Fun With Photonics
An Experiment With Polariscopes

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OSA Fellow Keigo Iizuka developed the hands-on learning program, "Fun with Photonics," to spark interest in optics among members of the general public. The series was first presented to automotive engineers at Omron Corporation, Komaki City, Japan. In the fourth installment, Iizuka describes how to improvise a polariscope. Previous "Light Touch" columns in the "Fun with Photonics" series have focused on polarization, three-dimensional displays and liquid crystal displays. Each experiment begins with an explanation of the underlying scientific principles that will be demonstrated.

Principle

In an anisotropic, or birefringent, medium, the refractive index for light polarized in one direction is different from that for light polarized in another direction. If, for example, a plastic sheet assumes a curved shape, the refractive index is lowered in the direction of the stress and the plastic sheet becomes birefringent. Polariscopes are used to observe the spatial distribution of the birefringence. The most popular application of the polariscope is in glassblowing workshops. Structural engineers who make plastic models of structures also use the polariscope to analyze the patterns created by stress distribution when a load is applied. The refractive index of crystals such as lithium niobate can be changed by applying an electric field. By inserting such a crystal between crossed polarizers (in essence forming a polariscope), the transmission of light can be varied electrically. Such devices are used as light modulators in fiber-optic communication systems.

Scientific explanation

Polariscopes consist of a pair of polarizer sheets, the transmission axes of which are oriented at right angles to each other. The second polarizer sheet is usually referred to as an analyzer sheet. No light is transmitted through the polariscope if there is no test object between the polarizer and analyzer sheets. When a birefringent medium is inserted between the sheets, a pattern of birefringence appears. Glassblowers observe the pattern of birefringence to identify stress patterns in the glass during annealing.

We can improvise an "instant polariscope" from a laptop computer because the front surface of the laptop screen itself is a polarizer sheet (see "Light Touch," November 2002 OPN). Laptops have all the necesssary characteristics: uniform illumination, a stand and a built-in polarizer sheet. The only additional item needed is an analyzer sheet.

Figure 1. A polariscope improvised by use of the display panel of a laptop computer.

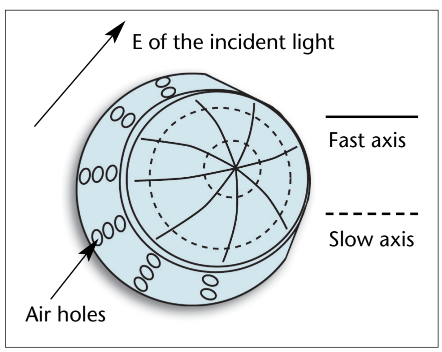

Figure 2(a). Cylindrically symmetric test object and its birefringence pattern. Fast and slow axes of a plastic cap.

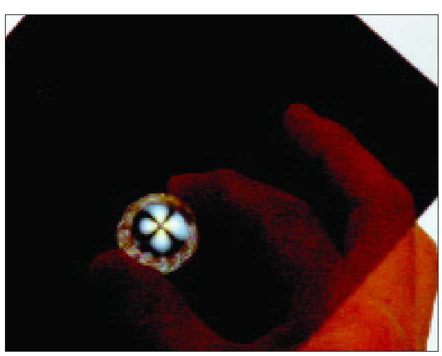

Figure 2(b). Birefringence pattern of a plastic cap viewed by means of the polariscope.

The experiment

Turn on the laptop and select a screen display with a white background, for example, a blank document in a word processing program. Hold the analyzer sheet so that the light from the laptop is at a null (see Fig. 1).

Insert an assortment of test objects between the laptop screen and the analyzer sheet. You will enjoy viewing the amazing patterns made by items such as a plastic ruler, polyethylene bags under stress, glassware, a gray hair or even a soap bubble. But be sure to include the following two objects as part of your tests.

A polarizer sheet

Insert a test polarizer sheet parallel to the analyzer sheet. While keeping the planes of the test polarizer and analyzer sheet parallel to each other, rotate the test polarizer sheet. Find the directions of the transmission axis of the test sheet that give the maximum light output. Also look for the directions of the null output light. Verify that the null occurs whenever either the transmission or extinction axis of the test sheet is oriented parallel to the direction of polarization of the light from the laptop display.

A plastic item with cylindrically symmetric stress

A good example is the clear plastic cap of a hairspray can that has been made by being stamped out of a plastic sheet [see Fig. 2(a)]. The direction of stretch of the plastic cap is radial, and the refractive index n of light polarized in this direction is decreased. The phase velocity c/n of light polarized in this direction is faster and hence the radial direction is called the fast axis.

On the other hand, the stretch of the plastic cap in the circumferential direction is minimal. The refractive index in the circumferential direction is higher than that in the radial direction. The phase velocity of the light polarized in the circumferential direction is slower than that of the light polarized in the radial direction. Slow axes exist in concentric circles [see Fig. 2(a)].

When you insert the plastic cap into your polariscope, dark crossed lines such as those shown in Fig. 2(b) should appear. One of the dark lines of the cross appears where the fast axis of the cap becomes parallel to the polarization of the light from the laptop display.

Note that the other dark line appears where the slow axis of the cap becomes parallel to the polarization of the laptop display light.

With the test polarizer sheet, nulls appear whenever either the transmission or extinction axis of the test polarizer sheet is oriented in the direction of the polarized light from the laptop display.

With the plastic cap, nulls appear when either the fast or the slow axis of the cap is oriented in the direction of the polarized light from the laptop display.

If the dark cross pattern does not move—even if the cap is rotated on its axis of symmetry—there is no flaw in the formation of the cap. (It is interesting to note that the dark cross pattern is called the Principal Isogyre.)

Conclusion

Polariscopes are simple and inexpensive but extremely useful. They are used by glassblowers for annealing, structural engineers for stress analysis, communication engineers for modulating light, and gemologists for verifying the authenticity of gems.

Next month's "Light Touch" column will feature the fifth experiment in the "Fun with Photonics" series, on the topic of optically active media.

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