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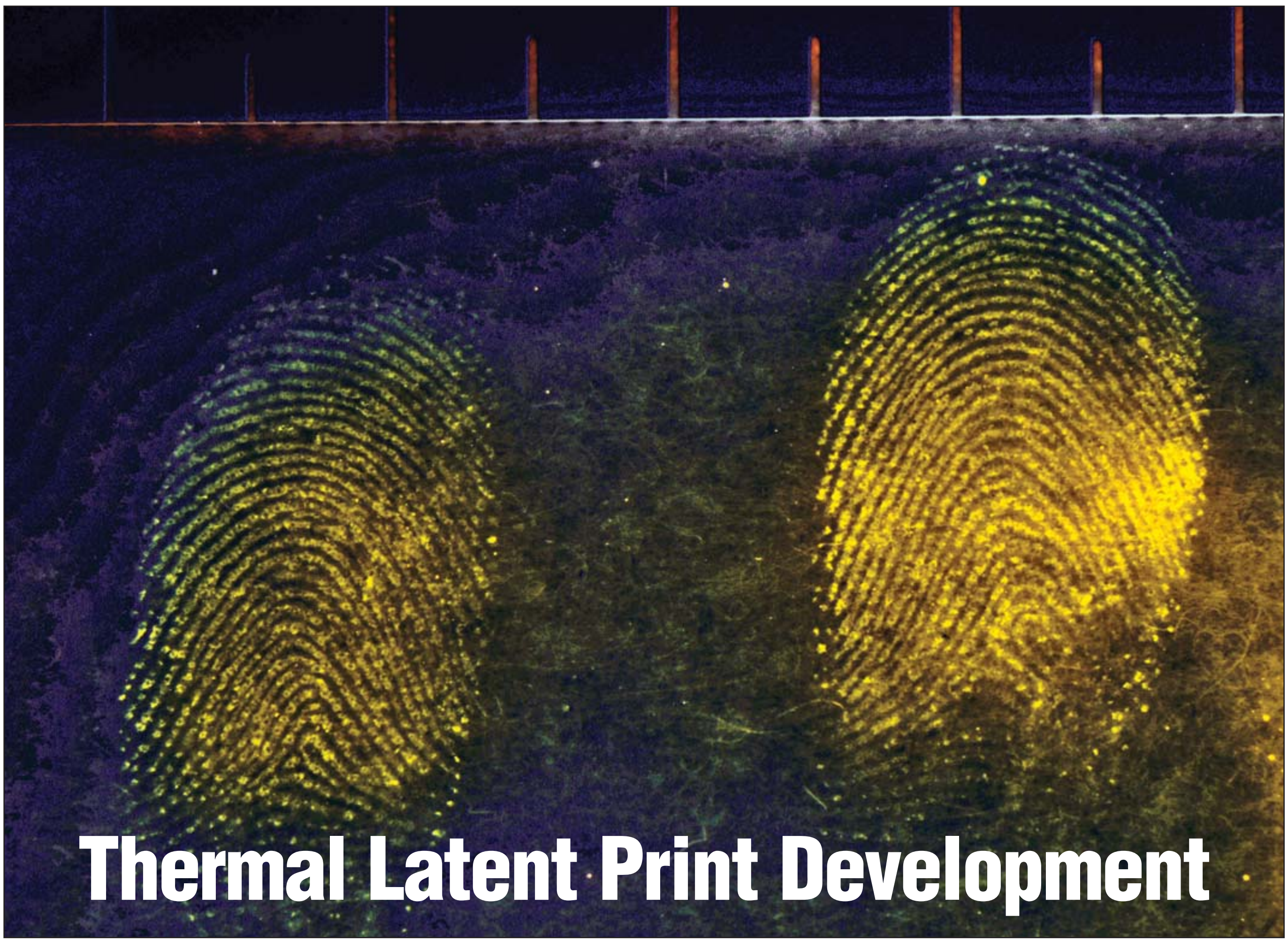

