应用表面物理国家重点实验室
State Key Laboratory of Surface Physics

Direct imaging antiferromagnetic domains and dynamic switching in thin films by magneto-optical birefringence effect

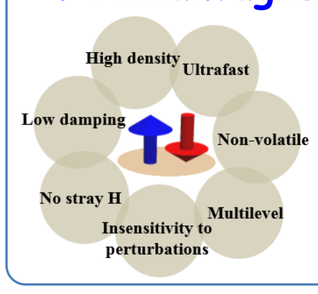
Jia Xu[1], Chao Zhou[1], Mengwen Jia[1], Dong Shi[1], Changqing Liu[1], Haoran Chen[1], Gong Chen[2], Guanhua Zhang[3], Yu Liang[3], Junqin Li[4], Wei Zhang[5*], Yizheng Wu[1*]

[1]Department of Physics and State Key Laboratory of Surface Physics, Fudan University, Shanghai, China
[2] Department of Physics, University of California, Davis, California, USA
[3] State Key Laboratory of Molecular Reaction Dynamics, Dalian Institute of Chemical Physics, Chinese Academy of Sciences, Dalian, Liaoning, China
[4]Shanghai Synchrotron Radiation Facility, Zhangjiang Laboratory, Chinese Academy of Sciences, Shanghai, China
[5]Department of Physics, Oakland University, Rochester, Michigan, USA

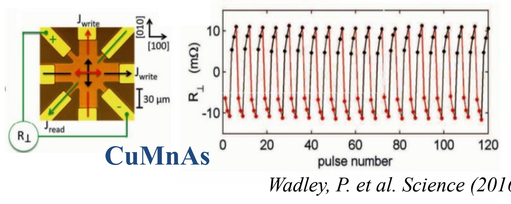
Introduction

AFM Spintronics

◆ Advantages



◆ In magnetic storage



Wadley, P. et al. Science (2016)

Microscopic scale?

AFM domain imaging

◆ XMLD-PEEM

Difficult to work with electric or magnetic field

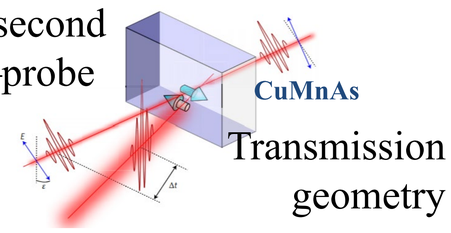
◆ MExFM & NV magnetometry

Require well-ordered, pristine sample surfaces

Optical imaging?

