PEM TECHNICAL OVERVIEW

The PEM 100 photoelastic modulator is an instrument used for modulating or varying (at a fixed frequency) the polarization of a beam of light.

The basic PEM system includes the PEM-100 controller, the electronic head, and the optical head (Figure 1).

By varying the material, size, and shape of optical element, and coupling closely-matched drive and control circuits to the PEM optics, Hinds Instruments has developed a range of photoelastic modulators for a variety of applications in a wide spectral region (UV to far-IR).

Figure 1. Model I/FS50 photoelastic modulator with model PEM-100 controller

OVERVIEW OF FEATURES

- High sensitivity
- A resonant device generating a sinusoidal retardation at a fixed frequency
- Digital display of retardation and wavelength in user-selectable units
- Internal RS-232 interface, allowing computer control and monitoring of all PEM functions
- A reputation for stable, trouble-free performance
- CE approval and FCC certification

PEM 100 APPLICATIONS

- Chopping a light beam (20 - 168 kHz)
- Birefringence Measurements
- Stokes Polarimetry
- Optical Rotation Polarimetry
- Linear and Circular Dichroism in UV-Vis and IR
- Magnetic Circular Dichroism
- FTIR Double Modulation Spectroscopy (VCD, VLD, IRRAS, etc.)
- Ellipsometry
- Fluorescence Polarization
- Waveplate Measurement

OPTICAL HEAD FEATURES

- Common isotropic optical material
- Wide useful aperture (1.5 - 3.0 cm for standard models)
- Wide acceptance angle (±25°)
- Retardation range: 130 nm - 18 μm
- High retardation performance
- Selection of optical materials and designs
- High quality and low residual birefringence optics

CONTROLLER FEATURES

- Multiple operational modes (front panel, remote, computer control, etc.)
- Optional IEEE-488 (GPIB) capability
- Display of retardation in waves, radians, degrees
- Display of wavelength in nm, μ, cm^{-1}
- Microprocessor control of retardation
- Front panel monitored PEM frequency
- Reference signal for use with lock-in amplifiers (1f and 2f)
- Key-selectable retardation (λ, λ /2, λ /4, user-defined)

OPTIONS AND ACCESSORIES

- Wide frequency range (20 - 84 kHz)
- Anti-reflective coatings
- Laser non-interference option
- Strong magnetic field option
- Vacuum compatibility
- Rack mount option
- Low birefringence option, on Series I PEM

OPTICAL HEAD SPECIFICATIONS

Model	Optical Material	Nominal Frequency	Retardation Range		Useful Aperture[1]
			Quarter Wave	Half Wave	
I/FS50	Fused Silica	50 kHz	170nm - 2μm	170nm - 1μm	16mm
I/FS20	Fused Silica	20 KHz	170nm - 2μm	170nm - 1μm	22mm
I/CF50	Calcium Fluoride	50 kHz	130nm - 2μm	130nm - 1μm	16mm
II/FS20A	Fused Silica	20 kHz	170nm - 2μm	170nm - 1μm	56mm
II/FS20B	Fused Silica	20 kHz	1.6μm - 2.6μm	800nm - 2.5μm	56mm
II/FS42A	Fused Silica	42 kHz	170nm - 2μm	170nm - 1μm	27mm
II/FS42B	Fused Silica	42 kHz	1.6μm - 2.6μm	800nm - 2.5μm	27mm
II/FS47A	Fused Silica	47 kHz	170nm - 2μm	170nm - 1μm	24mm
II/FS47B	Fused Silica	47 kHz	1.6μm - 2.6μm	800nm - 2.5μm	24mm
II/FS84	Fused Silica	84 kHz	800nm - 2.5μm	400nm - 2.5μm	13mm
II/IS42B	Fused Silica	42 kHz	1.6μm - 3.5μm	800nm - 2.5μm	27mm
II/IS84	Fused Silica	84 kHz	800nm - 3.5μm	400nm - 1.8μm	27mm
II/CF57	Calcium Fluoride	57 kHz	2μm - 8.5μm	1μm - 5.5μm	23mm
II/ZS37	Zinc Selenide	37 kHz	2μm - 18μm	1μm - 9μm	19mm
II/ZS50	Zinc Selenide	50 kHz	2μm - 18μm	1μm - 10μm	14mm
II/SI40	Silicon	40 kHz	FIR - THz	FIR - THz	36mm
II/SI50	Silicon	50 Khz	FIR - THz	FIR - THz	29mm

