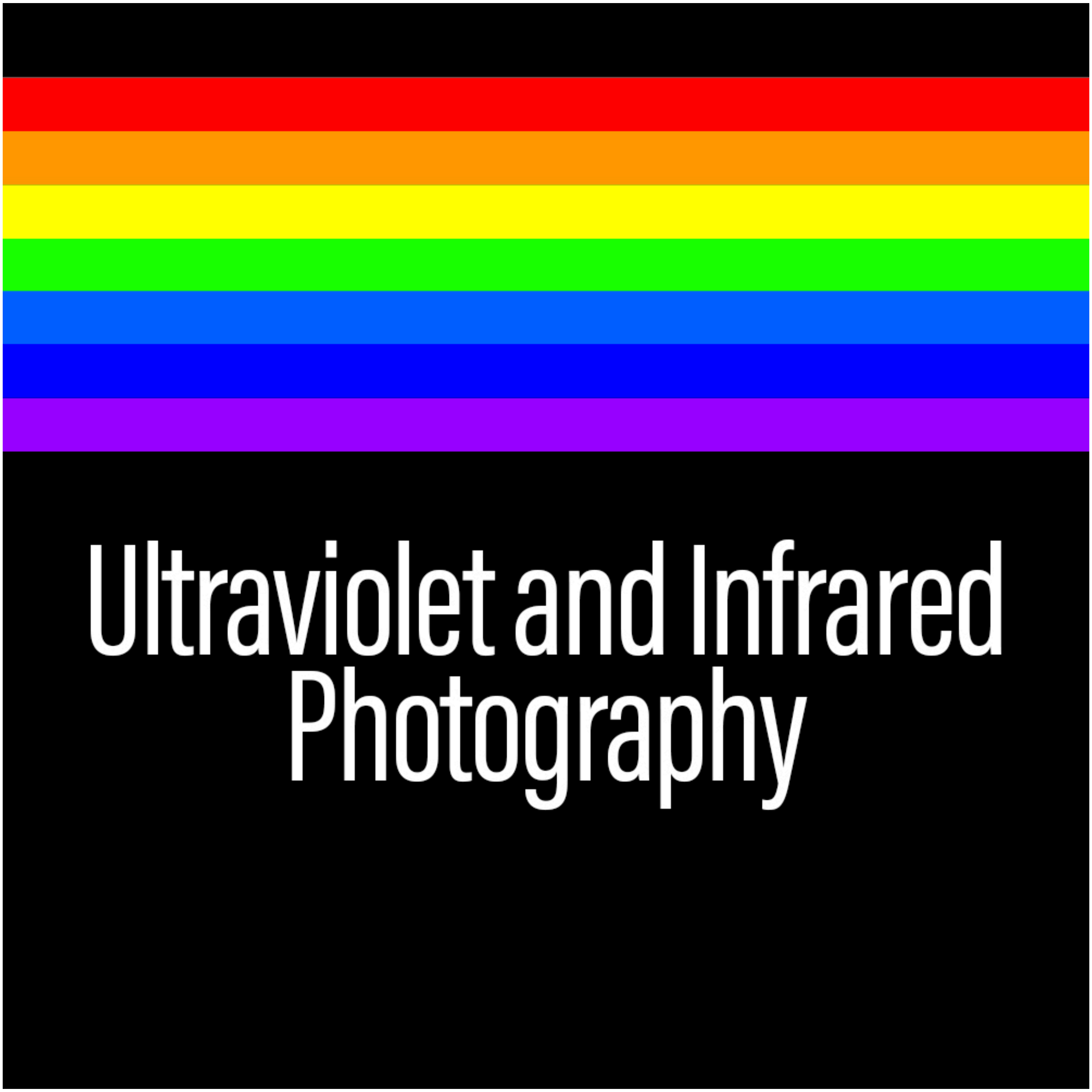
PHOTOGRAPHY



Written by Arthur H. Borchers

NEARLY ALL ASPECTS of forensic investigation require accurate documentation. The actual scene of any incident cannot be frozen in time and brought before a trier of fact sometime in the future. The best way to preserve a scene is through detailed photography.

Courts require admissible photographs be true and accurate representations of the original scene. Many photographers understand their cameras are recording only the visible light their eyes can see without understanding the complexities of how the light and their cameras interact.

Sir Isaac Newton showed what we take to be white light when passed through a prism comes out as rainbow: red, orange, yellow, green, blue, indigo, and violet. Now it is known that light bends when moving from air to glass (or other medium) and exits in its component colors. Visible light and its inherent colors are part of the electromagnetic spectrum and expressed as wavelengths (*Figure 1*) between 380-400 and 700 nanometers (nm)—or, in slightly more understandable terms, 0.0004 to 0.0007 millimeters.

