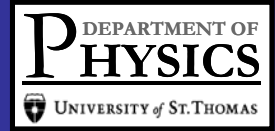


Polarimetric Characterization of Materials

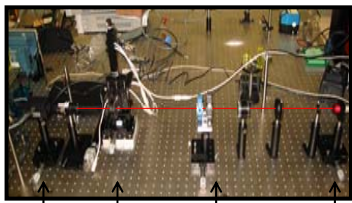
Jimmy Thielen, James Kavanaugh, Kyle Braun, and Dr. Adam Green



Introduction

We have constructed a semi-automated Mueller matrix polarimeter that is employed in a variety of optics experiments with interdisciplinary applications. This device comprises liquid crystal variable retarders and other high-quality polarization optics. We have written LabVIEW software that controls the apparatus and calculates Mueller matrices for nearly any target that we place in the system. These matrices contain complete information about the sample's polarization properties.

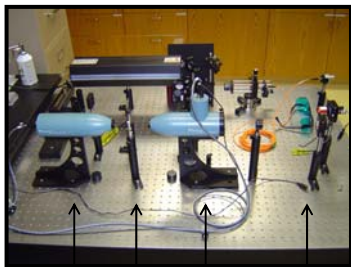
To compliment our homemade polarimeter and to expand our measurement capabilities, we have recently purchased a professionally manufactured polarimeter from Axometrics, Inc.



Homemade Liquid Crystal Mueller Matrix Polarimeter

polarization state analyzer sample holder on motorized x-y stage polarization state generator laser

- produces XY map of sample to display complete polarization properties across surface
- displays polarization diagram of light exiting the sample for all input states



Axometrics AxoScan™ Mueller Matrix Polarimeter

polarization state analyzer sample polarization state generator laser or white light source

- fast, high-precision measurements of Mueller matrices for entire visible spectrum
- sophisticated data reduction algorithms for extracting detailed information from matrices

What is a Mueller matrix?

A Mueller matrix describes how a material interacts with the electric field vector of light waves (polarization). This 4x4 matrix M is multiplied by a 4-component Stokes vector P_{in} , which indicates the light's polarization state before reaching the sample. After scattering from the target, the light is described by a new Stokes vector P_{out} :

$$P_{out} = M_{target} P_{in}$$

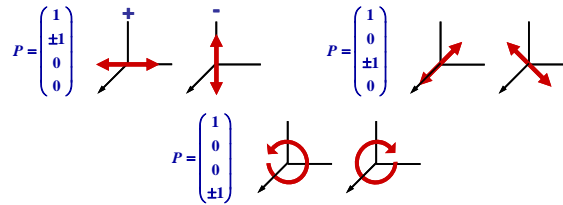
$$\begin{pmatrix} I' \\ P_1' \\ P_2' \\ P_3' \end{pmatrix} = \begin{pmatrix} M_{11} & M_{12} & M_{13} & M_{14} \\ M_{21} & M_{22} & M_{23} & M_{24} \\ M_{31} & M_{32} & M_{33} & M_{34} \\ M_{41} & M_{42} & M_{43} & M_{44} \end{pmatrix} \begin{pmatrix} I \\ P_1 \\ P_2 \\ P_3 \end{pmatrix}$$

output target input

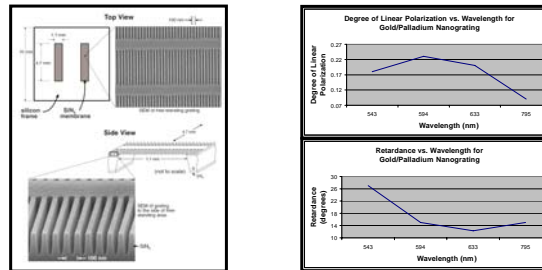
Stokes Vector

I ← Intensity
 P_1 ← Linear Polarization
 P_2 ← Linear Polarization
 P_3 ← Circular Polarization

The following six pure states are used to describe light's electric field vector. All other states are linear combinations of these.



Metallic Nanogratings as Potential Linear Polarizers for Visible Light



The graphs show that this particular nanograting with a gold/palladium coating does not act as a good linear polarizer; nor does it act as a good retarder. The former result is unexpected. However, we have higher hopes for gratings with coatings of other metals with greater thicknesses as well as different filling factors for the wire grid.

Applications

Reflective Polarization Properties of Insects



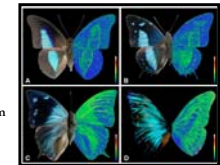
viewed through a right circular filter

viewed through a left circular filter

degree of circular polarization (difference over sum of top two photos)

Many types of scarab beetles reflect only left circularly polarized light because of chiral (handed) structures in their exocuticles. Many species of butterflies reflect linearly polarized light because of striations in their wings.

Not only might these optical characteristics play important roles in insect communication, they might also provide interesting new ideas for the manufacturing of reflective thin films.

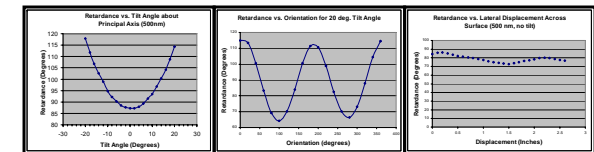


Left wing is as viewed normally. Right wing shows degree of linear polarization.

$$\begin{pmatrix} 1 & 0.0714 & -0.01963 & -0.9008 \\ 0.0240 & 0.1273 & -0.0040 & -0.0230 \\ -0.0322 & -0.0194 & -0.1332 & -0.0130 \\ -0.9736 & -0.0609 & -0.0155 & 0.7734 \end{pmatrix} \quad \begin{pmatrix} 1 & 0 & 0 & -1 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ -1 & 0 & 0 & 1 \end{pmatrix}$$

The measured Mueller matrix on the left is typical for the scarab beetles shown above for much of the visible spectrum (left: *Plusiotis gloriosa*, right: *Chrysophora chrysochlora*). It is very similar to the matrix for an ideal left circular polarizer (on the right).

Common Plastics as Inexpensive Polarizing Elements



We are investigating several types of plastic materials to see if they can be used as cheap, large-aperture, temperature-stable retardation plates for the visible spectrum. The graphs above show some of our results for polycarbonate with a thickness of 3/32". For certain tilt and orientation angles, it acts as a good quarter wave plate, and it has a modest retardance variation across its surface. More studies are in progress.

Future Applications

- Polarimetric analysis of geological samples to determine if they formed in ancient riverbeds (of interest to the oil industry)
- Stress birefringence tests of hydrocolloids like gelatin to see if they can be used as inexpensive polarization modulators