[1] *For a full discussion, consult the Useful Aperture Technical Note*

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PRINCIPLES OF OPERATION

The phenomenon of photoelasticity is the basis for operation of the PEM 100. If a sample of transparent solid material is stressed by compression or stretching, the material becomes birefringent, that is, different linear polarizations of light pass through the material at slightly different speeds.

If the optical element is relaxed, the light passes through with the polarization unchanged. If the optical element is stressed, the polarization components parallel or perpendicular to the modulator axis travel at slightly different speeds. The parallel component then either "leads" or "lags" the perpendicular component after passing through the modulator. The phase difference thus created between the two components oscillates as a function of time and is called the retardation or retardance.

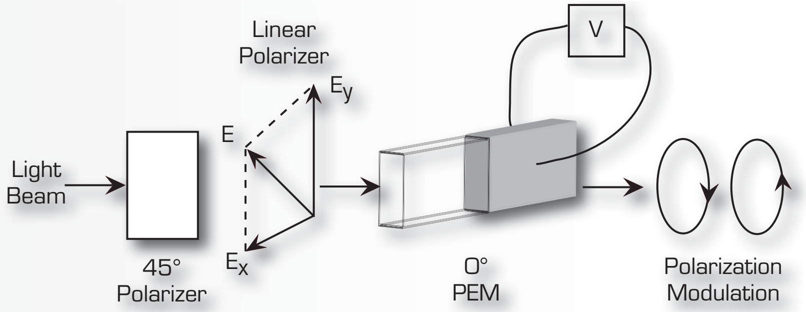

Figure 2a.

An important condition occurs when the maximum (peak) retardation reaches exactly one-fourth of the wavelength ($\lambda/4$) of light. When this happens, the PEM acts as an oscillating quarter-wave plate. At the peak, the polarization vector traces a right-handed spiral about the optical axis. Such light is called "right circularly polarized." The polarization oscillates between right circular and left circular, with other polarization states between (See Figure 2b).

Another important condition occurs when the peak retardation is one-half the wavelength ($\lambda/2$) of the light. When this happens, the PEM acts as an oscillating half-wave plate. The polarization is modulated between two orthogonal linearly polarized states at twice the PEM's frequency (2f).

The PEM 100 may be used in two basic modes: as a modulator, to produce polarization modulation of a light beam, or as an analyzer, to determine the polarization states of a light beam.

In a circular dichroism (CD) experiment, the PEM is used in the modulator mode of operation. The incoming light is linearly polarized at 45 degrees with respect to the optical axis of the modulator. At $\lambda/4$ PEM peak retardation, the result is a modulation between left and right circularly polarized light at the modulator frequency (1f). The differential absorption between right and left circular polarization ($\Delta A=A_L-A_R$) is measured with phase-sensitive detection.

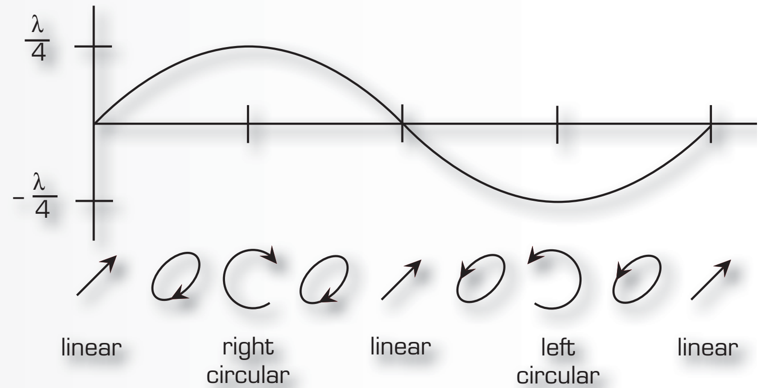

Figure 2b.