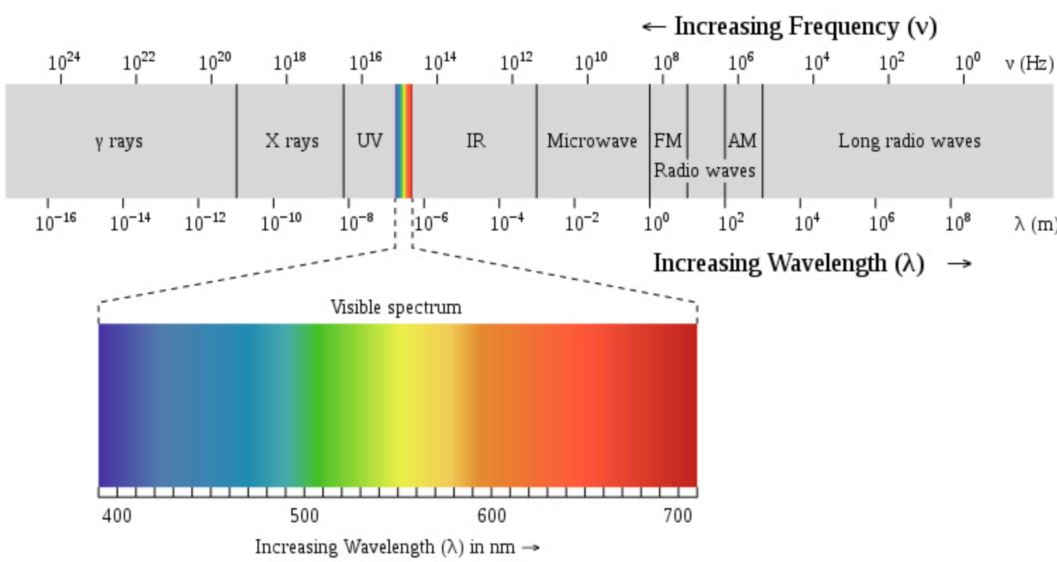


Figure 1—Electromagnetic Spectrum. Source

At both ends of the visible light range are infrared (IR), or "below red," and ultraviolet (UV), or "beyond violet." The infra/below and ultra/beyond prefixes derive from the light's frequency value, not the wavelength. UV-IR areas of the spectrum are not generally perceptible by the human eye. Some snakes can sense IR or heat sources, even in total darkness. Birds and insects can see in the UV range to better visualize flowers and food sources. Both IR and UV have forensic applications, but capturing images utilizing their illumination requires special care and equipment.

Light striking an object can be transmitted, reflected, absorbed, or converted (Robinson, 2010). Humans perceive the color of an object because the object either absorbs or reflects visible light: an apple absorbs all light except red, which is reflected back to our eye; grass reflects green light; and black objects reflect no light. Glass transmits light. Tinted glass transmits only specific wavelengths and eliminates all others. Filters which exploit the transmission property will be discussed a bit later.

Forensic UV has been in use for years because UV light will cause organic and other chemical compounds to fluoresce. Fluorescence is a reaction to UV light where a substance absorbs the UV photons, atoms in the substance are excited, and then they emit a photon of a longer wavelength—typically in the visible spectrum. Commercially, this can be seen in the use of "whiteners" in laundry detergent and fluorescent highlighters and markers that appear to "glow." The color of the fluorescence is related to the chemical structure of the substance being illuminated.

