FALL 1995

HINDS INSTRUMENTS, INC.

PEM™

APPLICATIONS
NEWS FOR USERS
OF PHOTOELASTIC
MODULATORS

DETECTOR/PREAMPLIFIERS

One of the most common problems for new PEM users involves the light detectors (photodiodes, photomultipliers, etc.) which are used in their systems. If care is not used, the user may inadvertently construct a "low-pass" electrical filter which severely attenuates and distorts the electrical signal from the detector. Also, many detector systems are "AC-coupled" and do not transmit the "DC" signal component which is proportional to the average intensity of light striking the detector.

For several years, Hinds Instruments has offered a line of silicon PIN photodiode detector systems optimized for use with PEMs. These units contain an op amp transconductance preamplifier which converts the detector current signal to a low-impedance voltage signal. The preamplifier "gain" is chosen to provide maximum signal strength consistent with an electrical bandwidth that is several times typical PEM operating frequencies. Their spectral response is in the near-UV, visible, and near-IR to about 1100 nm. They are designed for ± 12 to 18-volt power, but can be powered by two 9-volt batteries.

The silicon detectors are of three types: photoconductive, photovoltaic,

(Continued on page 3)

Chopping a Light Beam

Periodic interruption of a light beam, or "chopping," is a technique which has long been used with electro-optical systems to enhance the signal-to-noise ratio (S/N) of a detected optical signal (as compared to "DC" detection techniques). When used with lock-in amplifiers or other synchronous devices, detection systems with very narrow electronic band widths result.

There are numerous ways to modulate the intensity of a light beam. On the order of 100 Hz, a mechanical chopper may provide the simplest method for intensity modulation. For high frequencies on the orders of MHz and GHz, different types of electro-optic and acousto-optic modulators are available. The photoelastic modulator (PEM), with its wide wavelength range (UV to mid-IR), large acceptance angle, and large aperture, offers the scientific and industrial community an excellent solution for intensity modulation in the range of 20 to 200 kHz. Two basic techniques for using a PEM as a light chopper are described below.

Technique 1

An optical bench consisting of a PEM placed between two crossed polarizers is shown in Figure 1. When the PEM optical element is at its neutral position (neither compressed nor stretched), then in principle, no light will reach the detector. When the PEM optical element is compressed or stretched enough to give the retardation of $\pm\pi$ ($\lambda/2$ or half-wave), after passing through the PEM the light will be linearly polarized and parallel to the second polarizer. Consequently, light of maximum intensity will reach the detector. Operating the PEM at its resonant vibrational frequency (f), this optical setup modulates the light beam intensity.

The intensity vs. time of a light beam is shown in Figure 2. The vertical axis of the graph is $I/(K_1 I_0)$, where I is the intensity after the second polarizer, I_0 is the initial intensity, and K_1 is a factor which corrects for reflection, absorption, and scattering losses and rejection of light by the first polarizer.

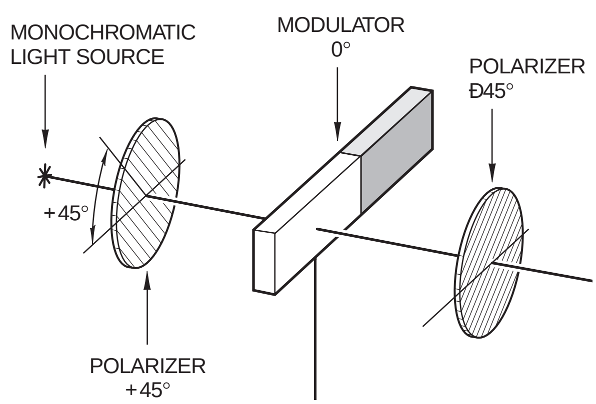

Figure 1. Optical setup technique 1 for light intensity modulation.

