Photographic Images and Optical Effects Using Birefringent Materials

Nik Semenoff

Abstract—The author reveals a method of producing colorful abstract photographic prints using polarized light and simple materials such as cellophane. Until recently the use of birefringent materials and polarization had been limited to the production of light shows or light boxes with ever-changing patterns. This paper explains how permanent prints can be made using positive-to-positive photographic print papers and a modified enlarger. Methods for producing optical displays and special effects for television using birefringence are also discussed.

INTRODUCTION

Anthropological discoveries indicate that man began using color at a very early time. Early civilizations worked with earth pigments and fugitive organic colors from plants to produce great works which, though limited in their palette, are still perceived as rich and colorful. Technological advances, inspired by the vivid colors of flowers, gems and feathers, have provided the artist with brighter and more permanent colors. Some artists, searching for even purer or richer colors, have discovered that by polarizing light through a birefringent material such as cellophane one can obtain colors of a single wavelength, the purest theoretically possible. Much has been discussed in other articles in *Leonardo*, including an excellent article by Edward and Langley [1], as well as in other books and publications [2–8].

To obtain brilliant colors, light is projected through one polarizing filter (polarizer) and passed through birefringent material to retard different wavelengths (color) in various degrees; the colors are then selected by another polarizing filter (analyzer). Birefringent materials, which have a uniform (constant) effect independent of their thickness, change white light into two parts, one passing through more slowly than the other. Retardance is the amount the one part is slowed down, and *is* affected by the thickness or number of layers used. The proportion of the two parts can be changed by using two polarizing filters, producing a new color by the interference of the two wavelengths. Rotating any of the three components (polarizer, retarder, analyzer) also changes the proportion of fast–slow light, producing shifts in color. A greater variety of hues can be obtained by selecting different sources and varying the layers of birefringent material.

Goethe was probably the first to produce entoptic color using two black mirrors and mica schist [9], but a practical method did not arise until the invention of polarizing sheet filters in 1928 by Edwin H. Land. These filters made it possible to produce colors using birefringent material between two plastic filters. Engineers first discovered that models of beams made from plastic would show stress, through a display of colors, when placed between such filters. The artistic possibilities of this discovery became apparent only years later.

My own interest in entoptic colors was aroused by a display at a student engineering show I attended in the 1950s. I read various technical texts and journals and experimented with photographic polaroid filters, discovering that I could polarize light to make colorful abstract designs. Using slides made from cellophane mounted between glass, I could project an ever-changing image by rotating the polarizing filter on the front lens (Fig. 1). I found these images stimulating, but they could only be seen in a darkened room using a modified slide projector, making it awkward to enjoy them. With the availability of Ilford Cibachrome material I found a practical way of displaying my art in a variety of settings.

PHOTOGRAPHIC IMAGES

The method I use for assembling my images (plates) is extremely simple. A sheet of neutral grey polarizing material is placed on the viewing table and modifies the photographic enlarger. The light table is constructed to allow the main polarizer to be rotated at least 90 degrees. The spectator wears an ordinary pair of neutral grey sunglasses or a goldsmith's binocular loupe if a larger viewing field is desired.

The plate support is made from glass, clear unexposed photographic film or 0.010 inch clear mylar sheet. The birefringent material is placed between any two of these to obtain a focal plane. I keep the birefringent material as thin as possible to avoid any soft focus. As Cibachrome's inherent sharpness shows even the smallest dust particles, and blowing off the dust can disturb the position of loose cellophane, a clean work area and care in handling the material is of primary importance.

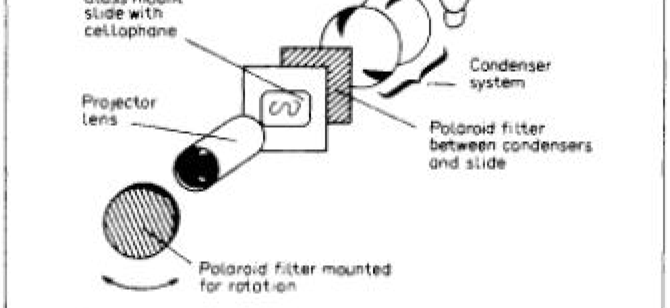

Figure 1. Placement of polaroid filters within a slide projector. The polarizing filter is built into the projector and cannot be revolved; this limits the colors obtainable.