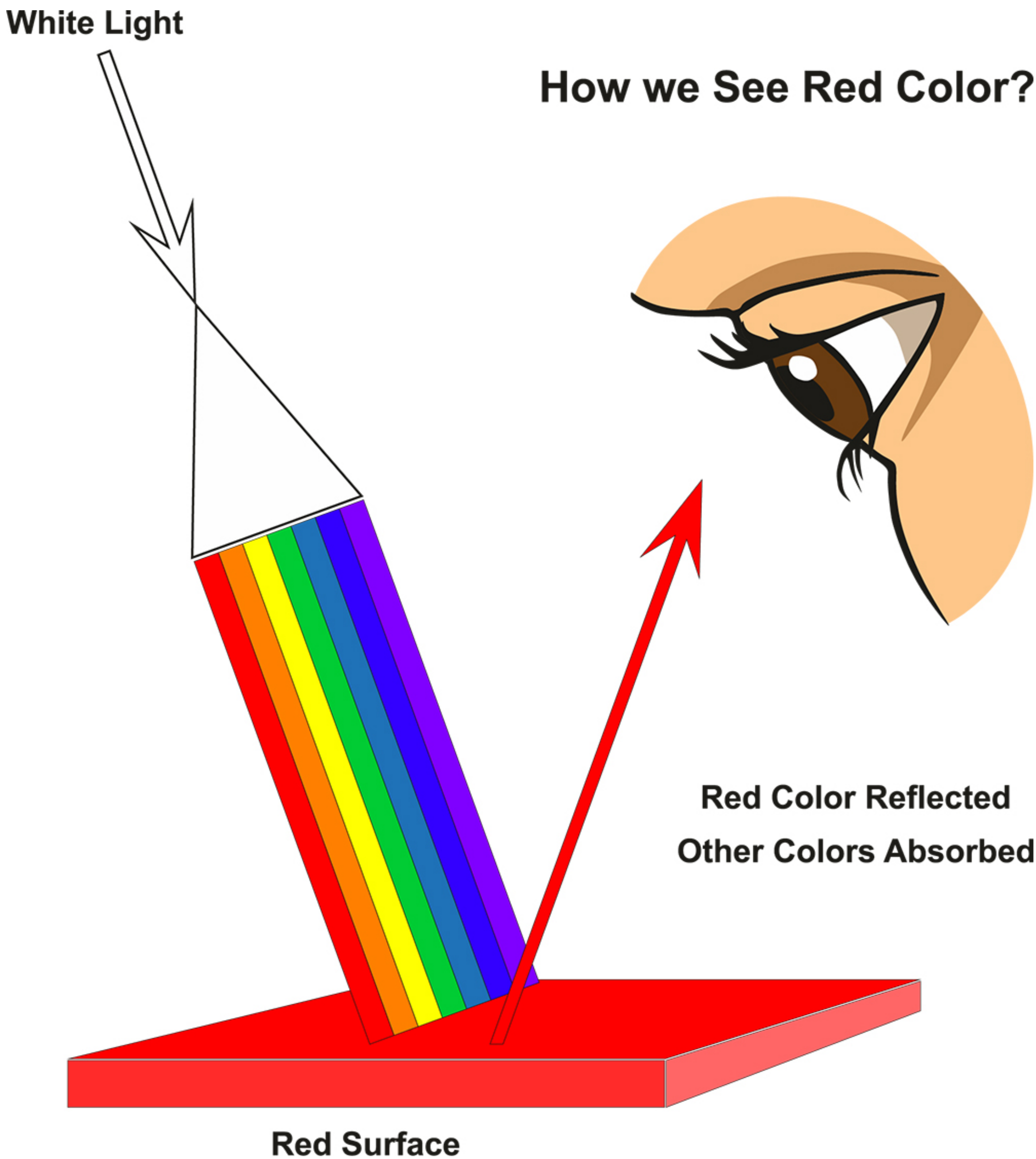


Figure 2—Reflection and absorption. udaix / Shutterstock.com

UV light is also broken into three general bands: UV-A, UV-B, and UV-C. UV-A, also called longwave or near UV, has a wavelength of about 320 to 380-400 nm. UV-B (mediumwave UV) falls between 280 to 320 nm. UV-C (shortwave UV) ranges between 200 to 280 nm. Most of the UV light that reaches the Earth from the sun is UV-A from 315 to 380 nm because all lower wavelength light is blocked by our atmosphere. UV-C is not naturally occurring on Earth and is dangerous to humans. UV-C is used as a commercial disinfectant in airplanes, hospitals, some office environments, and water-treatment facilities. The UV-C light destroys the DNA material within bacteria, viruses, and protozoa. For forensic purposes, use of UV-C lamps should only occur on a crime scene after any DNA search and recovery.

Below 300 nm, normal optical glass and its coatings absorb UV light. So, when using this light for imaging purposes, specialized lens materials like quartz or calcium fluorite are required. Lenses with these materials are quite expensive, often costing several thousands of dollars. Modern camera lenses are designed to reflect UV away from the sensor. The lower-wavelength UV photons are higher-energy than both visible and IR light, making its use dangerous to the eye and exposed skin. UV-protective glasses and high-SPF sunscreen protection are required.

Forensic UV light sources typically operate in the UV-A range and some visible light may also be emitted. A yellow filter is often used on the camera to enhance the fluorescent image by eliminating the bluish light.

IR light is divided into three common bands: IR-A, IR-B, and IR-C. IR-A, also called Near IR, has a wavelength range between 700 and 1400 nm. IR-B extends from 1400 to 3000 nm. IR-C is between 3000 nm and 1 mm. For photographic purposes, IR-A is the only range used. The IR laser in most laser scanners operates in the IR-B range, at 1550 nm.

In the film era, UV and IR images could only be captured with specifically formulated media. UV was captured only on black-and-white film. IR film was extremely sensitive and had to be loaded into the camera in complete darkness. The filter used, Kodak Wratten 18A, is no longer manufactured. The replacement filters, the U-360 and UG-11, are flawed with a near-IR light leak. For black-and-white film, that was not a significant issue as the film was not very red-sensitive. Using those filters on a digital sensor did not produce the expected results, primarily due to a lack of understanding about how digital sensors work.

In simple terms, a digital sensor detects focused light falling on its surface. A sensor has millions of photodiodes—or photosites—arrayed across its surface. A patterned color filter covers the sensor and makes each photosite sensitive to only one wavelength of light: red, green, or blue (RGB). The most-used pattern is called a Bayer Filter (*Figure 3*).

