Dynamic Quasi-Particle Behaviour of Geometrically Confined Domain Walls

Universität Konstanz

Magnetische Materialien
Magneto- und Spinelektronik

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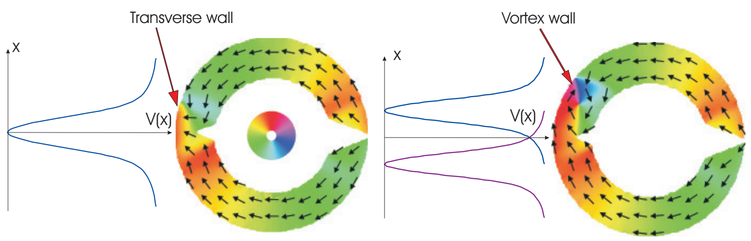
MA 20.64

Motivation

- A magnetic domain wall (DW) is a spatially localized variation of magnetization inside a magnetic structure.
- Depending on the lateral dimensions and material properties, two types of domain-walls appear in thin films, which are topologically not equivalent [1]: Vortex- and transverse walls.
- Domain walls behave like particles with a finite (inert) mass: The inert mass is being caused by a contraction of the DW during motion [2].
- Domain walls will interact with magnetic fields and can be manipulated with electrical currents due to several different mechanisms (momentum transfer / spin transfer /
- Oersted field/ hydromagnetic force) [3].
- The shape of a magnetic element will form a potential landscape for DWs due to the change in energy of a wall at different positions (e.g. structure width).
- Nanoconstrictions will cause a potential V which might be attractive (transverse wall) or repulsive (vortex wall):

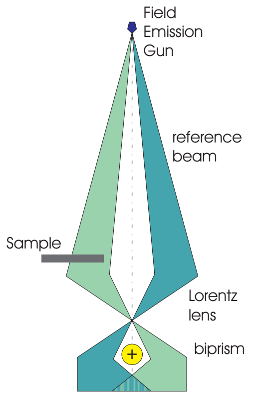


- Transverse walls are attracted by a constriction while vortex-walls are repelled by the constriction.
- In the case of spatial symmetry around the minimum the potential V can be calculated from the cycle duration T for different energies E as for the classical anharmonic oscillator:

$$x(V) = \frac{1}{2\pi\sqrt{2m}} \int_0^V \frac{T(E)\mathrm{d}E}{\sqrt{U-E}}$$

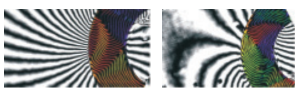
Imaging of DW in Constrictions

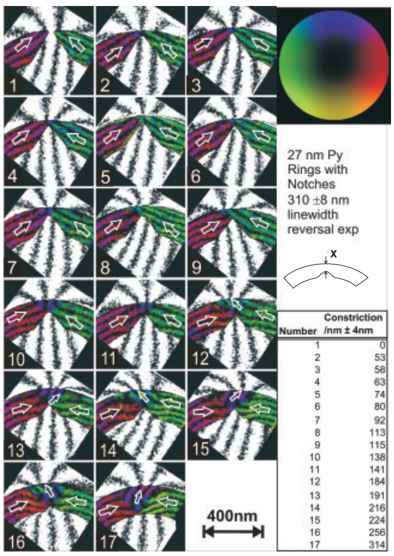
- PEEM (for results see **MA 20.117**), SEMPA, electron holography



Operating principle of electron holography:

- An electron beam is split into a signal and a reference beam.
- The signal beam passes through the sample.
- The biprism causes the beams to interfere on a screen.
- After considereble computation the field distribution can be obtained.
- The images below show the two different domain wall types.

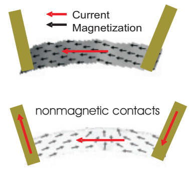




Number	Constriction /nm ± 4nm
1	0
2	53
3	58
4	63
5	74
6	80
7	92
8	113
9	115
10	138
11	141
12	184
13	191
14	216
15	224
16	256
17	314

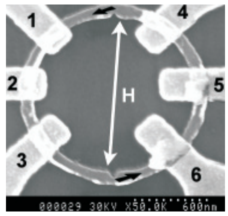
- Electron holographic image series showing domain walls in constrictions of different sizes.
- The smaller the constriction width x the smaller the domain wall.
- The insert shows the direction of the magnetic field.

