Dichroic Filters: Their Use in Questioned Document Examinations

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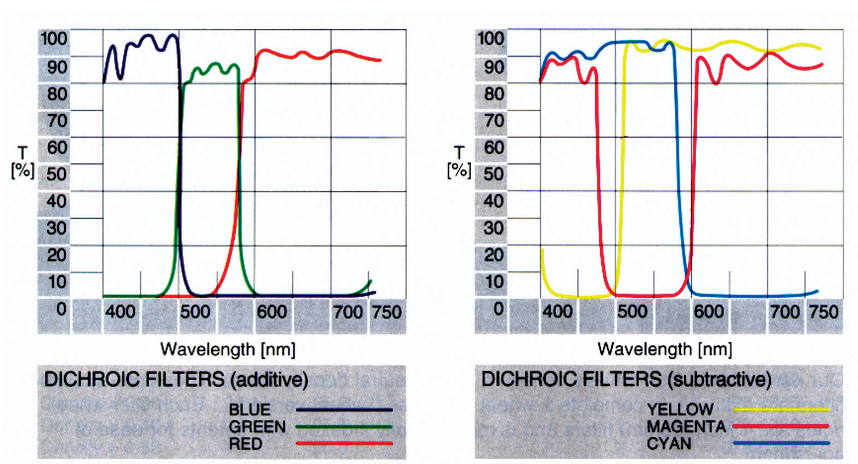
This paper provides a description and history of dichroic filters as they have been adapted and used by the forensic document examiner. In addition, an explanation is provided as to how the filters function in conjunction with the human eye or electronic imaging devise. Different types of filters and their sources are fully described.

Introduction

Since the early 1960s, forensic document examiners (FDEs) have known about a specific type of filter that is quite useful in differentiating between two seemingly identical inks or dyes. This filter is commonly known as a "dichroic" filter. Dichroic, in general terms, refers to any filter that transmits, absorbs, or reflects two colors of light. An example is a filter used in color projection, more commonly known as an additive color filter — red, green, and blue (Figure 1). These additive color filters are called dichroic because they absorb or reflect two major bands of light and transmit the third. Inversely, subtractive color filters cyan, magenta, and yellow are also called dichroic because they transmit two major bands of light and absorb or reflect the third (Figure 2). Almost any filter, or set of filters, that transmit, absorb, or reflect two bands of light can be classified as dichroic. However, the FDE has been interested in only one specific type of dichroic filter. That is, a single filter, or pack of filters, that permits a small amount of blue/green light to pass, and a large amount of red light to pass at the point where most human vision is at the end of its sensitivity.

History

A number of FDEs conducted early research into the hows and whys of the dichroic filter. In



Figures 1 & 2

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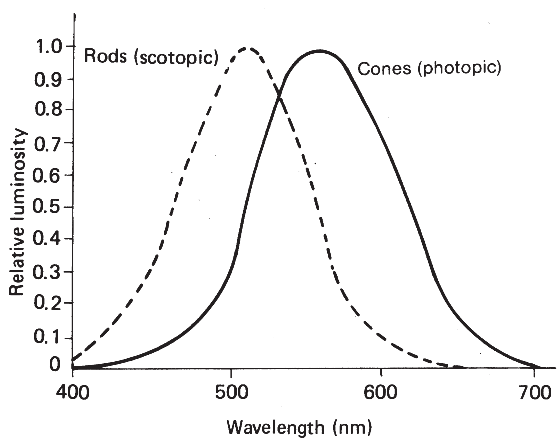
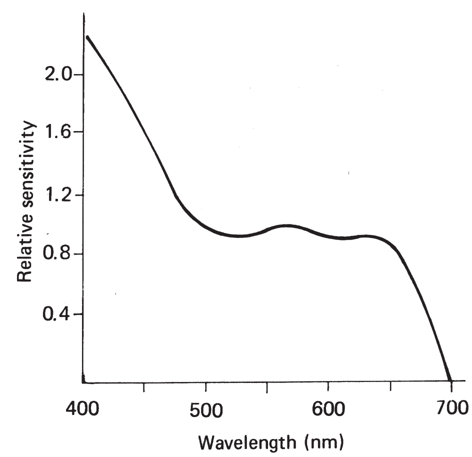
North America, it appears that the "father of the FDE dichroic filter" is Royston J. Packard of Ontario, Canada (1964). Packard credits E. W. Evans of Wores, England as the producer of the 'Evans Infrared Viewer,' an interesting attempt at making use of filters for selective wavelength examination of inks." In his book, Harrison (1966) provided four paragraphs vaguely referring to an unnamed light filter and incandescent light source used for the examination of ink writing. However, he held the view that an examiner using this filter is directly viewing infrared, claiming that the eye is not sensitive to the infrared. Packard, on the other hand, noted that many people can see quite far into the infrared portion of the spectrum, and the Evans Infrared Viewer did permit the observation of infrared energy. Also, Packard was of the opinion that the phenomenon observed through the use of dichroic filters was a matter of viewing reflected light from two parts of the visible spectrum.