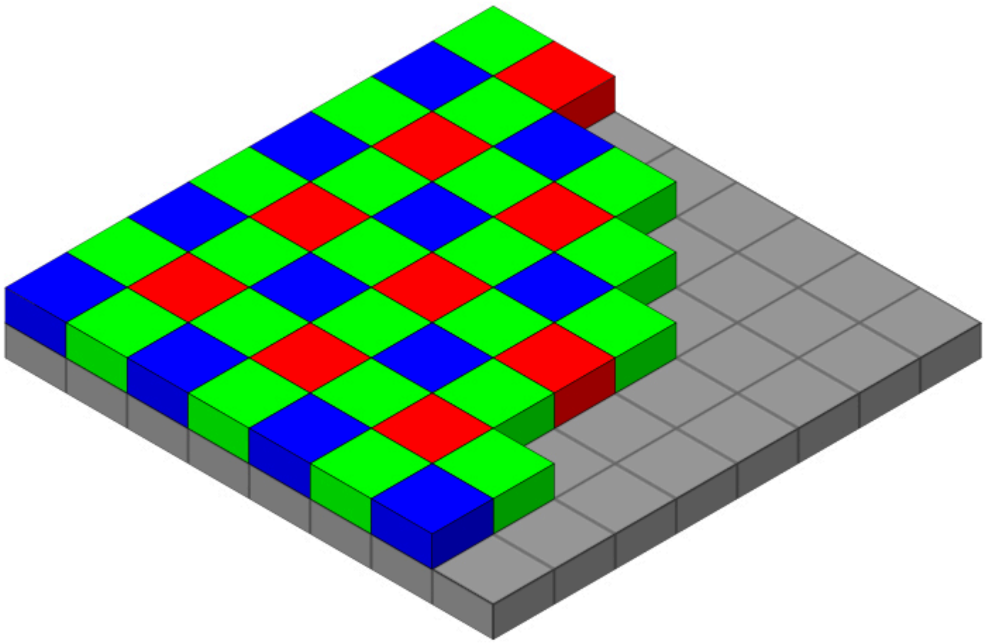


Figure 3—Bayer filter on a sensor. Image: Colin M.L. Burnett / CC BY-SA 2.0

If the light falling onto a photosite with a red filter has a red component, the light is converted to an electrical charge. The information from the red, blue, and two green photosites are resolved to form the color information for an individual photo element, or pixel, in the final image. Sensors are typically sensitive to light wavelengths from about 350–1050 nm. A special filter called a hot-mirror is mounted over the image sensor. The hot-mirror prevents image capture of fringe UV and IR light, making the camera capture light ranges typical of film cameras. *Figure 4* depicts an absorbing hot-mirror filter. There are reflecting versions of hot-mirrors that appear more mirror-like.

Figure 4—Hot-mirror filter. Image: Arthur H. Borchers

Modern DSLR lenses often do not work well in UV-IR applications, as their lens elements are designed with either coatings or glass that filters or reflects UV light away from the sensor. When they do work, one must use long exposures and higher ISO settings, requiring the use of a tripod. Due to the different wavelengths of UV and IR light, they focus at a different point than visible light. On film camera lenses, an IR dot was often included on the lens barrel (*Figure 5*). The procedure to focus an IR photo was to manually focus your composition, install any filters required, note the distance on the lens barrel, then turn the focus ring so that distance aligned with the IR dot, and then release the shutter (*Figure 6*). Older lenses from film cameras often lack the extra protective coatings, which makes them especially useful in UV-IR applications. Focus for UV images is accomplished by turning the focus ring to the left by a similar amount as in IR (*Figure 7*).

Figure 5—IR focus dot to the right of f/4 depth of field mark. Image: Arthur H. Borchers

Figure 6—Focus adjusted to align with IR dot. Image: Arthur H. Borchers

Figure 7—Focus adjusted to left for UV light. Image: Arthur H. Borchers

To avoid the UV lens-coating issues, a useful alternative is to search out a film camera lens. In a lab setting, an alternative is to use an old enlarger lens. Enlarger lenses are designed to project a focused center-to-corner image across a sheet of photo paper, called a flat-field design. Using an enlarger lens on a camera will provide better final coverage in-document or focus-stacked, layered images. Enlarger lenses lack the ability to focus, so a helicoid extension tube or rail-mounted bellows is required. (See *Figures 8 & 9*). The use of an extension tube or bellows also gives the added benefit of being used in macrophotography applications.

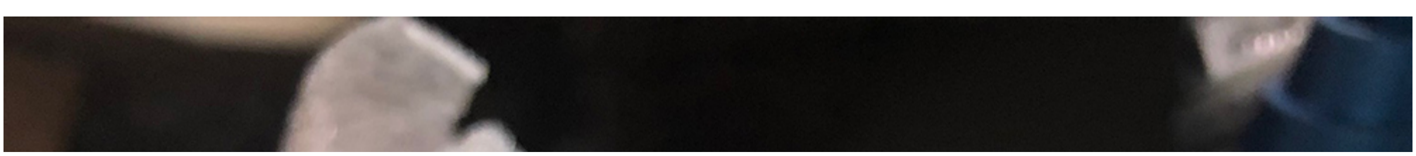


Figure 8—Screw-mount lens with helicoid extension tube and DSLR camera mount. Image: Arthur H.

