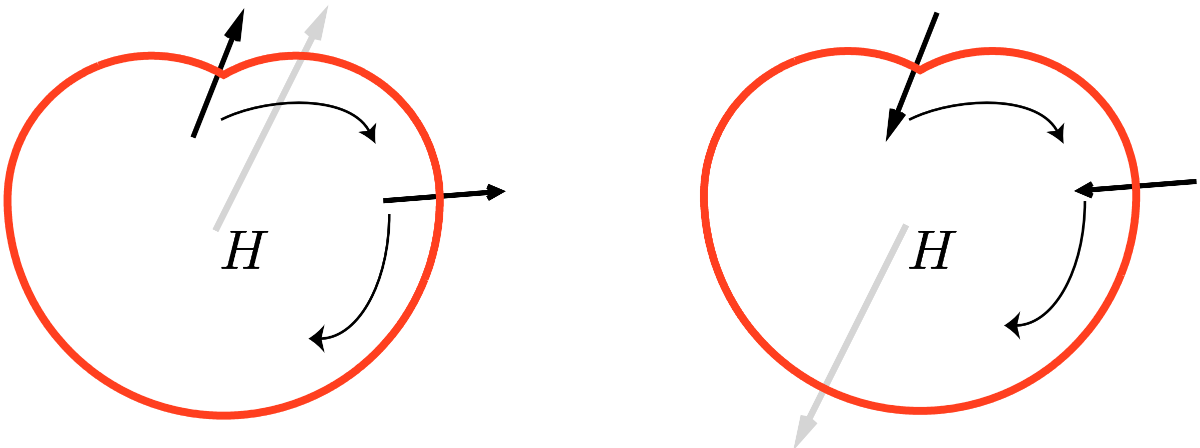




Fluxon Polaritity

Fluxon states of opposite polarity show symmetric $I_c(H_x, H_y)$-Patterns when biased in opposite current direction. The areas of multiple I_c-values in both patterns are found at opposite eld directions.





Summary

So far, we are able to

- show the existence of metastable states in long Josephson junctions.
- explain the features of the $I_c(H_x, H_y)$ pattern in terms of fluxon states.
- prepare fluxon states.

To be done

- calculation and examination of the additional pinning mechanisms (leads etc.) in the heart-shaped junctions
- measurement of thermal activation from metastable states
- experiments in the quantum regime (junction width $0.3\mu m$ or less [4])

[4]Narrow Long Josephson Junctions, Y. Koval, A. Wallraff, M. Fistul, N. Thyssen, H. Kohlstedt, A.V. Ustinov, Trans. Appl. Supercond.,9,1999,3957