When the PEM 100 is used as an analyzer, as in a Stokes polarimeter, a net circular polarization component will produce an electrical signal in the detector at the modulator frequency (1f). A net linear polarization component at 45 degrees with respect to the modulator axis will produce an electrical signal in the detector at twice the modulator frequency (2f). Thus, the polarization characteristics of a light source can be determined.

EXAMPLES OF APPLICATIONS

Chopping a Light Beam

The PEM is a polarization modulation device. However, it can also be used as an intensity modulator when placed between crossed polarizers. This device has no moving mechanical parts and provides a modulation frequency on the orders of 20 and 100 kHz.

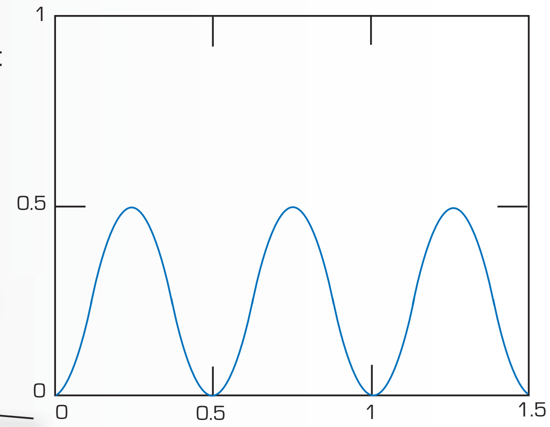

Figure 3a.

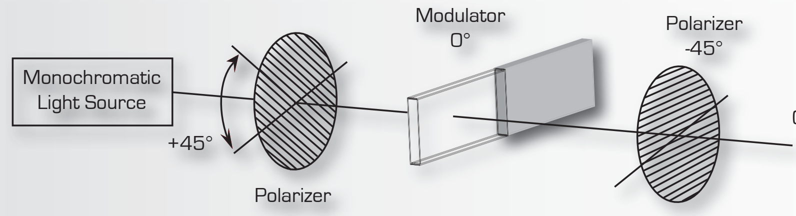

Figure 3b.

Birefringence Measurement

In this set-up, the orientation (θ) of the linear birefringence of a sample should either be known or be measured by rotating the sample until a maximum signal is observed. The magnitude of the birefringence (B) can then be determined from the lock-in outputs (1f and 2f) and the average signals.

The set-up can be used for measuring small residual birefringence of optical materials and for determining accurately the retardance of a wave-plate.

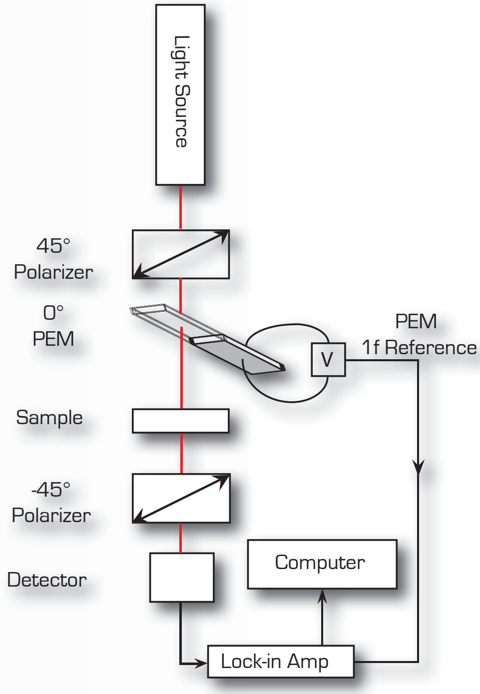

Figure 4.