Borchers

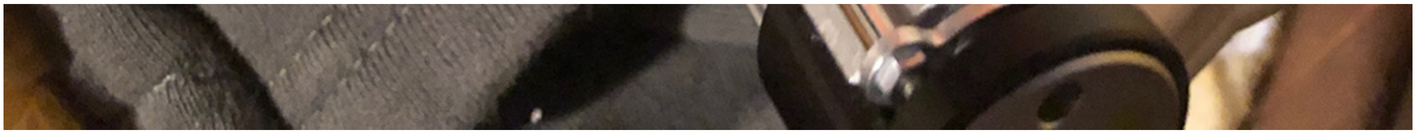


Figure 9—Canon Bellows FL for macro and focus stack work with various lenses. Image: Arthur H. Borchers

On the UV end of the spectrum, melanin in the body left as the result of a bite mark or deep bruise will absorb UV while the surrounding tissue reflects it for a significant amount of time—potentially several weeks—after the original bruise fades. Fingerprints and body fluids will absorb UV-C and stand out from a reflective background. New versus old paint on a car or wall can be easily identified. Inks all have different reactive qualities for questioned-document examination in both UV and IR. Writing on burned documents can often be discerned under IR light. Tattoos on decomposed or burned bodies may be enhanced to assist in identification. To avoid any confusion with color issues, UV-IR images are best viewed in grayscale.

Commercial forensic reflected UV imaging systems, called RUVIS, include both quartz lenses and an image intensifier that make such units prohibitively expensive for most agencies.

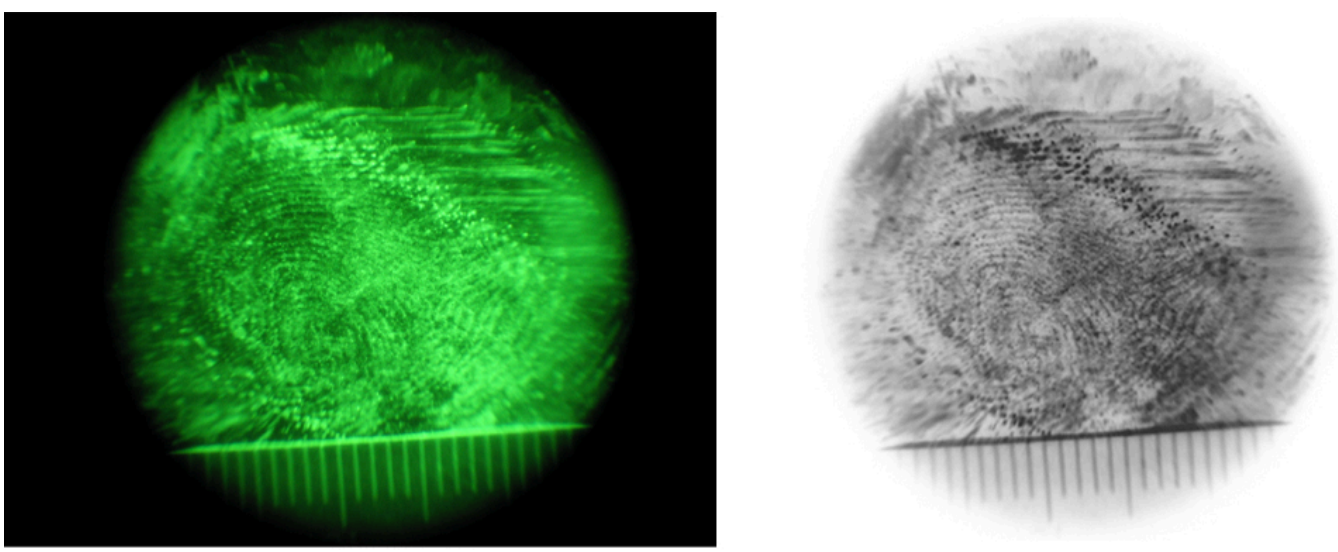


Figure 10—Example RUVIS image and grayscale conversion. Image: Arthur H. Borchers

Figure 11—Natural light and UV 780 nm capture of gunshot residue on black shirt at four distances. Image: Arthur H. Borchers

As mentioned, auxiliary lighting, long exposures, and a tripod are often required. The normal color image on the left in *Figure 11* is a black shirt with gunshot residue from four shots that was captured at 1/30, f/8, at ISO 800. The image on the right was captured with a 780 nm IR filter, 30 sec., f/11, at ISO 3200. The bullet holes and varying amounts of gunshot residue due to varying distance of each shot can be seen.