Birefringence effect

Femtosecond pump–probe

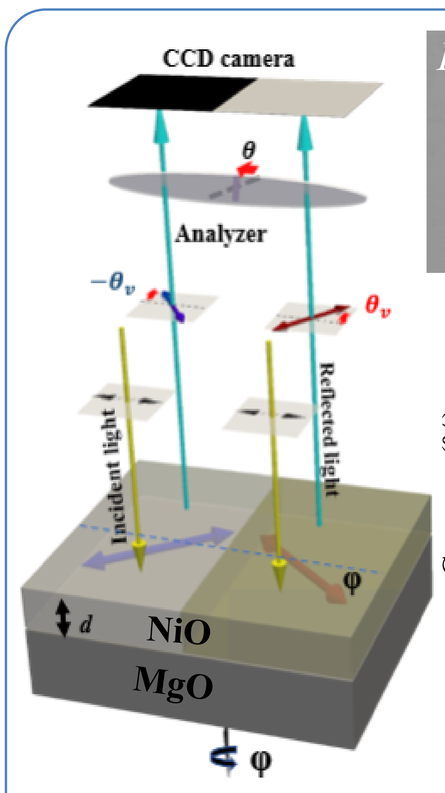


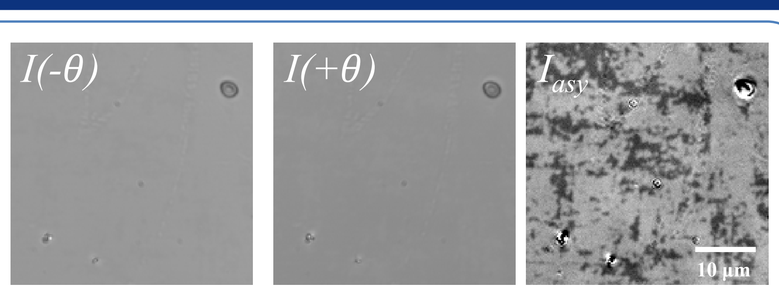
Transmission geometry

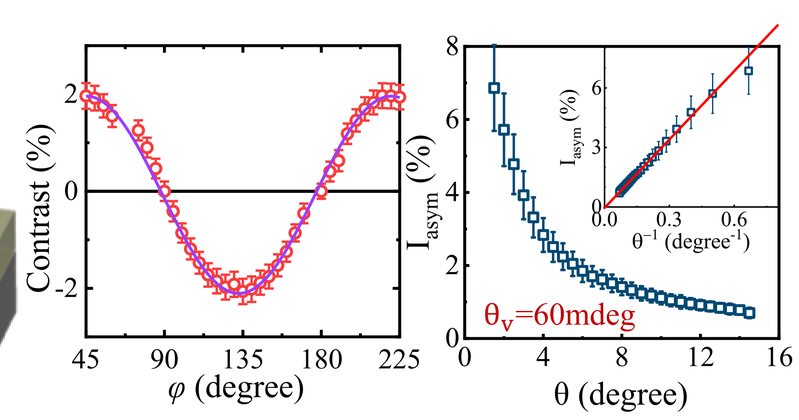
V. Saidl et al Nat. Photonics (2017).

General method?

Methods



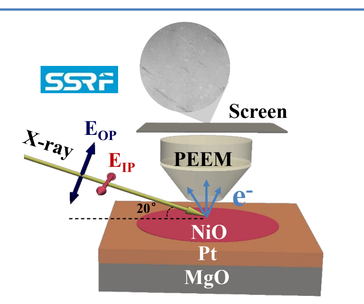


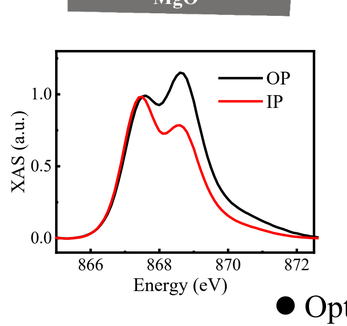


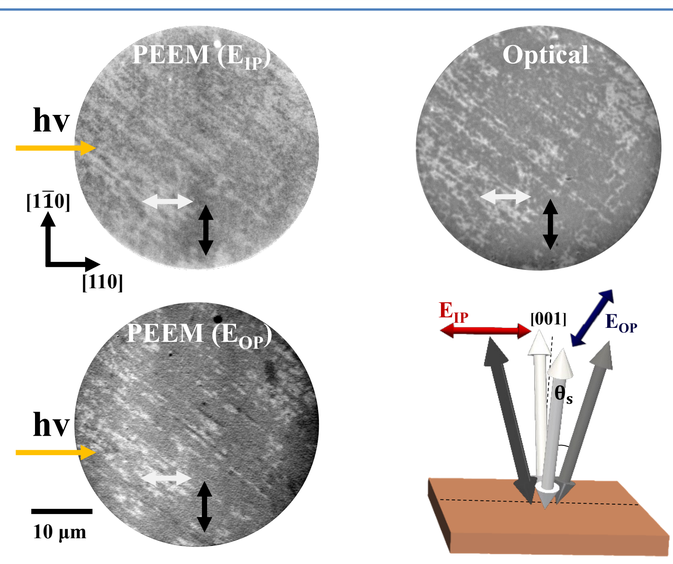
$$\text{Contrast} = \frac{r_{||}-r_{\perp}}{r_{||}+r_{\perp}} sin2\varphi \qquad \mathbf{I_{asym}} = \frac{I(+\theta)-I(-\theta)}{I(+\theta)+I(-\theta)} \propto \frac{2\theta_V}{\theta}$$

- We can observe the contrasts in NiO induced by the magneto-optical birefringence effect.
- A large polarization rotation angle of 60 mdeg is obtained .

Comparison with PEEM

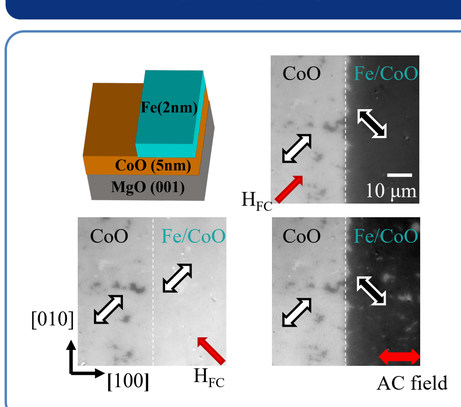




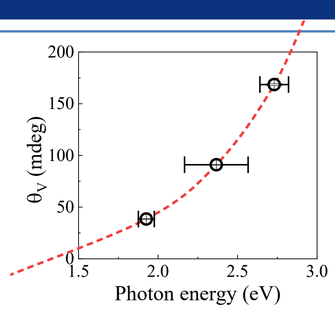


- Optical and PEEM images match well.
- Spin canting structure in NiO with $\theta_s \sim (10 \pm 2)^\circ$

