Electrical Magnetic Vortex Core Polarity Read-out and Switching

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Motivations

Scientific Motivation

The magnetic vortex core at the center of a vortex is the smallest magnetic spin structure in soft magnetic materials.

The magnetic vortex comprises complex in-plane and out-of-plane magnetization.

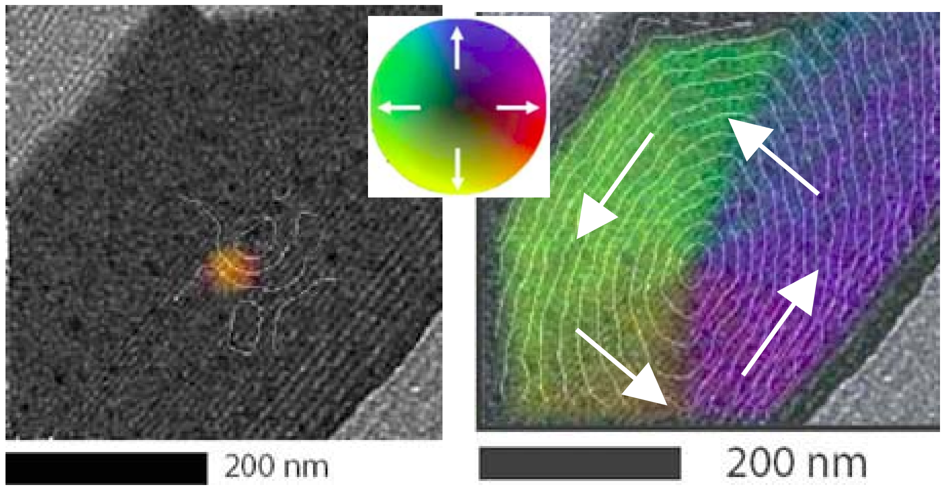
The switching time of the magnetic vortex core polarity (out-of-plane component) was shown to be about 20~40 ns.

Possible Applications

If we can read and change the polarity of the magnetic vortex core, it would be a new non-volatile memory device.

Magnetic Vortex States (Static Properties)

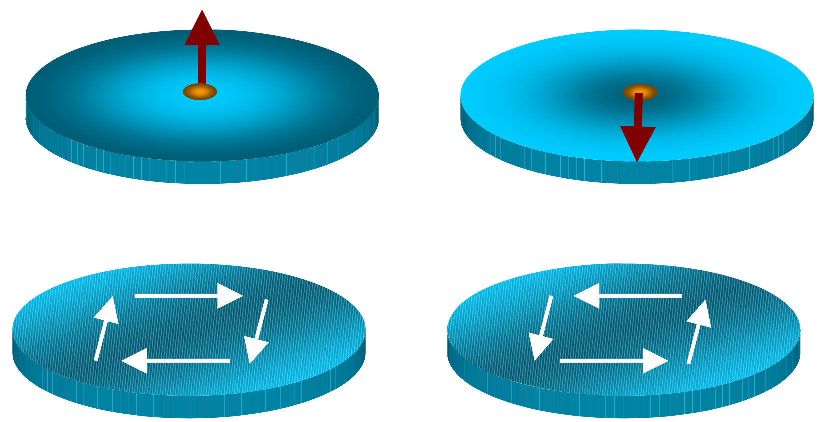
Imaging with high resolution electron holography