Digital cameras can be modified by removing the hot-mirror from the front of the sensor. Commercial camera conversions will remove the hot-mirror and install either a clear or IR-only filter in its place. Replacing the hot-mirror with a clear filter is called a full-spectrum conversion, leaving the camera with broader than original UV-IR coverage and sometimes allow handheld operation. A better practice is to always use a tripod to ensure a steady image. While it is possible to remove the hot-mirror yourself, having a skilled vendor perform the modification will provide a guarantee the operation is done competently, and the camera will focus correctly.

A camera with full-spectrum conversion can be equipped with a wide range of broad or narrow range filters, depending on your application or desired effect. The filter selection includes a hot-mirror (*Figure 3*), so that near normal appearance images can be captured.

In the DSLR age, filters are not often used. Certain film filters (FLD) were used to correct for fluorescent lights while using daylight balanced film. When using black-and-white film, color filters were used to enhance or subdue tones for artistic purposes. In a forensic setting, filters were rarely used. Now, DSLR cameras can be adjusted internally for custom white balance, increased color saturation, and other artistic settings. Neutral-density filters may be used to extend exposure time for creative reasons to include highlighting a laser path or object motion. In UV-IR photography, filters are used to custom tailor the specific wavelength of light striking the camera sensor. There are dozens of filters to choose from.

Filters for UV-only applications often have a slight IR, near 700 nm. This can be very detrimental to UV photos, as IR overpowers the less-prevalent UV light. Filters for UV applications are substantially more expensive, often costing several hundred dollars. The Venus U filter shown below (*Figure 12*) is a UG-11 filter with a dielectric coating on the front and back surfaces for UV light only transmission.

Filters often have transmission graphs available. The diabatic logarithmic scale shown in *Figure 13* demonstrates the optical density and wavelength suppression. In this instance, a U-340 filter is shown with and without a pairing with an S-8612 filter. The critical line in this graph is 1E-03, which shows that the U-340 alone has an IR leak above the 1E-03 line at 650–800nm. The U-340 used with the S-8612 filter does not extend above the 1E-03 line and therefore would be an acceptable pairing for UV-only use. IR filters are more reasonably priced and the numbers in their name often represent the light cut-off lower limit of IR transmission, e.g., 715, 780, 830, 850, and 1000 nm (*Figure 14*).