Determination of the Potential Landscape

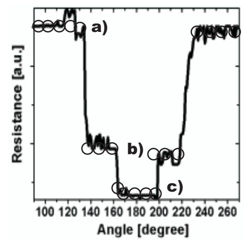


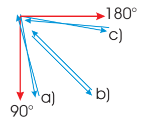
No domain wall between contacts: Magnetization parallel to the current ⇨ high resistance due to (A)MR.

Domain Wall between contacts: Magnetization perpendicular to the current: ⇨ low resistance [4].

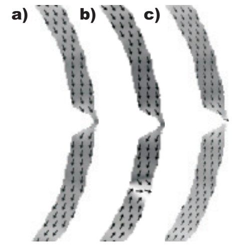


- Ring geometry: diameter = 0.5-2 μm, width = 100-300 nm
- Nonmagnetic contacts (10 nm Ti, 100 nm Au), fabricated by lift-off technique

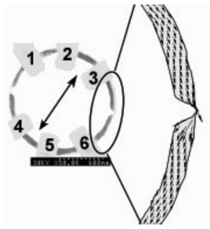




Direction of the external magnetic field for the three configurations



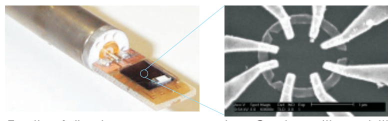
- Resistance measurements at remanence after saturation along different directions.
- Three distinct resistance levels are observed corresponding to the configurations a), b), c).
- The attractive potential well of the notch extends far beyond the physical dimensions [5].



- Simulation of the AMR signal by calculating the current distribution and magnetization configuration.
- Experimental and calculated resistance between contacts 3 and 6 shows a drop as the domain wall is pinned at the notch [5].
- By measuring the resistance the position of the domain wall with respect to the constriction can be determined.

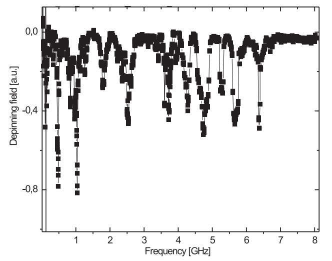
Microwave Excitation of DW in Rings

- For the following measurements the DW resistance has to be measured while injecting an RF field The rings will be positioned in the H-field maximum of a coplanar waveguide while measuring the resistance using several nonmagnetic contacts. The sample can be cooled down to about 2 K and is located inside a vector magnet which allows a rotation of the external magnetic field.

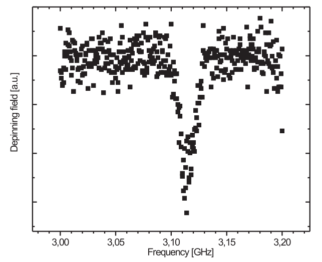


Sample holder:
The ferromagnetic ring is located on a coplanar waveguide fabricated from silicon.
The white square is a termination resistor.
Electrical contact is established through wire-bonding.

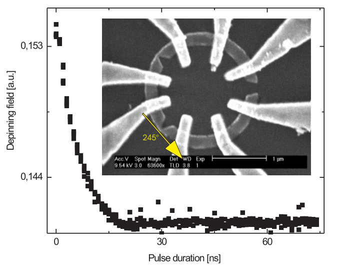
- For the following measurements a Co-ring with a width of 200 nm and an outer diameter of 2 μm has been used. The film thickness is 30 nm.



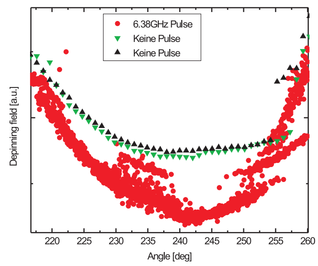
Depinning field as a function of microwave frequency. At resonance the field necessary is reduced by 15% .



Detail from the left figure. FWHM of the resonance line is about 10 MHz.



Depinning field at the resonance frequency 6.38 GHz as a function of microwave pulse duration.



Depinning field as a function of the angle of the external field. At an angle of 245° the field needed for lifting the DW out of the potential well is minimal because the field is perpendicular to the DW.

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