Out-of-plane vortex core In-plane magnetization

F. Junginger, M. Kläui et. al., APL 92, 112502 (2008).

4 Possible Configurations:



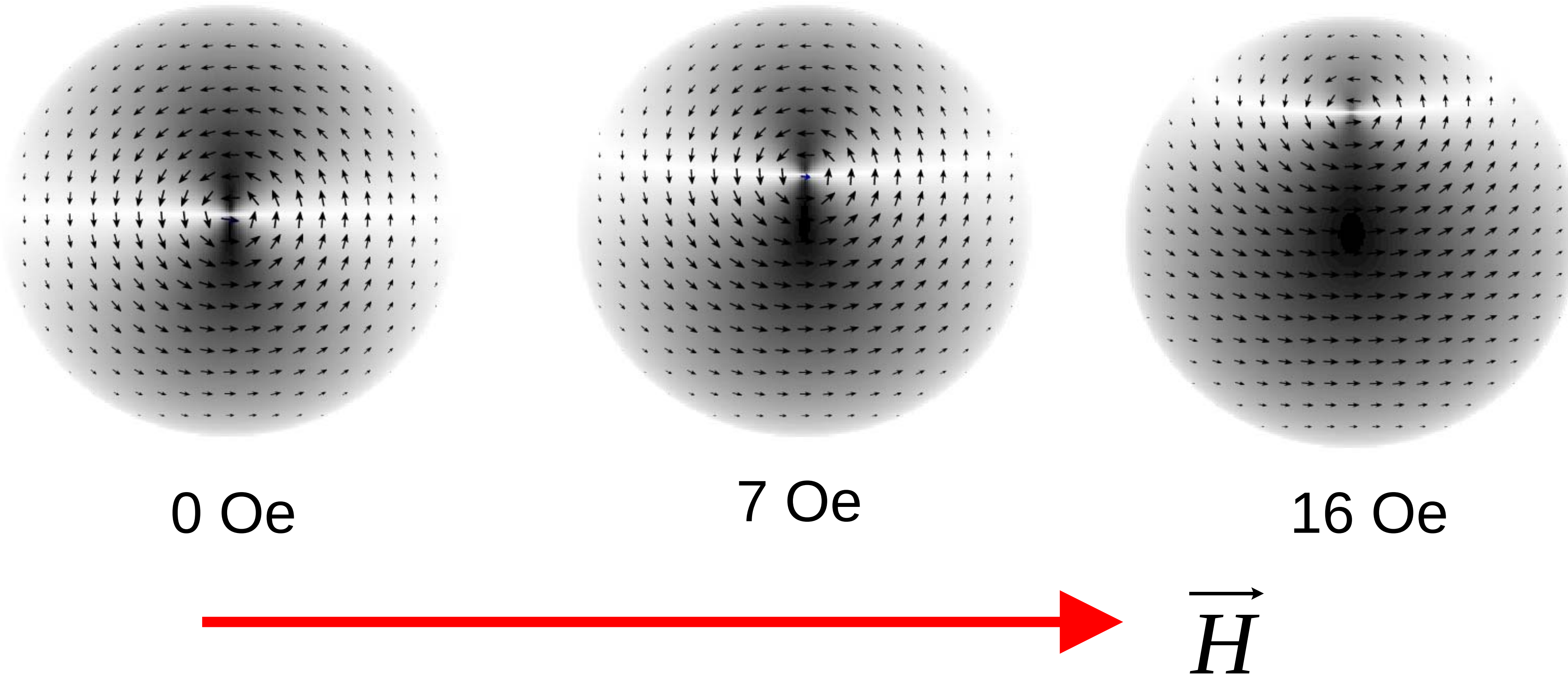
Out-of-plane

Core up / Core down

In-plane

Clockwise / Anticlockwise

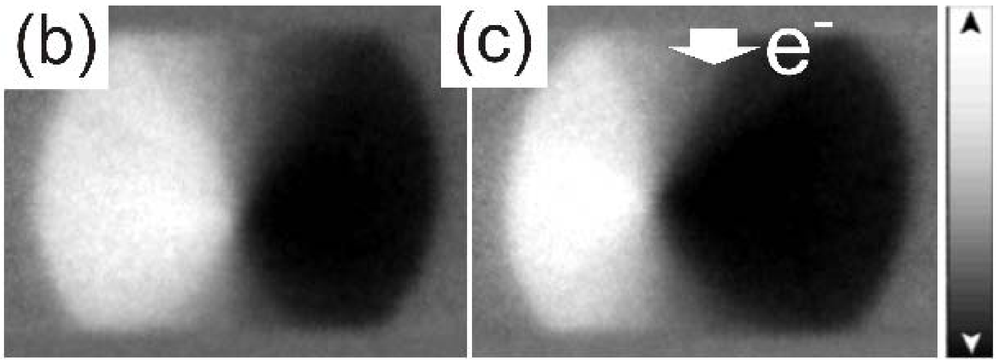
Magnetic Vortex States (Qusi-static Switching)



Due to the topology, vortex core is displaced perpendicular to external field.