Packard recognized and acknowledged that because the red reflectance was at the very end of the visible spectrum, and considering the differences in the red color sensitivity of each person or recording material, not all would see the same phenomenon with a particular filter or filter pack (Figures 3 & 4). Packard was the prime mover in the use of these filters by FDEs, and was directly responsible for Harris Tuttle, of Eastman Kodak Company, to have Kodak's research department produce a dichroic filter that could be used for general examinations. The first version of this filter was a cyan filter, Wratten Experimental Filter number 9186, which was used in combination with a Wratten 21 or 85B to form a dichroic filter pack. From this emerged the Wratten 97 filter which was described as a: "Dichroic filter used to detect visually the red fluorescence of chlorophyll in green foliage (Kodak, 1973)" (Figure 5). Again, this filter did not detect red fluorescence, but the reflectance of red. Unfortunately, Kodak has basically gone out of the filter business, and deleted most of the filters found to be useful by senior examiners.

Linton Godown, who corresponded with Packard on researching the dichroic filters (1964), listed a number of the Kodak Wratten filters that were useful in document examination. The Wratten filters listed were: 15, 16, 21, 22, 30, 31, 32, 33, 34, 34A, 35, 40, 44, 44A, 45, 45A, 50, 58, and 97. These were used in the following filter packs: 45+15 (or 16); 44+21 (or 22); 40+30 (or 34A); 55+30; 35+44 (or 45); and 97+11 (or 44). Of this long list, only the Wratten filters 15, 16, 21, 22, 32, 33, 33A, 44, 44A, and 58 are still available.



Phototopic and scotopic response curves for the human eye.



Relative spectral sensitivity of a panchromatic film.

Figures 3 and 4

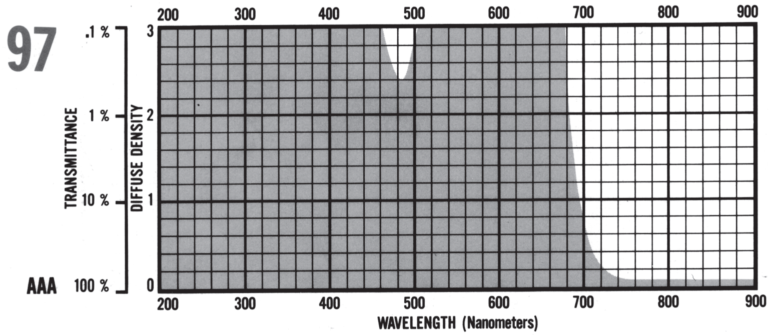


Figure 5

Godown observed that certain theatrical filters, used for controlling the color of lights, also worked well. Although Godown mentioned several sets of filters from two companies, the only set still available is the Rosco 13+131.

Ronald Dick (1970) conducted a number of experiments and determined that most inks that can be viewed as red using a dichroic filter, will also reflect and luminesce in the infrared. It is the author's experience that most inks do not "reflect," but transmit, or become transparent in the infrared. However, a number of inks have been observed that appear red with dichroic filters, but have no change in the infrared, leaving the dichroic filter a unique means of discrimination.

How Dichroic Filters Work

Dick (1970) perhaps best describes the physical process of how the dichroic filter works when he stated: "Certain blue, blue-black, and black inks, when illuminated by a light source that is rich in red radiation and viewed through the dichroic filter, will undergo a definite color change and appear as various shades of red and purple. Other inks will remain unchanged. The reasons for this phenomenon are obscure, but it appears that those inks that do undergo a change of appearance are reflecting a large amount of red radiation that is subdued in unfiltered viewing by the reflected blue-green radiation. When viewed through the dichroic filter, the blue-green region is subdued and the predominant red allowed to pass. Yet enough of the blue-green region is also transmitted that, when combined with the red, the visual appearance of the background material does not undergo a significant change."

In other words, the filter, or filter pack, has two components. The first is the transmission of a small amount of blue or blue/green light. This portion of the transmission is usually somewhere in the 400nm to 600nm range and, as a rule, transmitting about 5% to 10%. It should be remembered that the human eye is extremely sensitive to this portion of the spectrum and can easily detect this small amount of energy (Figure 2). The second component is the transmission of a large amount of red energy just at the very end of the visible spectrum. This portion of the transmission is usually somewhere in the 680nm to 750nm range, at 60% to 70%. There is a fine balance of these wavelengths and quantities for each individual to see a "normal" background. Changing either range of transmission, even slightly, may make the background appear blue or red. When the small amount of blue/green, for which the eye is highly sensitive, and the large amount of red, for which eye is insensitive, are combined, the result will give the general effect of white light. Therefore, when viewing a piece of paper with black ink that does not change through the filter, it would appear relatively normal. However, if a second black ink that had a high degree of red reflection, normally suppressed in white light, is placed on the paper, that ink will appear red when viewed with the dichroic filter.

