Surface magneto-optic Kerr effect

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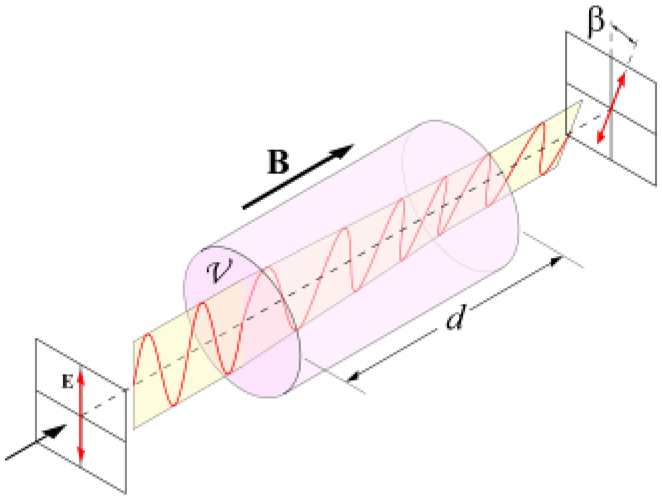
Faraday effect

$$\beta = \nu B \mathrm{d}$$



β is the angle of rotation (in radians)
B is the magnetic flux density in the direction of propagation (in teslas)
d is the length of the path (in meters) where the light and magnetic field interact
ν is the Verdet constant for the material.

Linear polarized light------ superposition of a right- and a left- circularly polarized beam-----electrons in the material will be circular and create magnetic field----magnetic field will enhanced in one direction and diminished in the opposite direction-------one of the beams will be slowed down more than the other

If it is ferromagnetic material, β is proportional to magnetization M

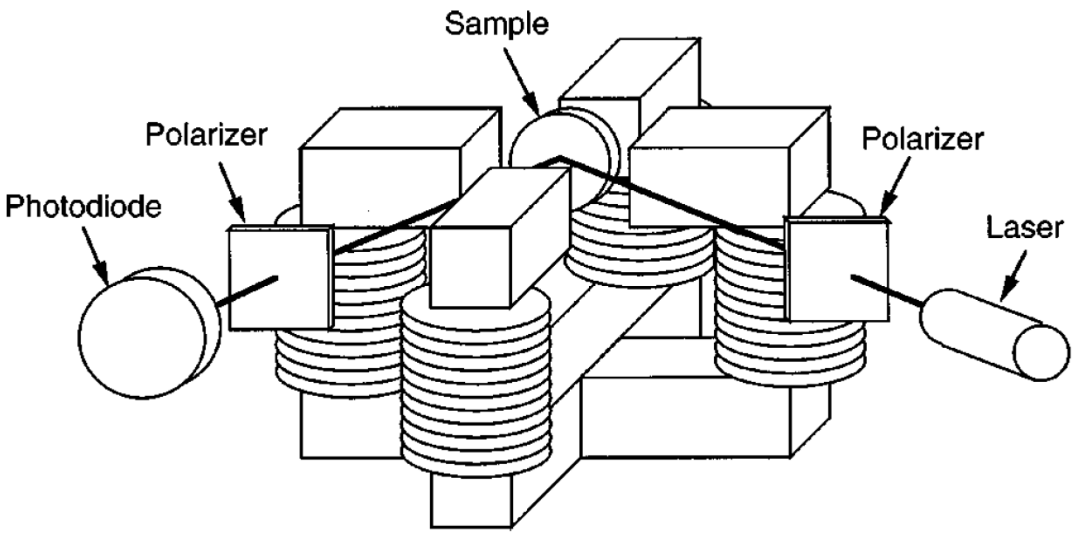
Surface magneto-optic Kerr effect (SMOKE or MOKE)

The Kerr effects are characterized by a complex rotation of the plane of polarization of linearly polarized incident light upon reflection from the surface of a ferromagnetic material.

The rotation is directly related to the magnetization of the material within the probing region of the light.

Light penetrates into metals >20 nm deep

SMOKE technique have the surface sensitivity as thin as one atomic layer.



Consider linear *p*-polarized light reflected from a sample surface.

$$E_{p0}$$

If the sample is ferromagnetic, then the reflection beam should consist of an *s* component (E_s) in addition to the dominant *p* component (E_p)

$$\frac{E_s}{E_p} = \phi' + i\phi''$$

ϕ' is the Kerr rotation and ϕ'' is the ellipticity

Experimentally, the measurement of the *s* component could be realized by placing a linear polarizer in front of the photodetector to eliminate the *p* component. But two disadvantages.

1. the photodetector measures the light intensity ($E_s{}^2$), the measured quantity is proportional to the square of the magnetization.
2. it is difficult to quantify the absolute value of the Kerr rotation.

usually p-polarized beam

$E_o\hat{p}$-----$E_o\beta\hat{s} + E_o e^{i\gamma}\hat{p}$

where β and γ are small numbers

$$\frac{E_s}{E_p} = \frac{\beta}{cos\gamma + isin\gamma} = \beta cos\gamma + i\beta sin\gamma$$

$$\phi' \sim \beta cos\gamma \sim \beta$$

$$\phi'' \sim \beta sin\gamma \sim \beta\gamma$$

$$\phi'' \ll \phi'$$

One way is to set the polarizer at a small angle(δ) from the p axis.(different from what we have in our lab)

$$I = \left|E_p sin\delta + E_s cos\delta\right|^2 \approx \left|E_p\delta + E_s\right|^2$$

Recall the expression

$$\frac{E_s}{E_p} = \phi' + i\phi''$$

$$I = \left|E_p\right|^2 |\delta + \phi' + \phi''|^2 \approx \left|E_p\right|^2 (\delta^2 + 2\delta\phi')$$

$$I = I_0(1 + \frac{2\phi'}{\delta})$$

where$I_0 = \left|E_p\right|^2 \delta^2$ means the intensity at zero Kerr rotation.

Since $\phi'$is linear proportional to the magnetization, so the measured intensity as a function of H yields the magnetic hysteresis loop.

You can also calculate the saturation Kerr rotation ϕ'_m by reversing a field which value is equal to or greater than its saturation value

$$\phi'_m = \frac{\delta}{4} \frac{I_{max} - I_{min}}{I_o}$$

In the MOKE system in our lab, we are using a 45 degree polarizer and measure both AC DC signal instead of the laser intensity itself, see Prof. Xu’s prestation https://xiaoshanxu.unl.edu/system/files/sites/unl.edu.cas.physics.xiaoshan-xu/files/private/2016_04_14_Xu_MOKE.pdf

Conclusion

The basic idea of Faraday effect which has the same physical mechanism with MOKE

A MOKE system that is a little different from what we have in our lab.