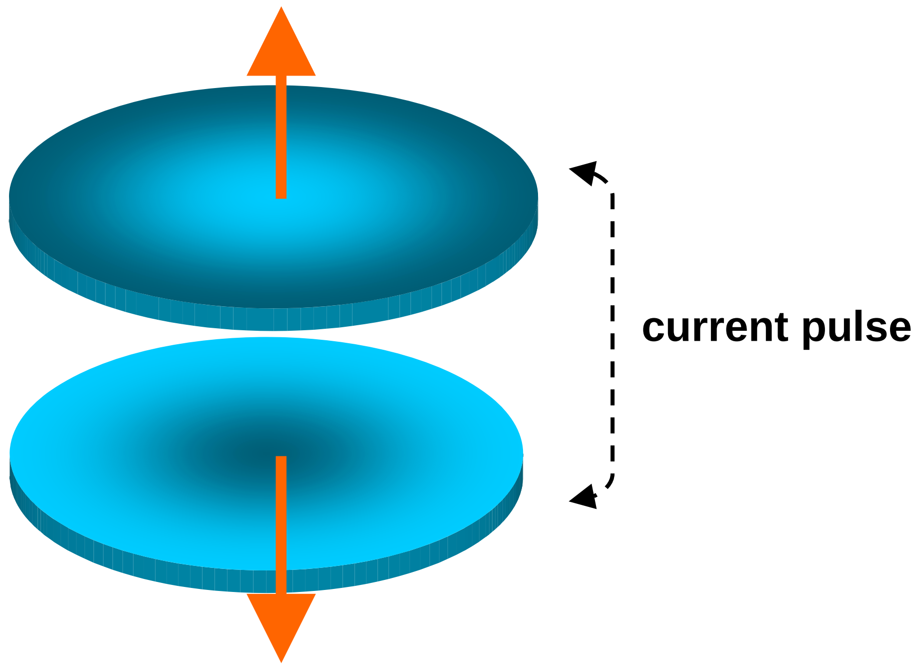
Dynamic Properties of Magnetic Vortex Core

Vortex core displacement due to a current pulse



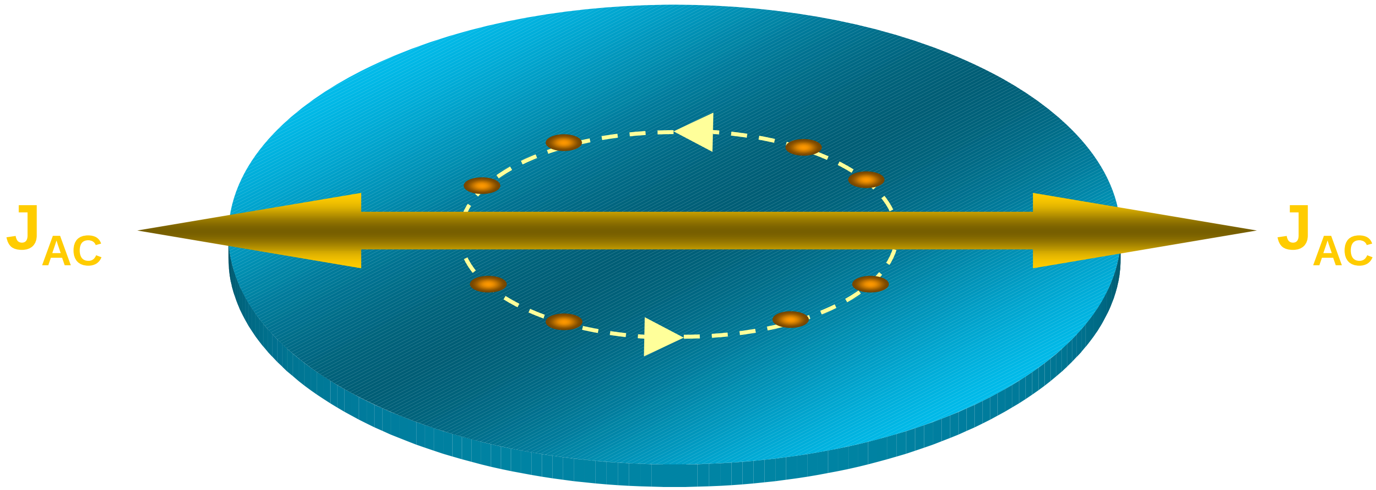
L. Heyne, M. Kläui et al., PRL **100**, 66603 (2008).