Chopping *(continued from page 1)*

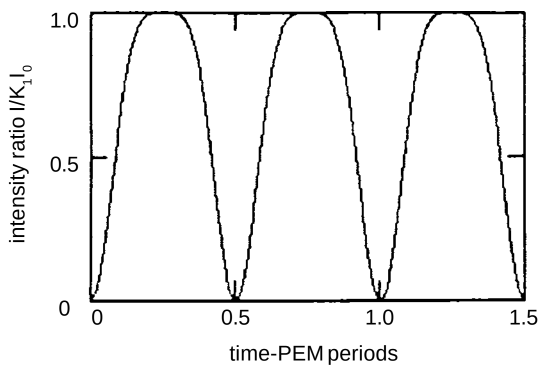

Figure 2. Intensity vs. time for half-wave PEM peak retardation.

The following features should be noted:

1) with high quality polarizers "modulation depth" is excellent – light intensity at minimum is very nearly zero;
2) the "duty cycle" of the function is not 50 percent – the light is on more than it is off; and
3) modulation is at twice the PEM frequency (2f).

A better duty cycle and nearly sinusoidal modulation function can be obtained by using quarter-wave peak retardation, as shown in Figure 3. The drawback for this procedure is that the maximum intensity has been reduced by a factor of two, compared with operation at half-wave peak retardation.

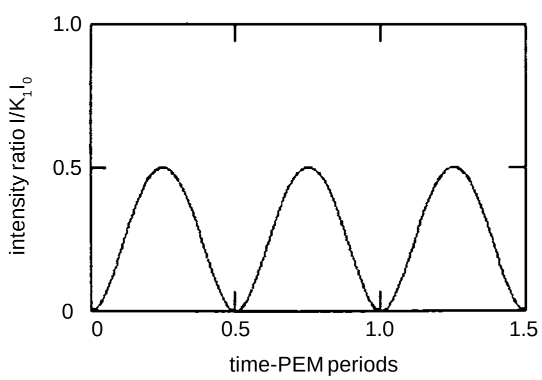

Figure 3. Intensity vs. time for quarter-wave PEM peak retardation.

Technique 2

If monochromatic or narrow spectral band light is used, performance can be improved by adding a quarter-wave plate to the setup, as shown in Figure 4. One waveplate axis (fast or slow) is oriented parallel to the PEM optical axis. The PEM peak retardation is quarter wave.

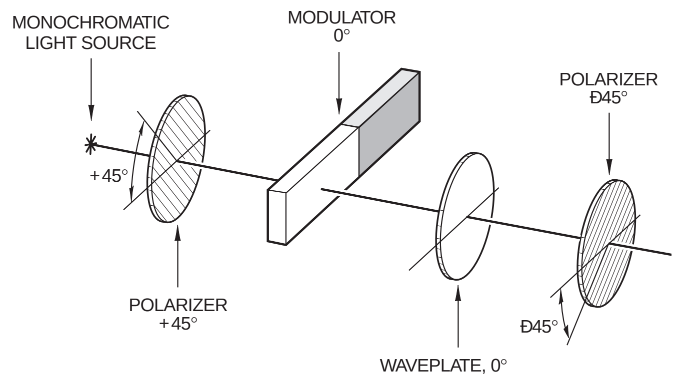

Figure 4.Optical setup technique 2 for light intensity modulation.

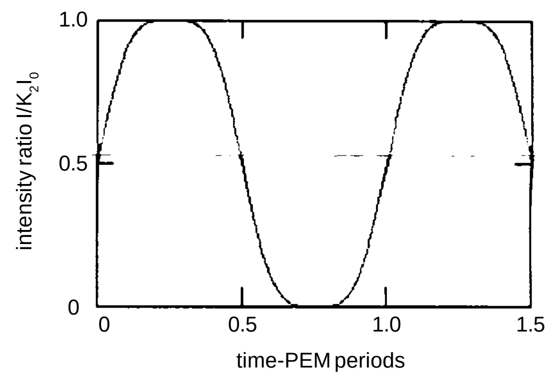

Figure 5. Intensity vs. time for quarter-wave PEM peak retardation using technique 2.

Figure 5 shows the resulting intensity function vs. time. The new constant K_2 incorporates any additional intensity losses due to the waveplate. The chopping frequency is now the PEM frequency f (rather than 2f). Although the waveform is not sinusoidal, it is symmetric and the "duty cycle" is now 50 percent. It resembles a "trapezoidal" waveform common to mechanical choppers.