Current Sources of Filters

As previously mentioned by Godown, certain theatrical filters used for controlling the color of lights can also be used for document examination. Although there are several companies that produce filters, such as Bogen, Gamproducts, LEE, and Rosco, the two largest and most widely available are LEE and Rosco. Both companies have well over one hundred color filters available. Each has free sample packs, or swatch books, that can be requested directly from the companies or obtained through distributors. These packs are used by the author, and many other document examiners, to produce 2x2 inch slides that can be hand-held to view a document, or projected onto the document via a slide projector. In addition, the remainder of the packs can be used to produce a filter reference chart (Figure 6). Also, by taking any two or more of these slides and forming a filter pack, the examiner can experiment with a wide variety of filters at no extra cost. Figures 7a through 7c illustrate ink from seven different pens when viewed with normal white light, with a LEE 20+85 dichroic filter pack, and using infrared luminescence.

Both LEE and Rosco filters can be obtained through photographic stores, theater equipment dealers, and a number of other sources. The LEE filter company's main address in the United States is: LEE Filters, 2237 North Hollywood Way, Burbank, California 91505, phone number

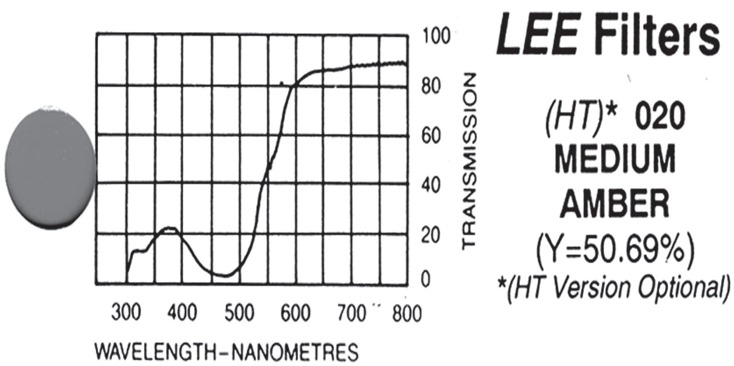


Figure 6

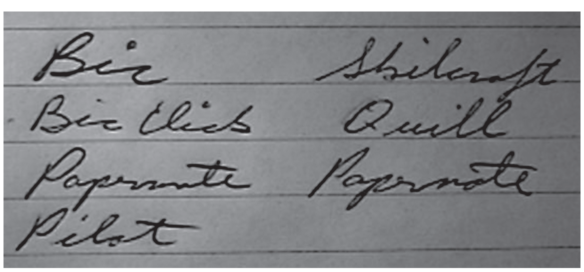


Figure 7a

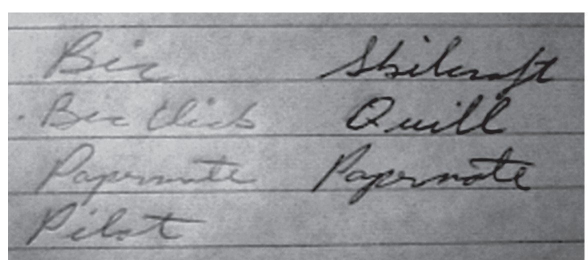


Figure 7b

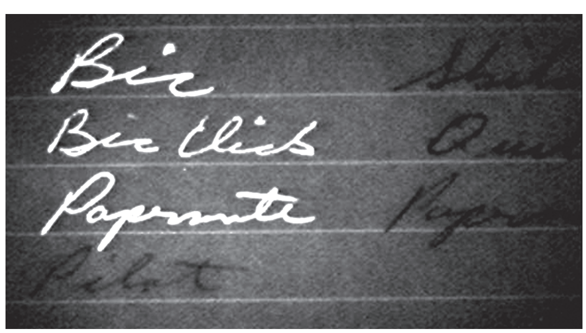


Figure 7c

(818) 238-1220. In Canada their address is: LEE Filters, 103-7 Labatt Avenue, Toronto, Ontario M5A 1Z1. The address for Rosco in the United States is: Rosco Filters, 52 Harbor View Avenue, Stanford, Connecticut 06902, phone number (203) 708-8900. In Canada their address is: Rosco Filters, 1241 Denison St. #44, Markham, Ontario L3R 4B5, phone number (905) 475-1400.