Vortex core polarity switching using a single current pulse



Keisuke Yamada, et. al., arXiv:0808.2858

Dynamic Properties of Magnetic Vortex Core

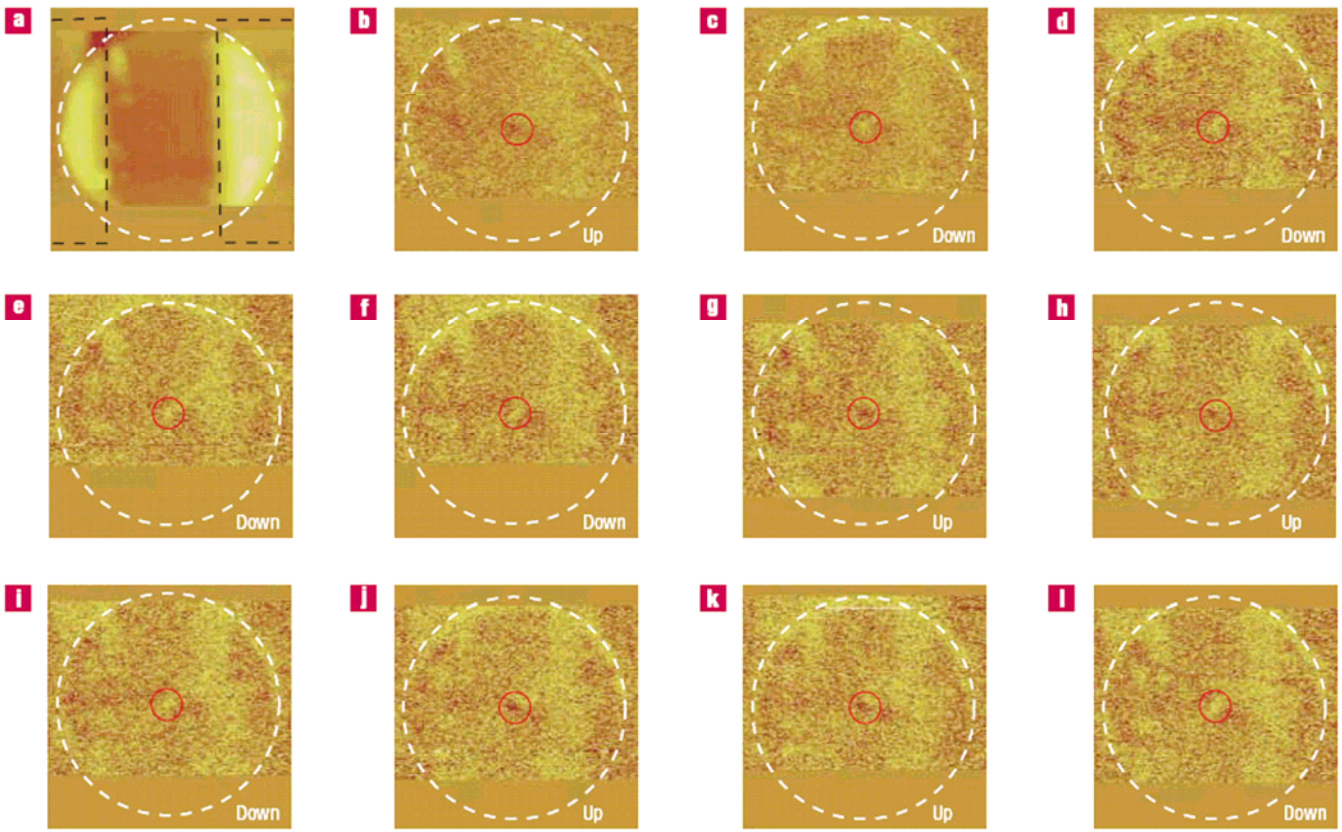


Excitations

Using AC fields or AC currents, vortex core gyration is excited:

Motion of vortex core on circular orbit around the centre of a disc.

Previous Results



$$f_{\text{experiment}}^{\text{resonance}} = 290\,\text{MHz}$$

KEISUKE YAMADA, *et al*.,Nature Phys. Vol 6, P 269 (2007)

AC current induced vortex core switching
Detection by MFM imaging is rather slow.

