Harvard Natural Sciences Lecture Demonstrations

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Circular Polarization

What it shows:

A linear polarizing filter followed by a quarter-wave plate whose slow and fast axes are at 45° to the axis of the polarizer becomes a circular polarizing filter, and incident unpolarized light emerges as circularly polarized light. This will not work if the order of the polarizer and wave plate is reversed. A quarter-wave plate converts circularly polarized light into linearly polarized light.

Unpolarized light emerges vertically polarized from the polaroid at A; a quarter-wave plate at B oriented 45° to the polaroid produces circularly polarized light; a second quarter-wave plate at C passes horizontally polarized light, which passes through the polaroid at D.

How it works:

The quarter-wave retardation plate is a sheet of birefringent (double refracting) material [1] of thickness such that horizontally and vertically polarized light entering in phase will emerge from the retardation plate 1/4 of a wavelength out of phase. Unpolarized light is not affected by this retardation plate (or by any thickness of birefringent material) because the retardation plate only changes the phase of each component of polarization. The situation dramatically changes when the incident light is polarized.

A polarizing filter is placed in front of the quarter-wave plate at a relative angle of 45° so that the incident horizontal and vertical components are of equal intensity. Because of the 90° phase shift between the two components after they pass through the retardation plate, the direction of polarization of the light that emerges from the wave plate will rotate in time. Thus incident unpolarized light emerges as circularly polarized light. (More generally, if the angle between the wave plate and polarizing filter is not 45°, the two components will differ in intensity and the emerging light will be elliptically polarized.) A second wave plate with the same orientation will result in a 180° phase shift, and the components will now sum to obtain linearly polarized light that has been rotated by 90°.

The circular polarization produced by the linear polarizer/quarter-wave plate sandwich is also made evident by placing a mirror behind it and looking through the circular polarizer at the mirror reflection. The mirror reverses the direction of circular polarization, and the reflected reversed circularly polarized light is converted back into linearly polarized light by the wave plate. However, it is now polarized perpendicular to the linear polarizing filter's orientation, so it is absorbed and the mirror appears dark [2] . The effect is undone by rotating the linear polarizer with respect to the wave plate. The effect is also undone by reversing the order of

the polarizer and wave plate. Finally, one can substitute a non-reversing mirror (two mirrors mounted together at right angles) to see what happens!

Setting it up:

Two quarter-wave retarders are placed between crossed polaroids. When the retarders are parallel with each other and at an angle relative to the polaroids, an illuminated object can be viewed through the series of filters using a video camera. Propping up the filters with wood blocks will allow for their easy reorientation.
A mirror with one retarder and one polarizer can also be used. Use a video camera to look through the circular polarizer and view the reflection of an illuminated foreground object as the angle between the polarizer and wave plate is changed.

Comments:

Circular polarizers are used to reduce annoying reflections, eliminate glare, and enhance contrast for a variety of commercial applications. [3]
Note that retardation plates do not influence the state of polarization of incident linearly polarized light, if the light's polarization direction lies along either the slow or the fast axis of the retardation plate. Also, a retardation plate can't convert unpolarized light into polarized light. We also have a half-wave and a full-wave plate available. A half-wave plate can convert right-handed circularly polarized light into left-handed circularly polarized light and vice versa.
1 Polaroid 140 nm 1/4-wave retarder--the retardation is 1/4 wavelength if the wavelength is 4 × 140 nm = 560 nm (which is green); the wave plate is backed onto 0.030" thick plastic and comes in 12" square sheets. Ours have been cut down to 6" squares and mounted in a wooden frame. ($65/sheet from Polaroid in 1985, product no. 605206))
2 An excellent explanation is given by Frank S. Crawford, Jr. in *Waves*, Berkeley Physics Course - Vol 3, (McGraw-Hill, NY, 1968), p 434. Indeed, the entire chapter 8 (on polarization) is one of the best found in any undergraduate textbook.
3 Polaroid non-glare circular polarizer HNCP 10% 0.030 (product no. 606953) is available in 19"×50"×0.030" sheets ($113/sheet from Polaroid in 1985).

See also: **Light and Optics**, **Polarization and Scattering**, **[S]**, **[t+]**, **[★★]**

Demo Subjects

Newtonian Mechanics
Fluid Mechanics
Oscillations and Waves
Electricity and Magnetism
Light and Optics
Quantum Physics and Relativity
Thermal Physics
Condensed Matter
Astronomy and Astrophysics

Geophysics
Chemical Behavior of Matter
Mathematical Topics

Key to Catalog Listings

Size: from small [S] (benchtop) to extra large [XL] (most of the hall)
Setup Time: <10 min [t], 10-15 min [t+], >15 min [t++] /span>
Rating: from good [★] to wow! [★★★★] or not rated [—]
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