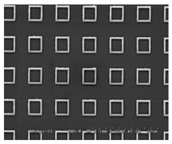
Diffracted MOKE: A New Tool for Nanomagnetism

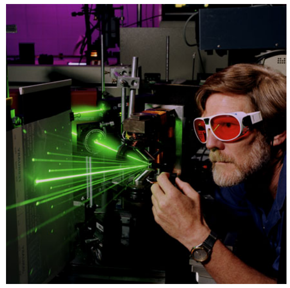
M. Grimsditch, V. Novosad, Mat. Sci. Div., ANL, P. Vavassori, Physics Department, Univ. Ferrara
V. Metlushko, Dep. of Electrical and Computer Engineering, UIC, Chicago.

Motivation: Novel lithographic techniques for fabrication of nanostructured materials has made it necessary to develop new tools for their characterization.

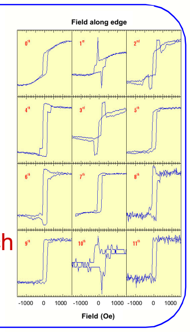
Lithographic techniques allow the fabrication of arrays of elements of any shape. Shown is an array of square Permalloy rings.

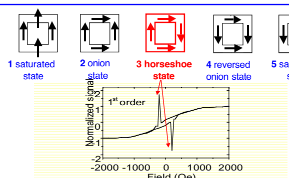


A laser beam incident upon a patterned array is diffracted as illustrated. In such cases it is possible to perform Magneto Optic Kerr Effect measurements (MOKE) on the diffracted beams.

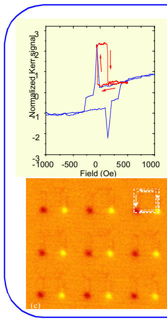


The Diffracted MOKE loops have unusual and sometimes striking shapes.
Their shapes can be traced to the various Fourrier components of the magnetization in each element.





In the case of rings the loops can be understood as due to the formation of a 'horseshoe' state. This state is generated by small asymmetries in the rings.



Asymmetric loops can be used to trap the rings in the horseshoe state and they can then be observed directly with MFM techniques.
When the field is applied along the diagonal we find that a vortex state is generated.

Theory

The electric field in the nth order diffracted beam is.

$$E^n_d \,\alpha\, E_o\,(r^o_{pp}\, f_n^{\,s} + r^m_{pp}\, f_n^{\,m}).$$

r_{pp} is the Fresnel coefficient.
The form factors are:

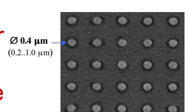
$$f_n^{\,s} = \int_S \exp\{i\, n\, G\ \ r\}\, dS$$

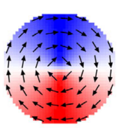
$$f_n^{\,m} = \int_S m_y \exp\{i\, n\, G\ \ r\}\, dS$$

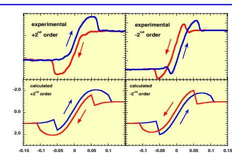
The resulting D-MOKE intensity is

$$\Delta I_n^d \,\alpha\, \mathrm{Re}[f_n^{\,m}] + A_n \mathrm{Im}[f_n^{\,m}]$$

In an array of circular dots we found that positive and negative diffraction orders were not equivalent. This was traced to the creation of a vortex state.

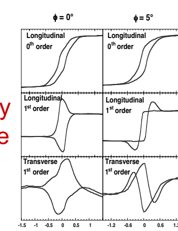






The combination of the above theory and micromagnetic simulations allows the loops to calculated and traces the origin of he left-right asymmetry to the chirality of the vortex.

In an array of elliptical holes, D-MOKE shows that the magnetization reversal path is strongly dependent on the angle that the applied field subtends with the ellipse axes.



In summary:
D-MOKE is a powerful, easy to use and nondestructive technique to characterize magnetic nanostructures.

Future Directions:
Having developed the experimental techniques and the theoretical interpretation the technique can now be used to investigate the properties of nanoarrays that might be suitable for the next generation of magnetic memory.

M. Grimsditch, P. Vavassori, V. Novosad, et. al., "Metastable states during magnetization reversal in square Permalloy rings", Phys. Rev. B, 67, 134429 (2003)

BES - DOE

This work was supported by the U. S. Department of Energy, Basic Energy Sciences, under contract W-31-109-ENG-38.

MSD - ANL