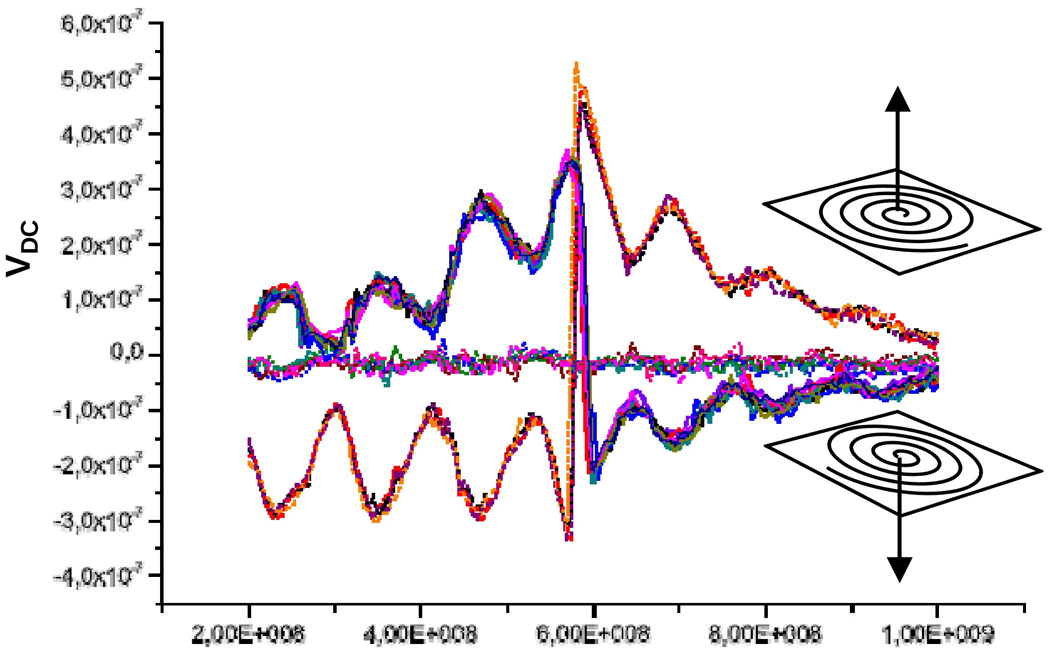
Homodyne Detection

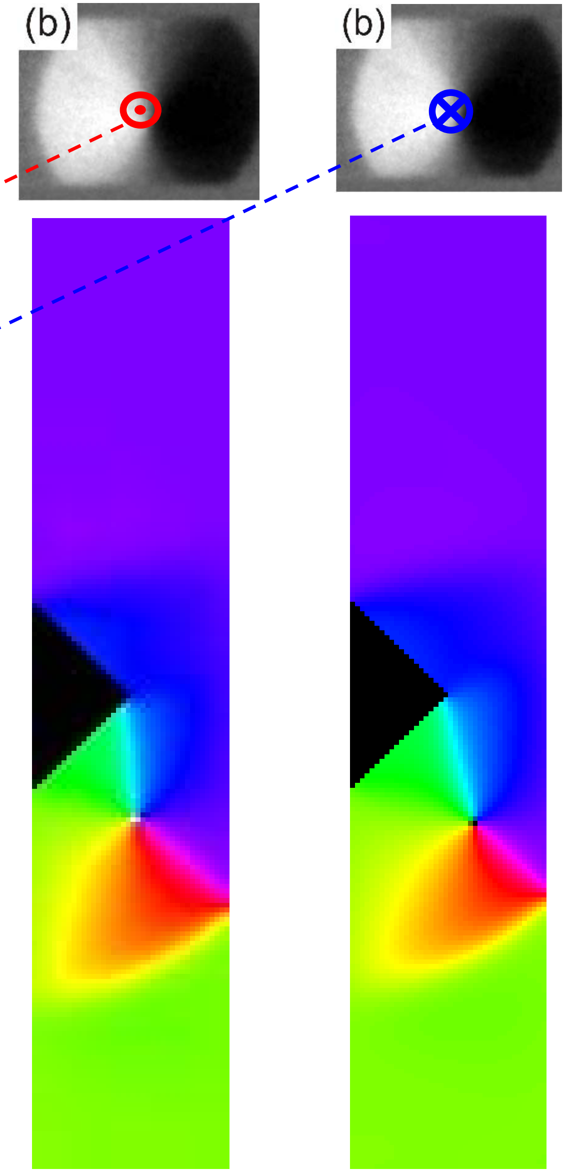
It is a better technique to measure the magnetic vortex core gyration and the polarity switching.

$$I = I_0 \cos(\omega t)$$