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The most useful materials for creating the image are clear cellophane, Sello or Scotch tape, stretched plastic and some types of plastic binding rope. (For a time I carried two scrap pieces of polaroid filter to test any material that looked suitable.) The materials are cut, torn and assembled to produce an image. By observing the progress through polaroid sunglasses one can control the image within the limits set by any media. Small pieces can easily be manipulated with tweezers. There is no advantage to increasing cellophane layers beyond three or four, as colors tend to decrease in saturation beyond this. Colors such as blue, dark yellow, lime green and magenta occur frequently because of the multilayer nature of the media, but by choosing various types of materials and by careful manipulation of both filters, a great variety of shades can be obtained. The print entitled *Hero* (Fig. 2) was produced using Scotch Tape, cellophane, pieces of plastic binding rope, and plastic strapping tape. This packaging tape is responsible for the mottled effect in the background. The print entitled *Hanging Form* (Fig. 3) was the result of using cellophane and a particular type of plastic rope. A single layer of packaging tape was added. Using clear mineral oil to keep the materials and plates together has some positive effect on the character of the

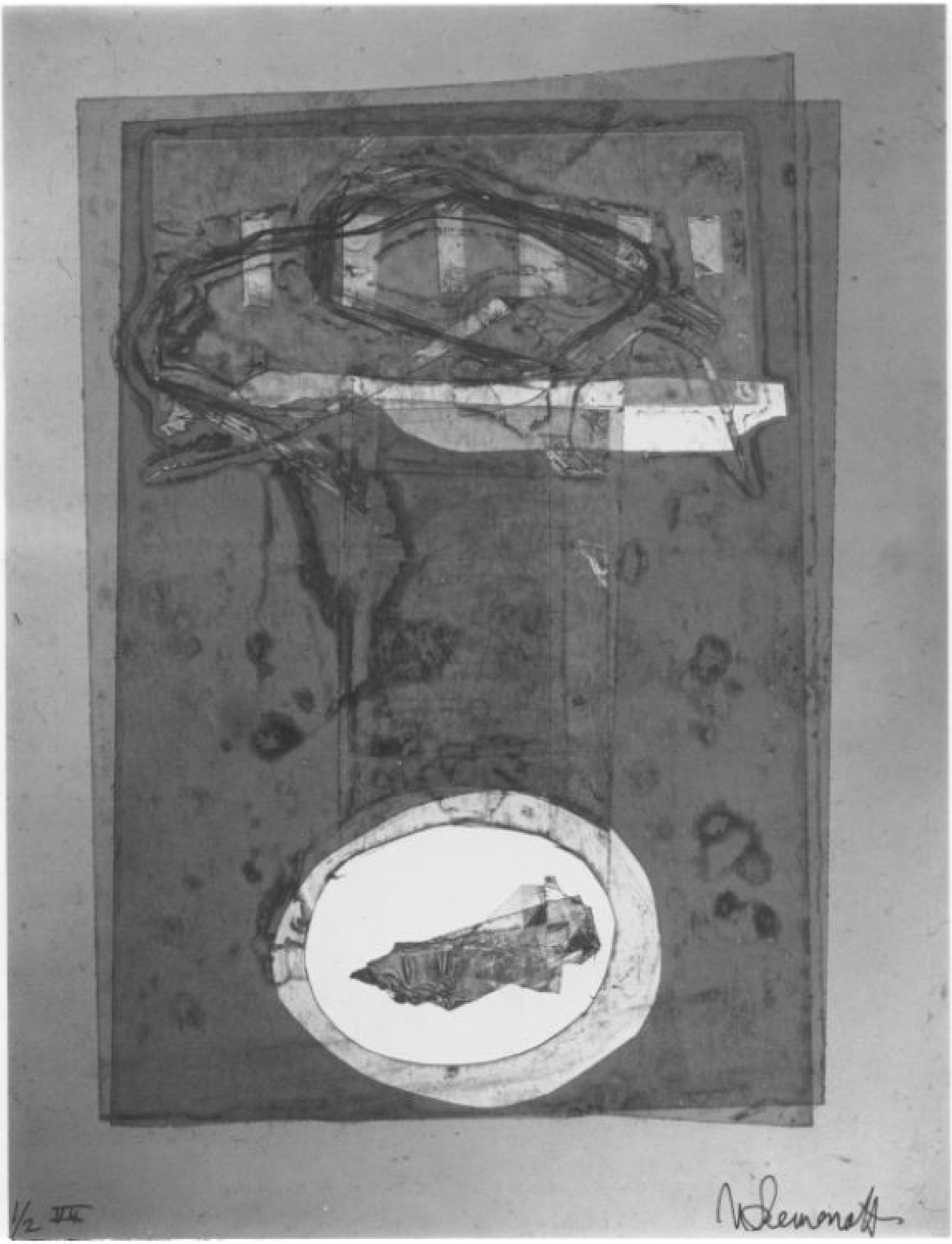

Figure 2. ***Hero*****, Cibachrome print produced using polarized light with cellophane and other plastics, 8 x 10 inches, 1982.**

