POLARIZATION

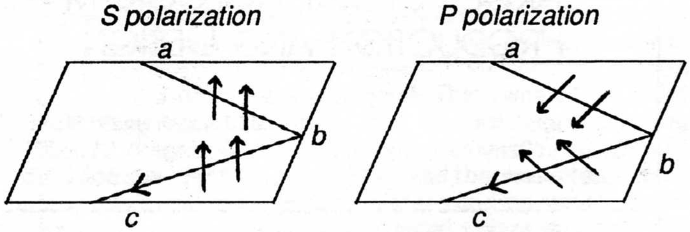
by Dinesh Padiyar

In this article I would like to continue the dicussion on polarization begun in the last technical tips articles in LASER NEWS. In particular I would like to discuss the effects of polarization on reflection and Brewster's angle as well as half wave plates.

As has been mentioned, electromagnetic radiation, visible light in particular, is transmitted through space by means of oscillating electric and magnetic vectors (the magnetic vector is usually ignored since its effects are minimal). This basically means that light can be considered as a series of arrows that propagate through space in an undulatory manner so that they contract and expand as they move forward. Since light is a transverse wave these arrows are transverse to the direction of the light beam, i.e. for light propagating left-to-right arrows are either up and down or away-and-towards you or some combination of these two. In all of the following discussion I shall assume light going from left to right. Plane polarization occurs when these arrows are only up-and-down or away-and toward, circular polarization is when the arrows rotate much like a cork-screw.

To understand the effects of polarization on reflectivity (the ratio of reflected light to incident light) another concept needs to be understood- that of s and p polarization. When light reflects off something it generally comes in at some angle and reflects off at some other angle so that the incident and reflected beams form a plane, called the plane of incidence (so that for a horizontal reference beam the plane of incidence is horizontal). In this situation the arrow of the electric vector, i.e. the polarization, can either be up-and-down (perpendicular to the plane of incidence), in which case s polarization results, or away-and-toward (parallel to the plane of incidence) in which case p polarization results.

Fig. 1



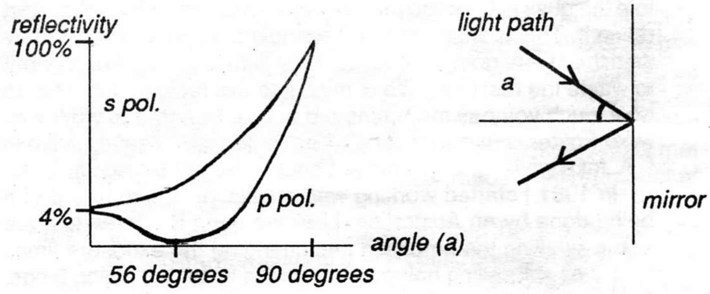
Plane of incidence *Plane of incidence*
Direction of beam is abc *Direction of beam is abc*

The reflectivity of a surface, glass or metal, is dependent on the polarization state of the light being reflected. For p polarization the reflectivity starts at some normal incidence value (4% for glass) and drops until the Brewster angle (56 degrees for glass) at which point it rises, whereas for s polarization it continually rises.

Therefore it can be seen that for Brewster's angle to work the light must be p polarized. For horizontal reference beams this means horizontal polarization and, of course, vertical for overhead reference beams. A simple way to test for Brewster's angle is to determine the polarization of the beam, reflect the unexpanded beam from a plane glass plate and rotate the plate in the plane of polarization until the reflected beam almost disappears (e.g. rotate the beam in a horizontal plane for horizontal polarization). Another trick to determine which is horizontal on a piece of polaroid material is that sunlight reflecting off the ocean or a lake is mostly horizontally polarized (completely horizontally polarized when the sun hits the water at Brewster's angle- about an hour or two before sunset). As a side remark, Brewster's angle and p polarization is used to get rid of 'woodgrain' caused by light bouncing around inside the emulsion. However at p polarization there is always an angle between the electric vectors of the two beams and this cuts down the efficiency of the hologram (the efficiency of the hologram is proportional to the cosine of the angle between the electric vectors – for you math enthusiasts). However, at s polarization the angle is always zero and so maximum efficiency results and therefore most scientific work is done at s polarization.

Fig. 2

Reflectivity Curves for Glass (not to scale)



A couple of interesting consequences are firstly that very bright areas on an object can be altered by altering the polarization of the object beam (see K. Bazargan's Ph. D. thesis) since reflectivity depends on polarization state as shown in fig 2 and, when making a single beam Denisyuk of metallic objects, the reflectivity of a metal object follows the same rules as glass, i.e. the reflectivity at p polarization is less than that of at s polarization; therefore if a metal object is illuminated at p polarization near its Brewster's angle there is not going to be a lot of reflection! However the Brewster angle for metal is pretty large so there's no need to worry too much.

The polarization of a beam can be altered by the use of a half wave plate (or retardation plate). This is a crystal that creates two light paths inside it for every light beam that is incident on it. On leaving the crystal the light paths combine to a single light path, however, the polarization of the exiting beam is twisted by an angle dependent on the thickness of the crystal. Commercial half wave plates are arranged so that by turning the half wave plate through an angle the electric vector is turned by twice the angle, e.g. turning the half wave plate by 10 degrees causes the electric vector to be turned through 20 degrees.

All that's left to say now is to quote my friend Mitch, "May you dream holographic dreams." ✧