Practical PEM-based light choppers can be made for use in the UV, visible, near-IR, and mid-IR spectral regions. This technique may be especially important in the deep UV and mid-IR, where few alternative modulation devices are available.

More details and a theoretical analysis for intensity modulation using these two techniques can be found in the application note "Light Intensity Modulation Using a PEM" by Dr. Theodore Oakberg and Dr. Baoliang Wang.

ABOUT THE SCIENTIST

Development and documentation of the light chopping technique described in this issue typifies the activities of Theodore (Ted) Oakberg, Ph.D., senior applications scientist at Hinds Instruments. The chopping technique originally was suggested by the late Dr. James Kemp, inventor of the photoelastic modulator, to assist in calibration of the PEM optical assemblies.

Much of Ted's work involves exploring and further developing reported PEM applications, and then documenting them for other PEM users. "My most important role is helping people understand what the PEM does, how it works, and how they can use it for their purposes," he says. "Our customers are our applications development staff. They find ways to use the PEM that we never would have thought of."

Ted works closely with customers to optimize their use of the PEM: "We help customers make the right choices about the PEM model and features they need. A bad choice can be very expensive both in time lost and unnecessary money spent."

Ted's close customer involvement has led to new PEM product and system development such as an industrial circular dichroism monitor and Hinds' line of photodetectors.

Current research includes development of techniques for measurement of strain birefringence in optical materials. "The PEM has the potential of measurements one or two orders of magnitude more sensitive than other techniques," Ted reports. These techniques will be useful at Hinds for product improvement, as well as for potential users such as optical component manufacturers.

In addition to his applications lab responsibilities, Ted travels about seven weeks a year to trade shows, conferences, and customers around the world. (See the list at right of upcoming events where the PEM product line will be represented.)

Dr. Oakberg has a B.S. degree in engineering from California Institute of Technology and M.S. and Ph.D. degrees in physics from the University of Cincinnati, with emphasis in optics and spectroscopy.

Detectors *(continued from page 1)*

and UV-sensitive photovoltaic. The photoconductive units provide maximum electrical output for a given input light intensity. The photovoltaic units feature very low dark current, good linearity over a wide operating range, and have better signal-to-noise characteristics than the photoconductive units. In particular, the photovoltaic units are free from "1/f" noise, which is particularly troublesome in systems in which DC techniques are used for measurement of the average or "DC" light intensity. The UV-sensitive units extend the spectral response from about 300 nm down to 200 nm.

Hinds also manufactures a germanium detector/preamplifier to extend the IR range to about 1800 nm, and a photomultiplier/preamplifier assembly which accepts a 1-1/8 inch 14-pin end window photomultiplier tube (PMT). Hinds does not supply the PMT; it is intended that the user select a model which meets his spectral range requirements.

For further information, request the PEM-90 Data Bulletin "Detector/Preamplifiers and Signal Conditioning Unit" or call Hinds engineers for assistance.

NOTES OF INTEREST

Upcoming Events

The PEM chopping demonstration is part of the new display Hinds will be exhibiting at these upcoming events:

- PittCon '96, Chicago, March 3-8
- Analytika '96, Munich, April 23-26
- CLEO '96, Anaheim, June 2-7
- SPIE Polarization Conference, Yokohama, June 12-14

Additional Information

- ❑ For more detailed information about chopping, request PEM-90 Application Note "Light Intensity Modulation Using a PEM."
- ❑ For further information on PEM system detectors request the PEM-90 Data Bulletin "Detector/Preamplifiers and Signal Conditioning Unit."

Call or fax Hinds Instruments, Inc.
Phone (503) 690-2000
Fax (503) 690-3000
Toll-free 1 800 688-4463

HINDS INSTRUMENTS
3175 NW Aloclek Drive
Hillsboro, OR 97124 USA

Address correction requested.

BULK RATE
US POSTAGE PAID
Hillsboro, OR
Permit No. 76

INSIDE PEM

- Chopping a Light Beam
- Detector/Preamplifiers
- Other notes of interest

Printed in USA. 5M/11-95.