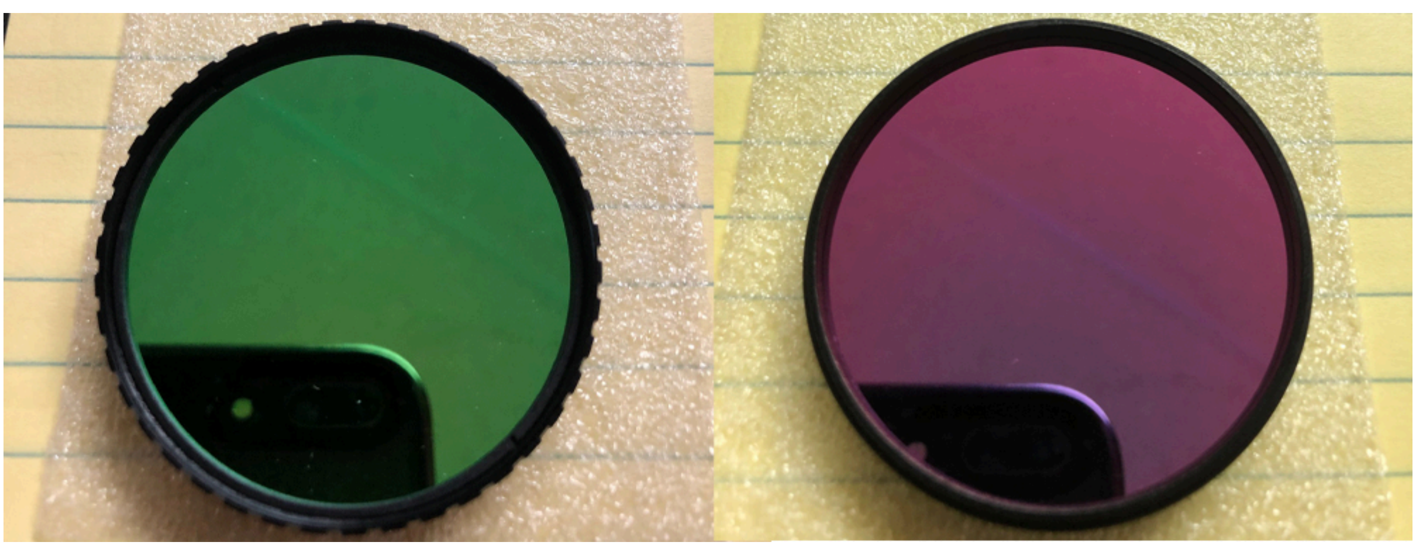


Figure 12—Front and back images of Venus U filter. Image: Arthur H. Borchers

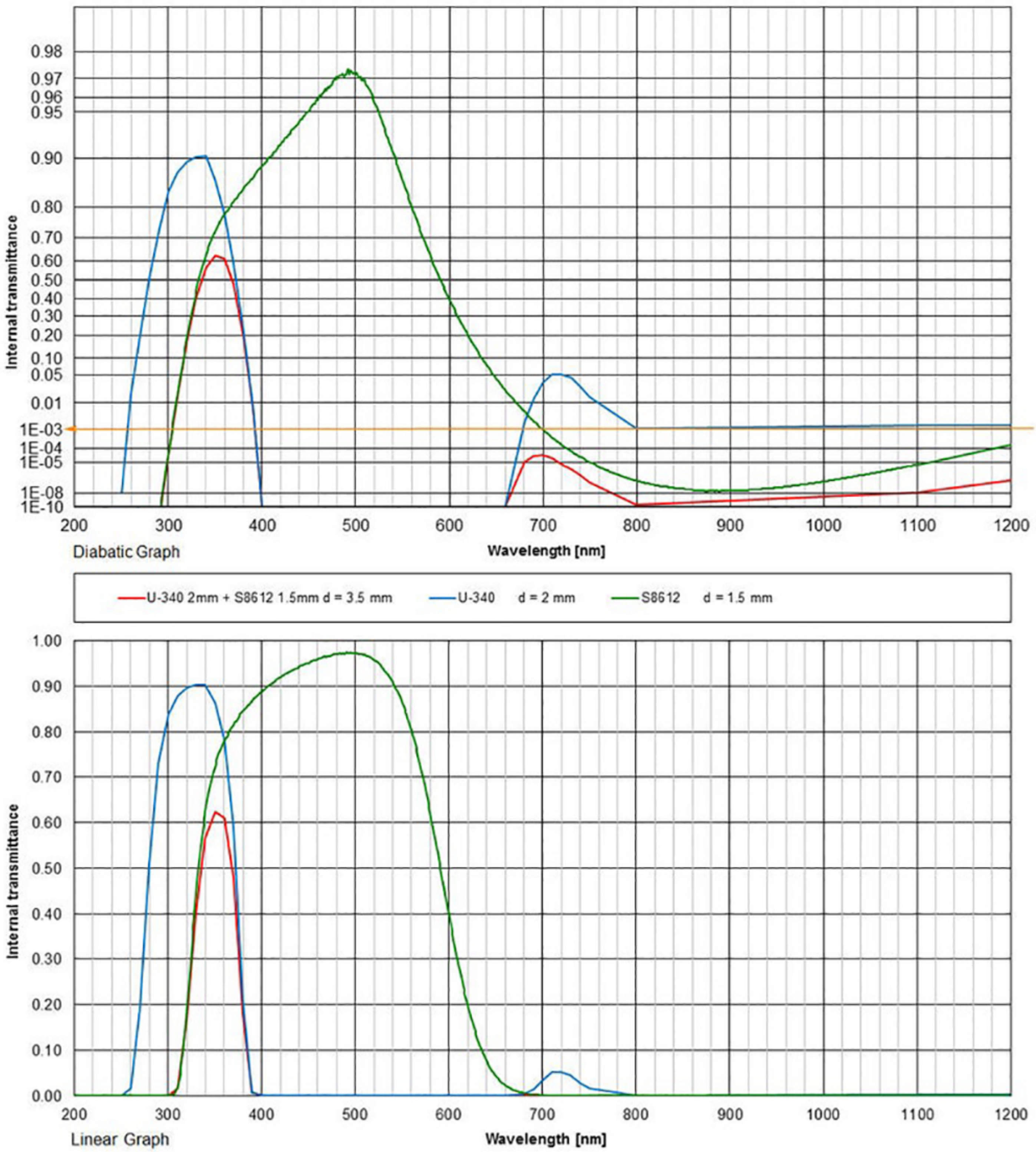


Figure 13—Sample UV-IR light transmission graph. Image: UVIROPTICS

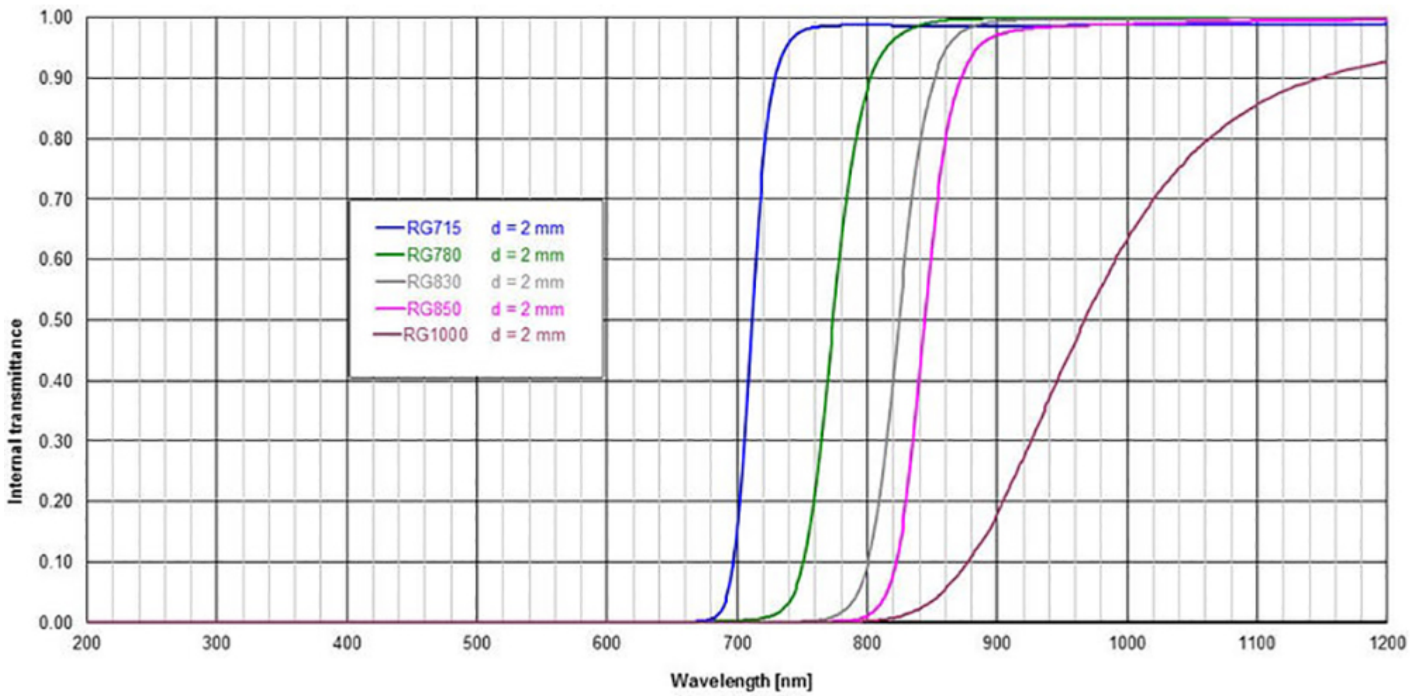


Figure 14—IR filter transmission graph. Image: UVIROPTICS

Lighting for UV-IR applications is an important consideration. IR is often considered in the context of heat. Outdoor scenes are helped by the sun. However, anyone with forensic experience knows most serious events happen at night. LED and fluorescent lamps will not work for IR. Photographic flood lights or quartz halogen work lights will provide broad spectrum light suitable for UV-IR purposes. Some LED lamps are available in the 365-nm range, but the majority are commercial "black lights." UV-B/C lamps are "germicidal" bulbs with peak output in the 254-nm range.

A standard photo flash can be modified for UV-IR photography by removing the plastic filters in front of the xenon flash tube. Once the original filters are removed, application-specific filters can be mounted over the bare flash tube to limit output to required wavelengths, as well as give some protection to and from the exposed parts. Extreme caution should be taken when opening a flash, as the internal capacitor can retain an injurious electrical charge. If you are not comfortable with such a modification, the camera modification vendors can often do the work.

UV-IR is not a normal, everyday photo assignment. Understanding the complex nature of

