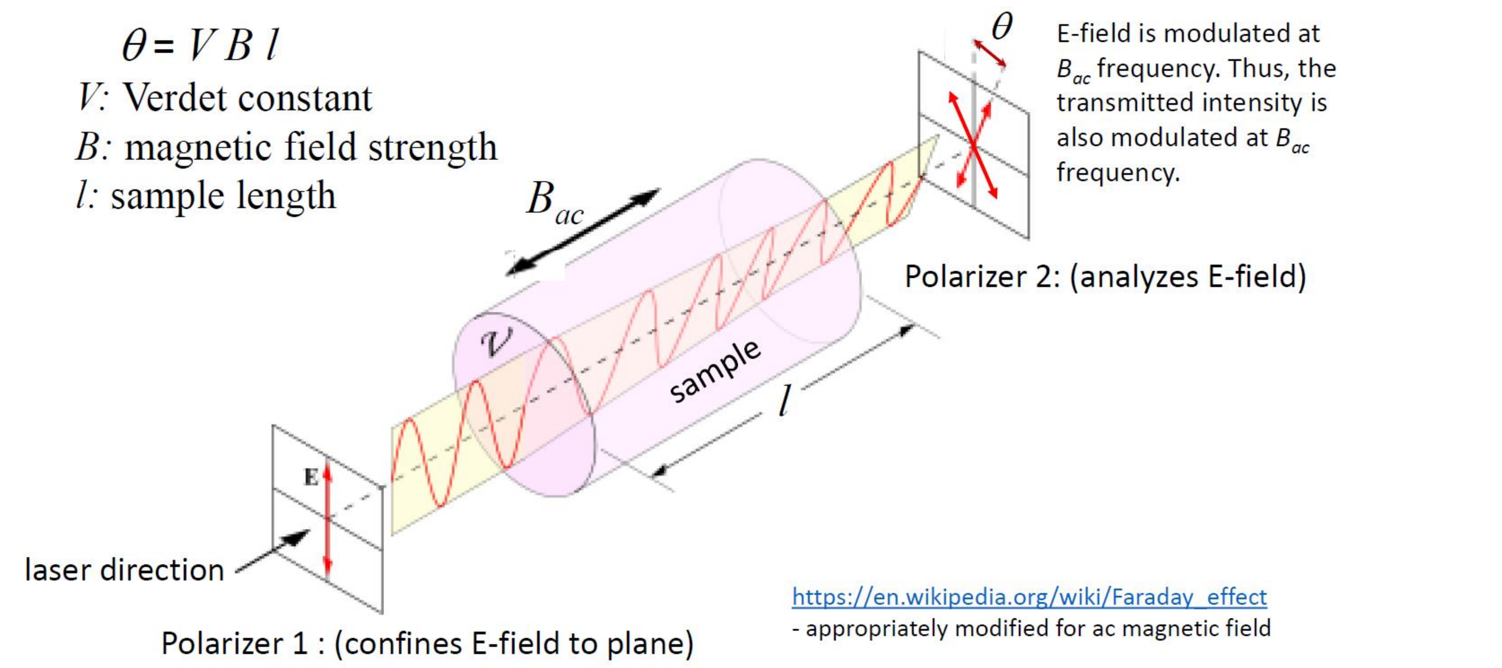
Introduction to the UNCP Magneto-Optical Facility

W.D. Brandon

Department of Chemistry and Physics

University of North Carolina - Pembroke

The **FARADAY EFFECT**, named for physicist Michael Faraday, is a magneto-optical phenomenon characterizing the rotation of the plane of polarization of light – a form of optical activity due to Zeeman splitting.



Applications (to name a few)

- optical- switches, rotators, circulators, isolators, modulators
- laser gyroscopes
- satellite altitude monitors
- sensors- magnetic field & electric current
- quantum computing
- characterizing astrophysical phenomena
- nonlinear quantum electrodynamics (photon interaction)
- search for dark matter (axions)

$\theta = V B l \rightarrow V(\lambda)$: spectral capabilities

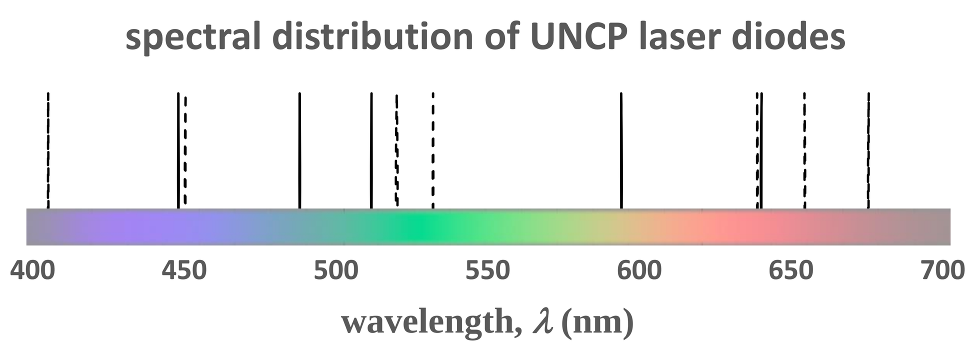
Laser Diodes (LD) – wavelengths shown in nm = 10^{-9} m