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Longwave UV Imaging

A Way to Find Invisible Evidence Fast

Written by Dr. Austin Richards and Rachel Leintz

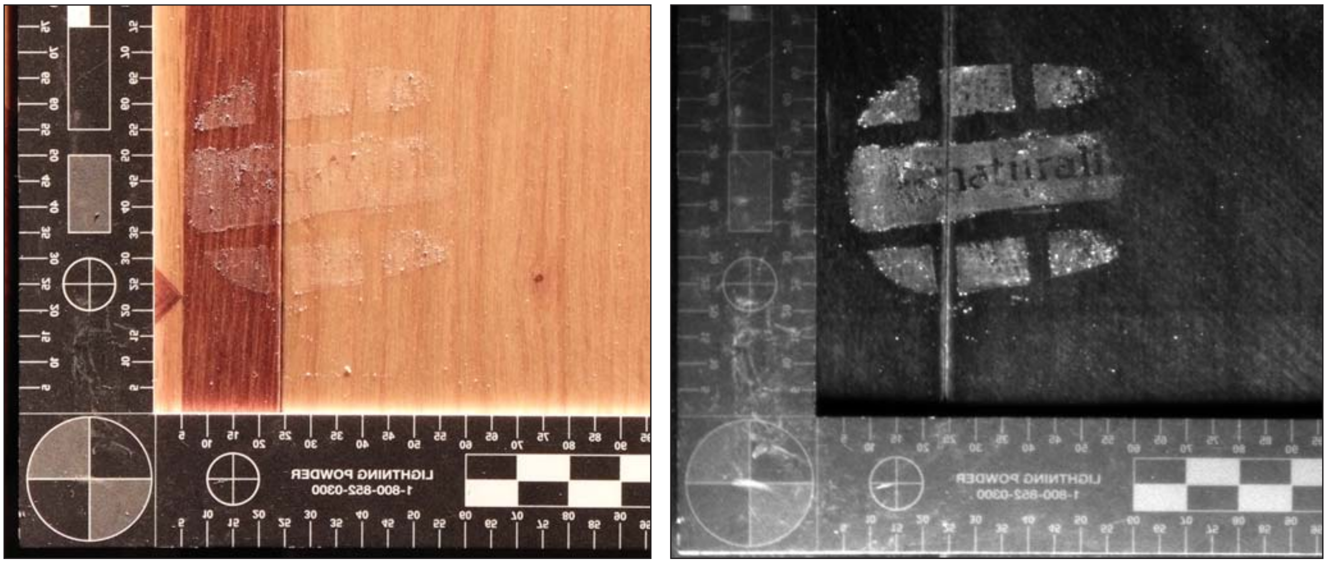


***Figure 1a and Figure 1b**—These are images of a dusty shoeprint on a wooden floor. The image on the left is a color photograph taken in visible light. The one on the right is a longwave UV image. Notice how the brand name of the shoe (“Naturalizer”) is clearly visible in the longwave UV image.These images were flipped horizontally for readability of the brand name. (Photos courtesy of Rachel Leintz)*

PATENT SHOE PRINTS on hard floors are one of the most difficult types of evidence to locate and document at a crime scene. The soles of shoes are sometimes covered in dust, blood, or some other contaminating material that can transfer to a floor surface when a suspect walks on it. The prints can be quite faint initially, but when they are superimposed on a floor with complex patterns, they become very hard to see. The difficulty in visualizing these prints increases as the print trail moves farther away from the original source of contamination. As difficult as this type of evidence is to document, capturing the individualizing characteristics of these prints can be crucial for investigative leads and prosecution of suspects. In fact, the visibly fainter prints will often have the best identifying characteristics, since a very wet or thick print can have its details completely obliterated by the thick level of contamination.

Electrostatic dust print lifters (EDPL) are used to lift dusty shoe impressions and transfer a portion of the dust from the surface onto a uniform black sheet of mylar film so the impressions can be photographed or scanned with high contrast. But the lifters can be destructive to the print itself, expensive, and—due to the concern over contamination—are often not reusable. It is also not easy to figure out where to put the EDPL just by visual inspection and random placement. While it may capture the prints, this technique is prohibitively expensive and could result in partial print lifts.

Ultraviolet (UV) imaging techniques for crime scene investigation have been around for many years. But the methods used were often time consuming and sometimes difficult to reproduce. Longwave UV imaging of crime scenes is a very useful technique that has come of age due to the development of key technologies.

Forensic investigators have always needed a method of precisely locating these prints so they can be marked for processing. A powerful method known as *reflected longwave ultraviolet (UV) imaging* makes it possible to image dusty and bloody prints with high contrast without coming in physical contact with the print. First, the surface is illuminated at an oblique angle with longwave UV radiation. Then, the investigator uses a longwave UV camera system or viewing device to visualize the prints. Longwave UV is defined as electromagnetic radiation in the 300-400 nm wavelength range. For comparison, visible light is 400-750 nm, and shortwave UV is 200-300 nm. Oblique illumination works well because UV radiation is scattered up toward the investigator’s imaging device by the dust in the impressions.

The shorter wavelength of the UV makes it scatter much more readily off tiny dust particles compared to visible light. The higher energy of the UV radiation results in it being absorbed by many types of surfaces found at crime scenes, like wooden or vinyl floors. The combination of more scattering by the dust and more absorption by the substrate creates contrast that often far exceeds that of a visible-light image.