UV-IR spectrum is demanding. The moderately expensive gear requires justification that an administrator might not understand without a demonstration of its value. The fact that UV-C can damage potential DNA recovery may cause further hesitancy. However, the potential benefits are significant. The skill requires dedicated practice and documentation to have value and be accepted in a court setting. Your commitment as a forensic photographer is key. Merely having the equipment is just a first step. Frequent practice will make you ready when the important job comes in.

About The Author

Arthur Borchers is an adjunct instructor for the Homeland Security Training Institute at the Suburban Law Enforcement Academy / College of DuPage and a forensic consultant with Larsen Forensics & Associates, both in Glen Ellyn, Illinois. Borchers has advanced training and experience in photography, photogrammetry, firearms, shooting, crime scene, and traffic-crash reconstruction after retiring from the Oak Park (Illinois) Police Department. He is also a contributing author to Sanford Weiss' forthcoming book, *Forensic Photography for the Preservation of Evidence* from CRC Press.

Reference

Robinson, E. M. *Crime Scene Photography, 2nd Ed*. (2010) Cambridge: Academic Press.

Sources for additional information

Kolarivision.com
Lifepixel.com
Maxmax.com
Company7.com
Midopt.com
Baader-Planetarium.com/en

etsy.com/shop/UVIROPTICS

Photographyoftheinvisibleworld.blogspot.com

InfraEdd.blogspot.com

Edmundoptics.com

Spencerscamera.com

Contrastly.com