LD1: single diode (fixed)
488.0

LD2: triple diode (switch selectable)
448.0, 511.7, 640.3

LD3: single diode (fixed)
588.3

LD4: single diodes (interchangeable)
405.1, 448.1, 520.1, 532.0, 638.8, 654.4, 675.6

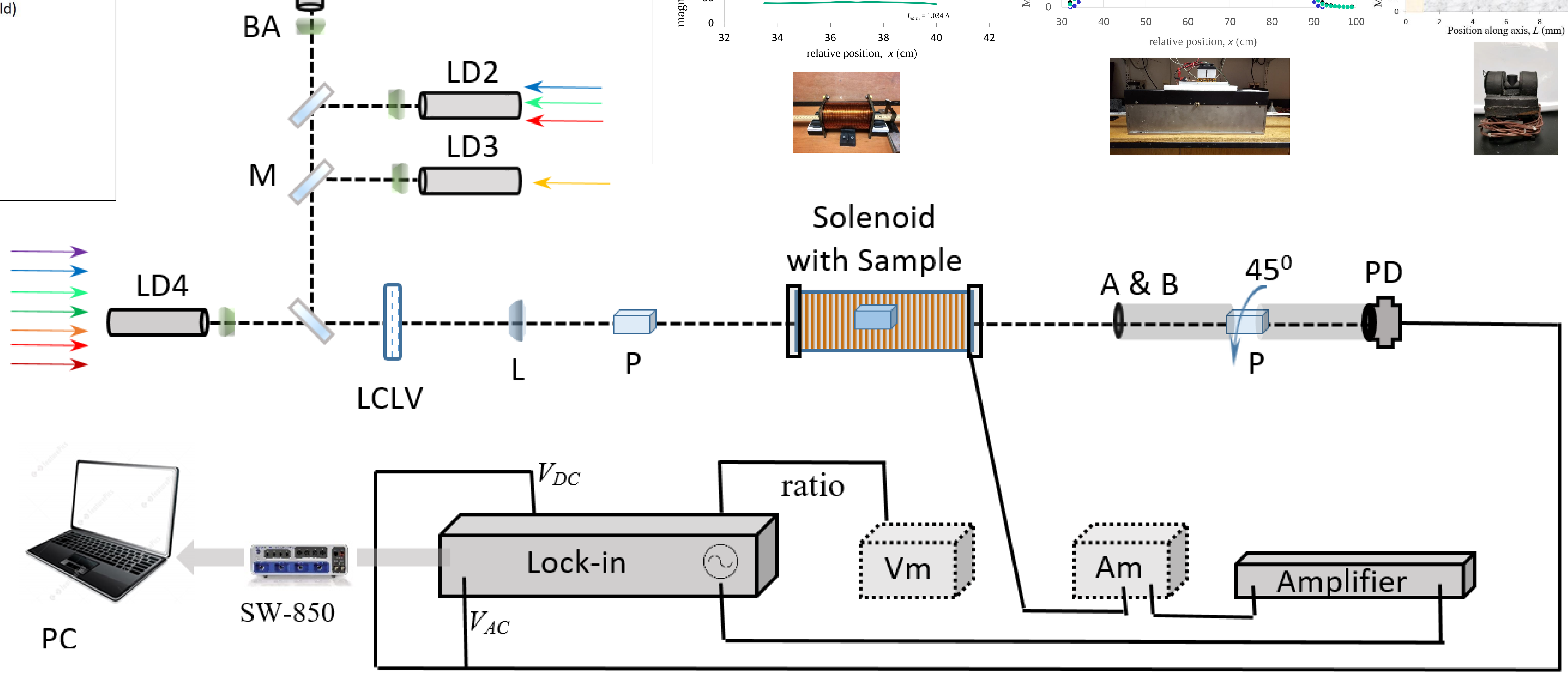


$\theta = V B l \rightarrow$ Faraday rotation, θ measurement using lock-in detection (PSD)