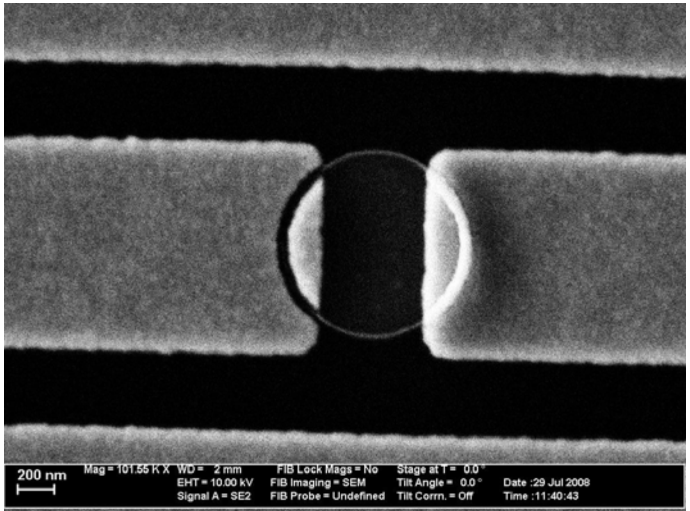
$$\Delta R(\omega) = R_0 \cos(\omega t + \chi)$$

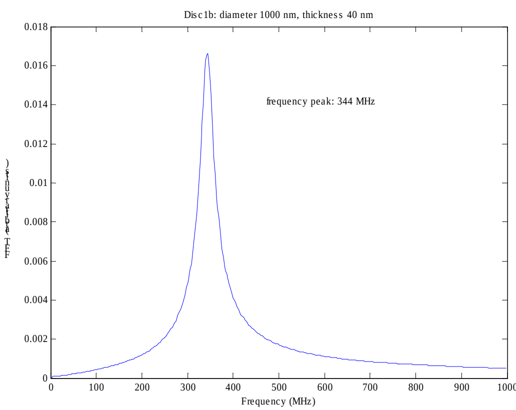
$$V_{DC} = I_{AC} \frac{\Delta R(\omega)}{2} \cos(\chi), \quad \chi = \text{phase shift}$$