Figures 8a through 8d represent an example of the transmission characteristics of a LEE 20+85 filter pack.

Types of Filters

Almost all the filters discussed in this paper have base materials that are polymers; i.e., acetates, vinyls, polyesters, and polycarbonates. In addition, many of the filters made by LEE and Rosco can be provided with a glass base. The great majority of the filters are dyes in a polyester base. If the number designation includes HT (High Temperature) at the beginning, the base is polycarbonate. The reason for the different materials is that polyester melts at approximately 356 degrees Fahrenheit, while polycarbonate melts at approximately 536 degrees Fahrenheit. It should be remembered that these filters are produced for hot theatrical lights.

Rosco uses a number of names to describe the infrared filters. For example, Roscolene is a filter set that uses either acetates or vinyls (PVC) as a base material. These materials can only be used with cooler light sources. However, most of these materials can be used as either barrier filters (in front of the eye) or excitation filters (in front of the light source) in conducting document examinations. Roscolene numbers are three digits beginning with an "8." The current swatch book starts at 801 through 883. The Roscolene filters are more difficult to obtain, since many distributors do not carry the full line. Roscolux, or Supergel as it is called outside of the continental United States, is the newer more heat resistant base material. Approximately 35% of Roscolux filters are made from polyester, and approximately 65% are made from polycarbonates. Many of the Roscolux filters are produced using three layers, with the color layer sandwiched between two extremely thin clear layers.

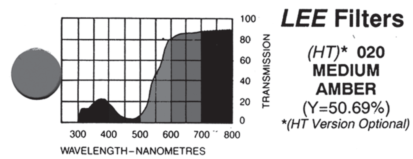


Fig. 8a. LEE 20

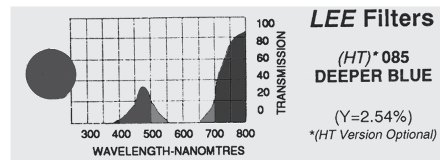


Fig. 8b. LEE 85

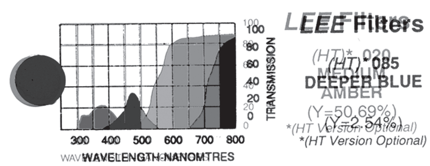


Fig. 8c. 20+85 Overlaid

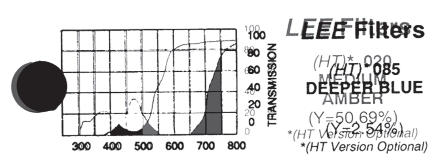


Fig. 8d. Transmission when 20+85 combined

Conclusion

The biggest single problem with the use of dichroic filters is the variance in the red sensitivity of each observer or recording media. Many document examiners have a group of filter packs that contain enough variation that most observers can find a filter that will work for them. However, it should be noted that there are some individuals who do not have enough red sensitivity to ever observe the phenomenon. This should be considered before using a dichroic filter to demonstrate a finding for a jury.

Over the years, many well-known FDEs have shared their experiences using various combinations of theatrical lighting filters. Miller (1998) recommended the Roscolene 856+813 and 878+855. Tytell (1998) reported his favorite combination is the Roscolux 20+83. Hart (1997) recommended a Roscolux pack 21+80. There are several filter packs the author has found useful including the LEE 20+79, 21+79, and 20+85, along with the Roscolene 815+857 and 815+862. Hart and the author agree their favorite and most used combination is the Roscolux 21+80. However, these are only suggestions, and it is imperative that each examiner obtain a swatchbook and test the numerous combinations in order to find the set or sets that suit their own eye sensitivity and equipment. It should also be remembered that this process will only work when illuminated by a light source extremely rich in red. Almost any very bright incandescent light will work.

When conducting an examination regarding substitution, alterations, insertions, etc. it is necessary to use all the tools at your disposal. Although ultraviolet and infrared are mainstays, the humble filter still can be a valuable aid. Even though the reactions encountered when using a dichroic filter will closely correlate to the reactions found with infrared, a number of instances have been noted by many examiners wherein the inexpensive dichroic filter was the only discriminator.

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Sources of Figures

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Figures 3 & 4	Stroebel, Leslie, et al, *Visual Concepts for Photographers*, London; Focal Press Ltd., 1980. p 247.
Figure 5	Kodak Filters for Scientific and Technical Uses, Kodak Publication No. B-3, revised June 1973, Rochester, N. Y.
Figure 6	LEE Filters, Swatchbook, Burbank, California.
Figure 7	Richards' Forensic Services Pen collection.
Figure 8	LEE Filters, Swatchbook, Burbank, California.