Figure 3. ***Hanging Form*, Cibachrome print produced using polarized light with cellophane, binding tape and other plastics, 8 x 10 inches, 1982.**

image, but is messy, so I now work only with dry materials.

When a satisfactory image is achieved, the covering piece is put on top and held in place by taping the edges or using narrow strips of two-sided carpet tape. I have produced plates with glass-mounted 35 mm slides but prefer the larger 4 × 5 inch format. Any plate has a number of possible color combinations depending on the filters and plate. As in changing the image of lithographs or etchings, a particular combination can be printed as a second or third state.

The plate is printed photographically with a color enlarger modified slightly to accept the polarizer between the plate and the light source (Fig. 4). The best position for the polarizer is directly above the plate. When polarized light is passed through a set of condenser lenses the overall image is divided into quadrants with opposite quadrants displaying complementary colors. If the opal glass is between the polarizer and the image-carrying plate, a diffusion enlarger head negates any polarization. A system for revolving this filter simplifies darkroom work. Heat-absorbing glass and color-correction filters are normally needed for Cibachrome. An arrangement to hold a camera-quality polaroid filter on the enlarger lens can be developed by using

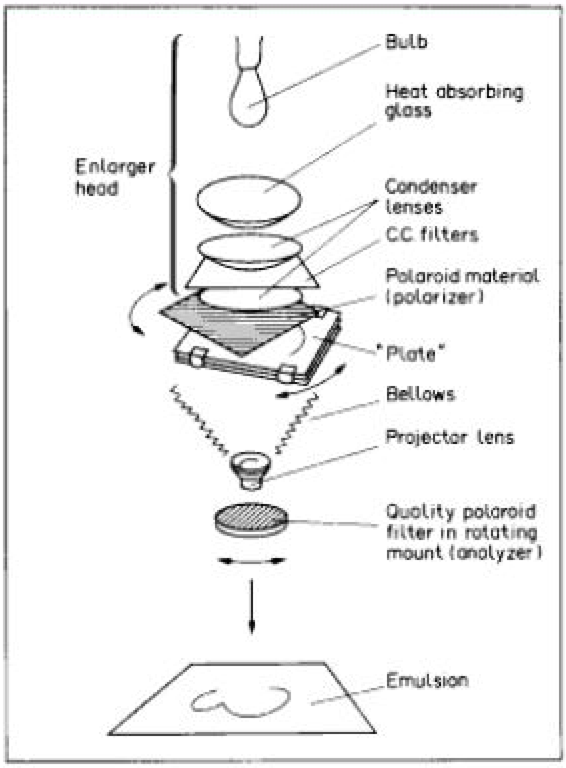

Figure 4. Placement of polaroid filters in modifying an enlarger. Note that the polarizing filter is positioned between the condensers and the plate. This prevents the background of the print being divided into quadrants, the opposite corners showing the same color.

various sizes of camera filter adapters, many of which allow for rotation. Color balance should be first established by printing any photographic transparency which would indicate a color shift before printing images from the plates. Neutral grey images can be used to show the subtle shifts which may occur when using color printing materials. Records of exposures, color correction filters and developing data can save time and paper if one is not familiar with the technique. Much can be saved by documenting procedures.

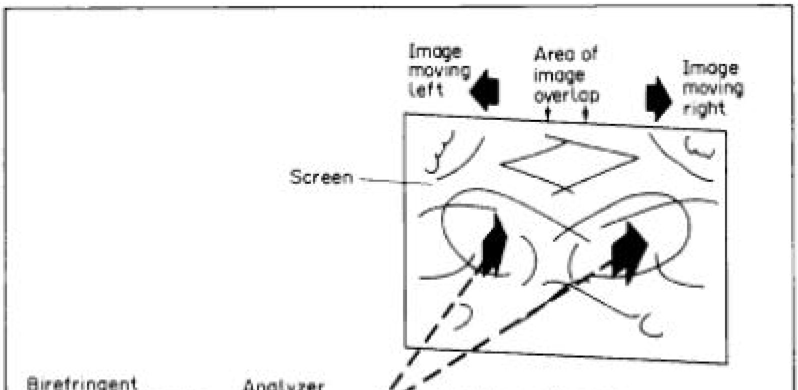

Figure 5. Arrangement of components to produce an optical display. More complex color variations can be obtained if the polarizer can be rotated.