Polarimetry

PEMs may be used for measuring the polarization characteristics of a light beam (Stokes polarimetry) or measuring the rotation of the plane of linear polarization (optical rotation) induced by an "optically active" sample. An experimental setup for measuring optical rotation is shown in figure 5.

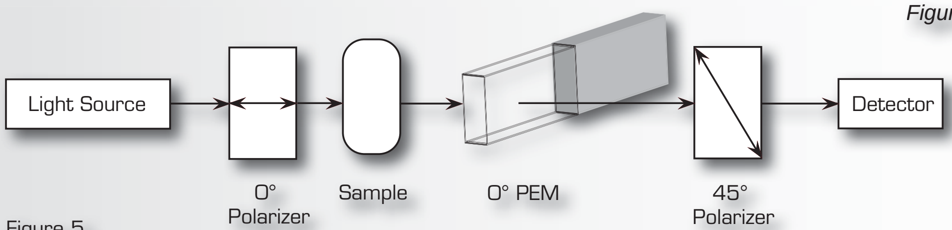

Figure 5.

OPTIONS

Antireflective Coating

Hinds offers several standard coating options for both the visble and IR regions. Our standard coatings are:

I/FS50 modulators: 633nm, 450-650nm, 800nm, and 633 - 1000nm
II/ZS37 or II/ZS50: 3-12μm and 9-12mm

Antireflective Coatings can be provided on a custom basis for any of our modulator optical elements. Both narrow and broadband coatings are available.

Non-interference Option

This option deflects internally reflected beams from the primary beam path, thereby eliminating modulated interference (see PEM Newsletter #8).

Magnetic Field Compatible

The Optical Head is manufactured without any ferromagnetic materials. This option is recommended for magnetic fields exceeding 100 Gauss.

Vacuum Operation

PEM optical heads may be operated in a vacuum. Hinds offers a custom vacuum head option or several custom flanges. Hinds' CaF_2 modulator in our custom vacuum chamber is rated for e^{-10} torr with a maximum bakeout temperature of 120 degrees C.

ADDITIONAL INSTRUMENTS

Detectors

Hinds Instruments also produces a series of photodiode detectors for the UV-Vis and near IR spectral regions.

Our DET-100 silicon and germanium photodiode detectors are specifically designed for polarization modulation experiments.

DET-100 MODEL OPTIONS				
Model	Type	Spectral Range, nm	Active Area	Frequency Response
001	Si-PC	350 - 950	5 mm²	DC – 1 MHz
002	Si-PC	350 - 950	16 mm²	DC – 1 MHz
003	Si-PV	350 - 950	5 mm²	DC – 350 kHz
004	Si-PV	350 - 950	16 mm²	DC – 300 kHz
005	Si-PV	200 - 950	5 mm²	DC – 400 kHz
006	Si-PV	200 - 950	20 mm²	DC – 200 kHz
007	Ge-PV	800 -1600	3 mm²	DC – 260 kHz
PC = Photoconductive			PV = Photovoltaic	

DET-100

PEMlabs

The APD-100 Avalanche Photodide Detector Module is for use in very low light experiments, especially for circular dichroism and fluorescence applications.

APD-100

APD-100 DETECTION CHARACTERISTICS						
Model	Type	Spectral Range (nm)	Peak Sensitivity Wavelength, λ	Photodiode Diameter	Effective Active Area	Frequency Bandwidth (3dB)
001	Si-APD	200 - 1000nm	620 nm	5 mm	19.6 mm^2	DC to 450 kHz

Signal Conditioning Unit

Hinds' SCU signal conditioning unit is used with PEM applications where both AC and DC signals need to be measured. The SCU-100 separates the AC and DC signals and applies selectable amplification gains to them.

Lock-in Amplifiers

Hinds' Signaloc 2100 is a dual-phase, analog lock-in ampifier designed to work at the Photoelastic Modulator's resonant frequency (1f). There are two configurations: one provides maximum sensitivity at 1f using a band pass filter; in the second configuration (without the band pass filter) both the 1f and 2f signals can be amplified.

Signaloc 2100