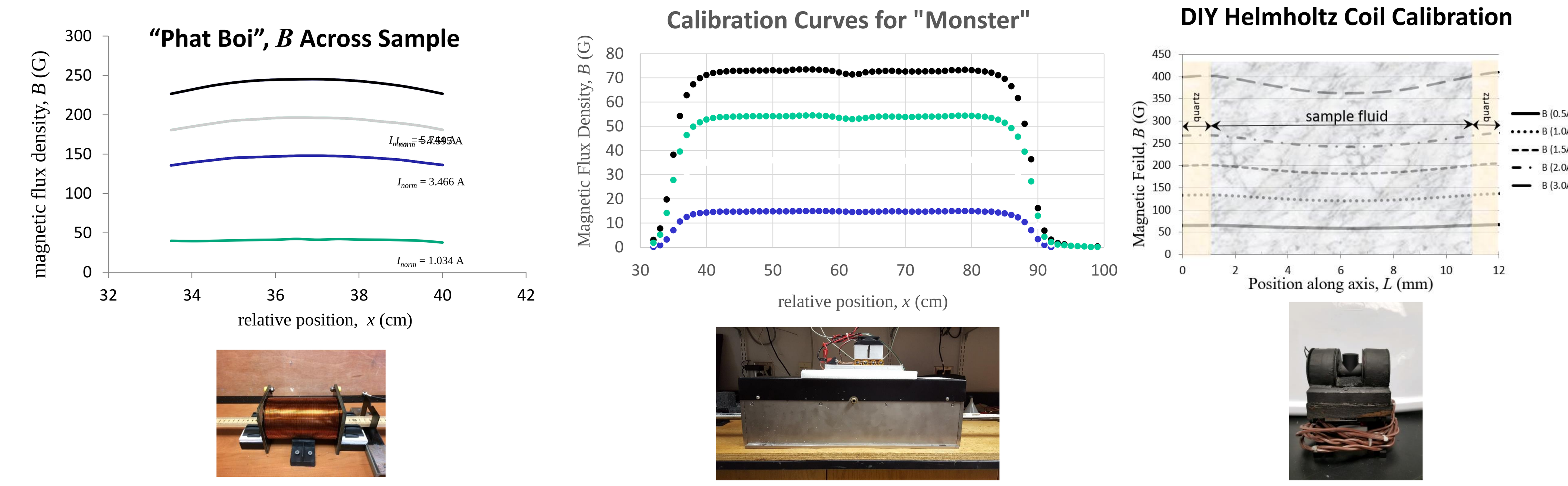
Lock-in amplifiers (LIAs) record an input signal as RMS volts. It can be shown that the rotation, in radians, induced by a modulating magnetic field, follows from the relations[1,2,3]

$$\theta = \frac{1}{2}\sin^{-1}\left(\frac{V_{AC}}{V_{DC}}\right) \sim \frac{V_{AC}}{2V_{DC}},$$

which are valid for the small rotations occurring in the UNCP-MO apparatus. The Verdet constant is extracted using measured quantities defined by a measured AC voltage signal, V_{AC}, a measured DC voltage signal, V_{DC}; both of these utilizing a lock-in amplifier. The magnetic flux density B, which is a function of the suppled current, I is obtained from the appropriate solenoid calibration along the sample of interest.



$\theta = V B l \rightarrow B(I)$ must be determined from appropriate **solenoid calibration** (three examples)



UNCP-MO Apparatus - Experimental Arrangement (above figure): LD-laser diodes with BA-beam attenuators, M-turning mirrors, LCLV-liquid crystal light valve, L-lens, P-crystal polarizer, A&B-aperture and baffle arrangement, PD-photodetector, Am-ammeter, Vm-voltmeter.

signal processing 1: Lock-in amplifier: SRS830-LIA [inputs: Aux-V_{dc} (avg. sig.), R- V_{AC} (PSD sig.), outputs: (~)- AC voltage & ref frequency, ratio = R/Aux = V_{AC} / V_{dc}, θ- phase], ⇐ - signal outputs for further processing - 2

signal processing 2: SW-850-Science Workshop 850 interface and PC with Capstone software

Data Analysis Utilizing Various Theories, via nonlinear curve fitting, characterizes the dispersion of the Verdet constant for samples of interest.