I chose Ilford's Cibachrome material because it is a positive-to-positive method of printing, using very rich azo dyes which are considered permanent. The print is sharp and the substrata is mylar, which is considered to be more permanent than regular photographic paper. Although the colors on the print are not quite as rich as in the projected image, still they are very bright, the best dyes available at this time. The Cibachrome material is processed using standard darkroom techniques. Some knowledge and experience in color photo printing is useful. I believe that the Cibachrome system equals or betters the permanence of lithographs and other graphic media. Prints that are stable and lightfast can be made using meticulous darkroom procedures.

I number and sign my editions according to the accepted printmaking practice. For example, 2/2 III indicates that this is the second of two prints made from a third state obtained by rotating the analyzer filter on the lens. I tend to limit the number of prints from any single state. I have printed up to seven states from one plate by rotating the filters. As in most photographic work, prints can be cropped and can vary in size from 4 × 5 inches to large prints.

OPTICAL EFFECTS

Birefringent techniques can also create unusual moving optical displays. I have designed introductions for several television series using a colorful projected image recorded on a video tape recorder. Full studio production facilities are necessary for a high technical quality of programming.

To create a moving display, I used an old SVE (Society of Visual Education) filmstrip/slide projector with a removable gate. I constructed a simple wooden frame to take the place of the gate with a long piece of glass (approximately 50 × 400 cm) which can slide horizontally through the frame. On this glass I secured birefringent material such as stretched plastic sello tape, to make a suitable design. I inserted a piece of polaroid filter in the light path and constructed a variable-speed rotating analyzer filter for the projection lens. I used another variable motor drive to pull the glass plate through the gate at a steady rate, adjusting motor speeds for the proper degree of movement (Fig. 5).

To produce a sense of the motion originating from the centre of the screen, I placed a 45-degree prism in the path of the projected image to shade about half the screen, replacing it with a mirror image of what was on the other half. The sharpness of the dividing line can be controlled by moving the prism closer or further away from the lens. A degree of overlap where the image originates can have a pleasing effect. A television camera records the projected image and combines it electronically with titles and other parts of the program.

Another possible method would be securing birefringent material to cleared 35 mm film stock which has been made into a loop. The length of the loop could vary, using rollers and various guiding systems as a magazine to hold the film. The loop would be driven through the film gate of the SVE equipment, using its sprocket arrangement for advancing the film. Many older filmstrip projectors made by SVE have film gate arrangements to take slides and filmstrips in both regular and full-frame format. In the filmstrip mode the film could be advanced by single frame or by means of the sprocket drive. A motor could be attached to this sprocket drive, introducing a steady flow of changing images into the projection system with either vertical or horizontal movement. By placing prisms or mirrors in the projection path, the artist could obtain opposite directional movement on the screen. Kaleidoscope mirror arrangements produce ever-changing images and are useful for a variety of projects. Artists historically have used 'controlled' accidents to produce exciting abstract images that have become part of art history. The ability to control colors and design in my Cibachrome prints take them out of found-object art. I consider this an important technique which has only begun to be explored.

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GLOSSARY

analyzer—the second polarizing filter, which recombines the two waves, which are out of phase, producing colored light through interference. Rotation of this filter brings out the various colors dictated by the type of retarder materials used.

azo—a chemical dye based on nitrogen, carbon and hydrogen used in acrylic color palette because of its acceptable degree of permanence.

birefringent—the property of a material to break down incoming polarized light into two parts, the fast wave and the slow wave, due to phase shift. Birefringence is not affected by the thickness of the material.

color correction filters—a series of filters for producing progressively more intense color, used to correct deficiencies of film or print material.

entoptic color—color obtained by interference between waves of different energy or phase shift.

polarizer—the first polarizing filter through which white light passes and emerges polarized at an angle determined by filter rotation.

retardance—part of the property of birefringence which causes the slowing or phase shift of one of the two waves. The thickness of the material controls the amount of phase shift.

retarder—the birefringent material consisting of cellophane, select plastics or certain minerals. Polarized light passing through any of these materials is broken into two parts.