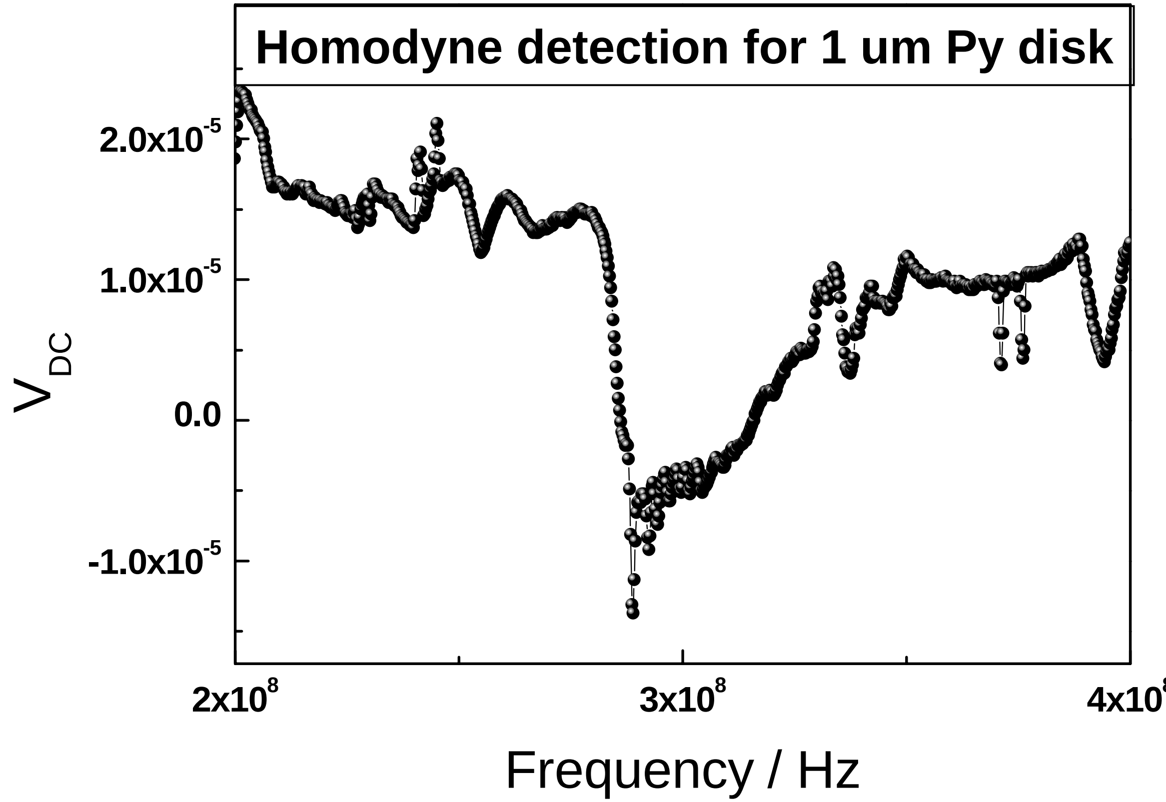


Homodyne Detection of VC resonance in a disc





$$f_{\text{simulation}}^{\text{resonance}} = 344\,\text{MHz}$$



$$f_{\text{experiment}}^{\text{resonance}} = 286\,\text{MHz}$$

Reasonable agreement of resonance frequency

Summary

1. We can detect the resonance frequency of the magnetic vortex core gyration by measuring the DC response (homodyne detection).

2. Homodyne technique is very fast to measure the exact the vortex core polarity.

3. In a next step the vortex core polarity switching due to pulses or AC excitations will be probed.

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Thank you for your attention!