Longwave Ultraviolet Images

Figures 1a and *1b* are images of a dusty shoeprint on a wooden floor. The left image is a color, visible-light photograph for reference purposes. The right is a longwave UV image taken with a Fujifilm IS Pro camera, a Universe Kogaku quartz lens, a Baader Planetarium UV Venus filter (to block everything but longwave UV) and a high-intensity UV LED light source from Clearstone Technologies.

Bloody prints can be imaged with this method as well. *Figures 2a-b* show a pair of unprocessed bloody fingerprints on a smooth white background. The prints are faint to the unaided eye, as shown in the color image, but the UV image has much higher contrast. Blood absorbs longwave UV radiation much more strongly than it absorbs visible light, and the longwave UV image shows ridge detail. A high-resolution longwave UV image can produce enough detail for AFIS, and the print itself is left unprocessed and untouched, reducing possible questions about contamination or dilution if DNA evidence is then extracted from the prints.

Longwave UV imaging makes certain types of evidence very easy to identify and document. When coupled with the latest equipment, UV imaging can be a major asset.

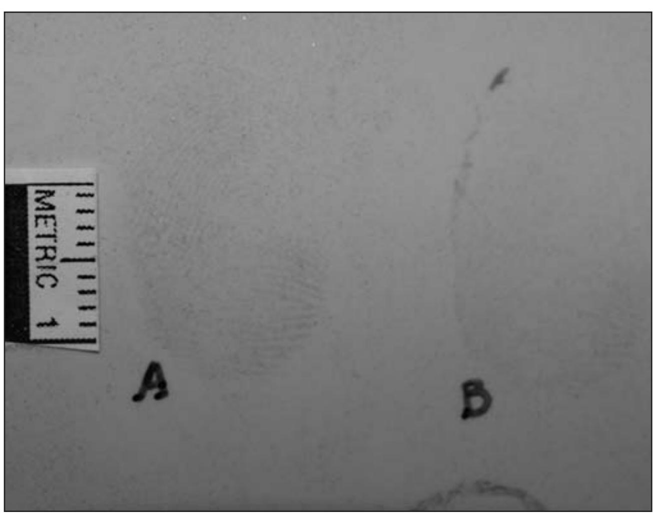
History of Forensic UV Imaging

Ultraviolet imaging techniques for crime scene investigation have been around for many years. Forensic photographers once used black-and-white film and special UV bandpass filters to record images in the longwave UV waveband. The method was very time consuming and results were often very hard to consistently reproduce. The photographer did not know the results until after processing the film and could not be sure about focus or exposure, since the eye could not see the UV image through the viewfinder with the bandpass filter in place, and the built-in light meter on the camera was not calibrated to work in the UV band. Even if the filter was removed for focusing, the UV light focused differently than the visible light the eye could see through the viewfinder.

In the digital photography era, the forensics field is still trying to get its bearings when it comes to longwave UV imaging. It is an underutilized method of crime scene photography, since most digital cameras (by design) have little or no sensitivity to longwave UV.

The current state of the art uses special Fujifilm cameras like the Fujifilm S3 Pro UVIR and the IS Pro, combined with the Baader Planetarium UV Venus filter and a high-intensity longwave UV source that is generally based on an array of LEDs. Special quartz lenses designed for UV photography are useful but not strictly necessary, since there is reasonable transmission of longwave UV through standard camera lenses.

The Fujifilm forensic cameras are no longer in production, but there are still legacy units in circulation and several third-party vendors can modify certain DSLRs to work in the longwave UV band. The modification is the removal of the sensor's cover glass with filter layers (that block both longwave UV and near-infrared radiation), and replacement with an unfiltered cover glass. The Fujifilm cameras have the major disadvantage that they cannot be easily used to *continuously* scan a crime scene to search out evidence. The IS Pro, for