Observe AFM domains in CoO

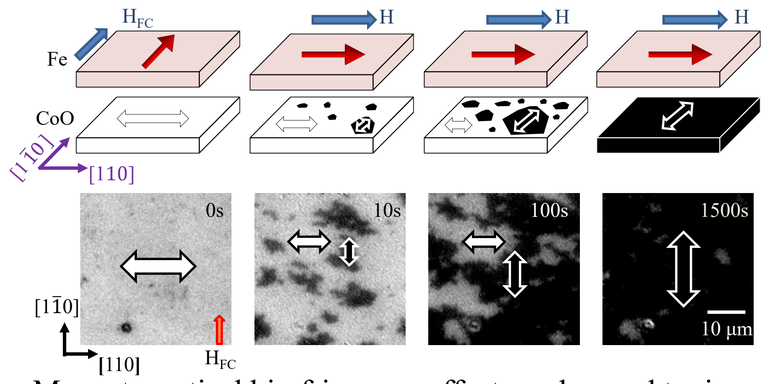


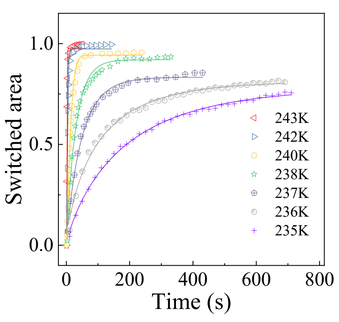
$$\frac{T_N(\infty)-T_N(d)}{T_N(\infty)} = \left(\frac{\xi_0}{d}\right)^{\lambda}$$



Strongly depend on the photon energy of incident light.

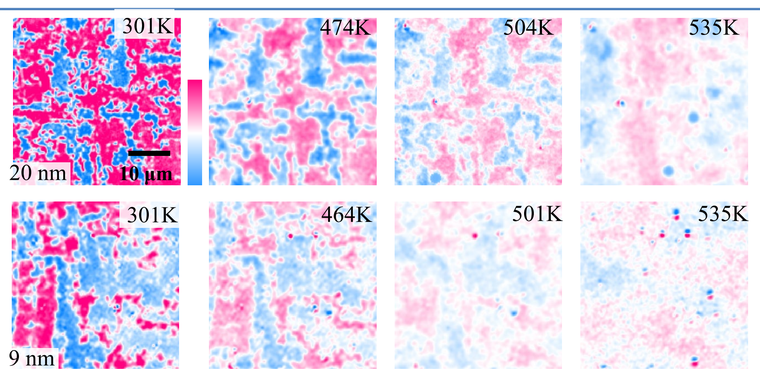
Dynamic switching in Fe/CoO

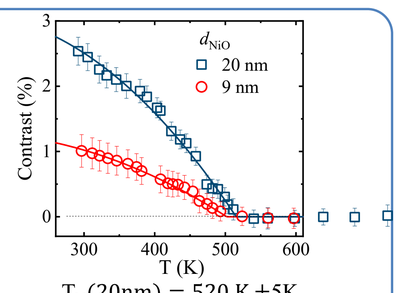




Magneto-optical birefringence effect can be used to imaging AFM domain under field.

Temperature dependence

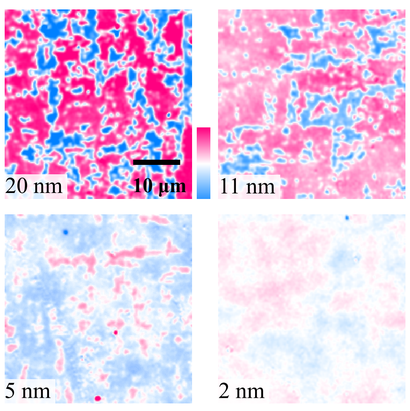


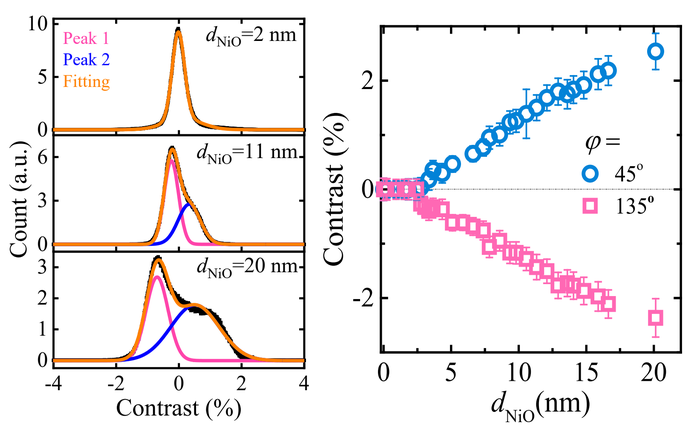


$T_N(20\text{nm}) = 520\ \text{K} \pm 5\text{K}$
$T_N(9\text{nm}) = 501\ \text{K} \pm 5\text{K}$

Mean-field theory $< M >^2$ behavior

Thickness dependence





40* 40μm^2

The contrast is linearly dependent on the NiO thickness.

Summary

- Optical birefringence effect can be used for imaging AFM domains.
- A new understaning of spin canting structure of NiO grown on MgO.
- Dynamic switching of CoO AFM domain under field can be observed.