SG[4] → $V = \frac{\pi}{\lambda}\left(a + \frac{b}{\lambda^2 - \lambda_0^2}\right)$

BHL[5] → $nV = a\left\{\frac{1}{b}\left[(1-b)^{-1/2} - (1+b)^{-1/2}\right] - 1\right\}$

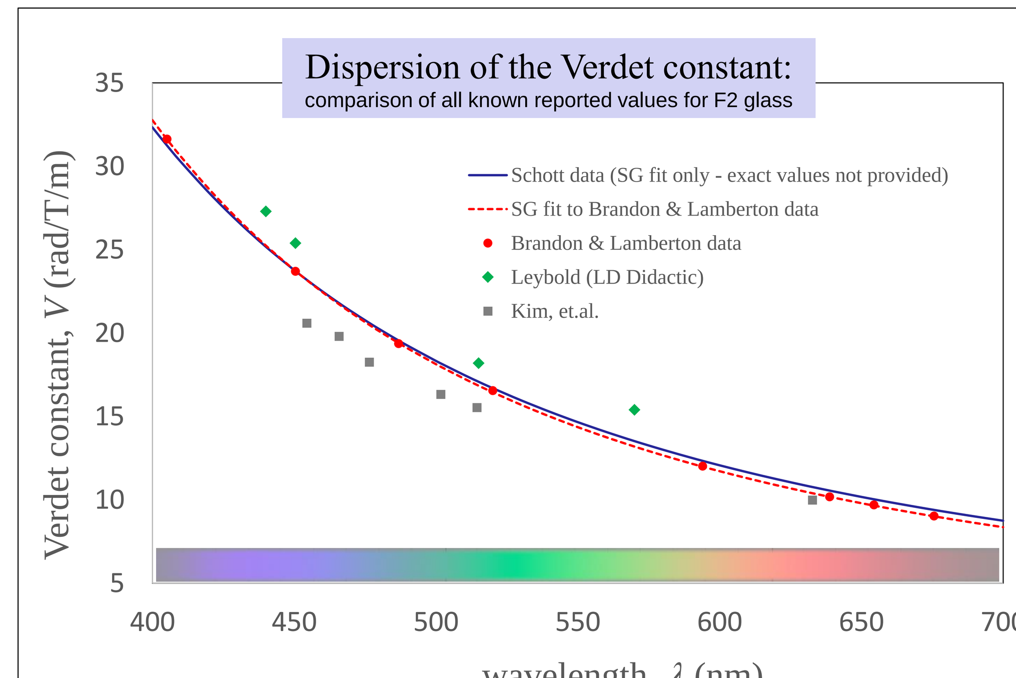
KLN[6] → $nV = a\left\{\frac{1}{b}\left[(1-b)^{-1/2} - (1+b)^{-1/2}\right] - \frac{4}{b^2}\left[2 - (1-b)^{1/2} - (1+b)^{-1/2}\right]\right\}$

SG[4] → a,b are fitting parameters, and λ_0 is the "mean resonance wavelength" obtained from the dispersion of the refractive index of the sample of interest.

BHL[5] → a,b are fitting parameters ($b = \lambda_g/\lambda$), n is the refractive index

KLN[6] → a,b are fitting parameters ($b = \lambda_g/\lambda$), n is the refractive index

Interestingly, an energy gap can be calculated from the fitting parameter, $b = \lambda_g/\lambda$ using the BHL and KLN theories according to $E_g = hc/\lambda_g$ (units: eV)



Initial Testing (Figure to the left). Verdet constant of F2 glass reported by four different sources. Our data (red circles), shown with SG fit (red line), is in **excellent agreement** with the Schott Glaswerke[4] group (blue line). The exact values for the Verdet constant were not reported by that group – only the fitting parameters were provided, from which the blue curve was generated. It appears that the Verdet constants reported by Leybold[7] are too high, whereas those reported by Kim, et.al.[8] are, for the most part, too low.

References:

1 - Jain, A. Kumar, J. Zhou, F. Li, L. *A simple experiment for determining Verdet constants using alternating current magnetic fields*. Am. J. Physics. 1999 67, 714-717.

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3 – V.K. Valev, J. Wouters, and T. Verbiest, *Precise Measurements of Faraday rotation using ac magnetic fields*. Am. J. Physics. 2008 76, 626-629.

4 – G. Westenberger, H.J. Hoffman, W.W. Jochs, and G. Przybilla, Schott Glaswerk, *The Verdet constant and its dispersion in optical glasses*. SPIE (1991) 1535

5 – I.M. Boswarva, R.E. Howard, and A.B. Lidiard, *Faraday effect in semiconductors*, Proc. Roy. Soc., **A269**, 125 (1962)

6 – J. Kolodziejzcak, B. Lax, Y. Nishina, *Semiclassical dispersion theory of interband magneto-optical effects,* Phys. Rev. **128**, 2655 (1962)

7 – LD Didactic GmbH, Faraday effect: Determining Verdet's constant for flint glass as a function of the wavelength. Physics Leaflets. P5.4.6.1

8 – S.Y. Kim, Y.H. Won, and H.N. Kim, *Measurement of the Faraday effect of a few optical glasses using a direct polarimetric method*. J. of appl. Phys. 1990 7026, 67