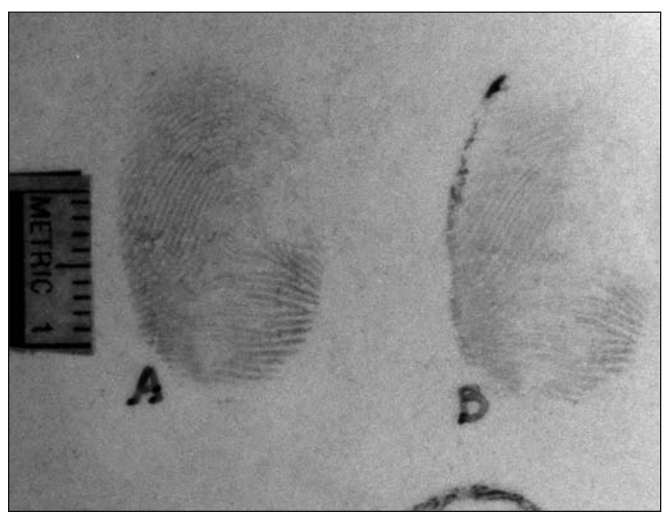


Figure 2a and Figure 2b*—These photos show a pair of bloody fingerprints on a smooth, white background. The prints are hard to see with the unaided eye, as shown in Figure 2a. But the UV image in Figure 2b shows much more detail because of the higher contrast. The reason for this difference is explained in the accompanying article. (Photos courtesy of Rachel Leintz)* example, has a button that one presses to retract the mirror and start a continuous stream of video on the rear LCD viewfinder. But the video stream will only last for 30 seconds before the button needs to be pressed again. Meanwhile, the process rapidly consumes battery power. Finally, the image on the rear LCD is generally dark unless the UV lighting is very bright, and it is hard to see anything clearly in the presence of ambient light. This camera was never designed to be a video camera, yet live viewing is the most practical way to find evidence that is invisible to the eye.

Until recently, the only way to continuously search a crime scene in the UV band (without repeated button pushes on a Fujifilm S-3 or IS Pro camera) was to use a RUVIS device.

RUVIS Shortwave UV Imaging Device

RUVIS devices are based on image intensifiers (similar to those used in military night vision goggles), and are designed to image in the shortwave UV band. These systems can image shoeprints and even latent fingerprints, but they require special shortwave UV light sources to illuminate the scene. This shortwave UV radiation is irritating to the skin and eyes. If a large area of a crime scene is to be illuminated in order to search for prints, the operator of the system and anyone else in the vicinity must wear face shields and body suits with hoods to prevent severe "sunburn" on any exposed skin. The shortwave UV radiation will quickly damage any DNA evidence; furthermore, the illumination of the oxygen in the room air generates ozone gas, which is an irritant to the eyes and respiratory system.

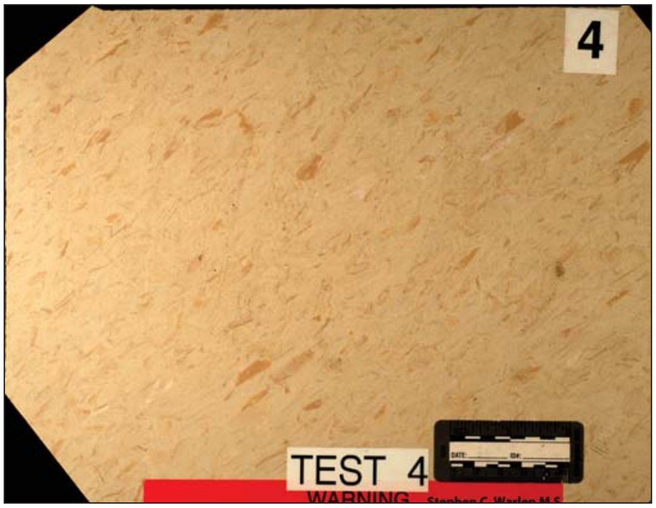
In addition, the sources are all based on mercury-vapor discharge lamps, and it is difficult to evenly illuminate a large scene with these lamps because they are inefficient at producing shortwave UV light. In addition, their brightness cannot be controlled. A large array of lamps must be used to light up a substantial area with enough radiation to use the RUVIS effectively. Even then, there are issues with the spatial distribution of the light itself. Both longwave and shortwave UV-imaging techniques are quite sensitive to the incidence angle of the light relative to the surface under inspection. The best results are obtained with highly oblique lighting. Since shortwave lamps are very diffuse sources, the incidence angle of the radiation they produce is hard to control and they tend to send UV radiation in unwanted directions.

Figure 3—*This device, the UVScanner, is a longwave UV imager developed by Oculus Photonic's for forensic purposes. (Photo courtesy of Austin Richards)*

Because of the requirements for protective gear, the bulky, fragile light sources, and the challenges to obliquely lighting a scene with shortwave UV, the method is rarely used for wide-area imaging of a scene. Instead, most forensic investigators use it at short range to search for fingerprints on surface areas that are likely to have them. Yet, individualizing evidence is often found in unlikely spots. Searching a wide area with a RUVIS system and a close-in shortwave UV light source can be very time-consuming. Recording images with the system is clumsy, as a camera must be attached to the back of the device—making a long and bulky stack-up of tubes and adapters.

Longwave UV Imaging Device

Oculus Photonics has developed a longwave UV imager for forensic investigation (*Figure 3*). It is called the UVScanner, and it works like a pair of binoculars to give the operator longwave UV vision. Now the investigator can patiently scan for evidence, since the unit operates for several hours on a rechargeable lithium ion battery. The device is generally used in conjunction with powerful LED-



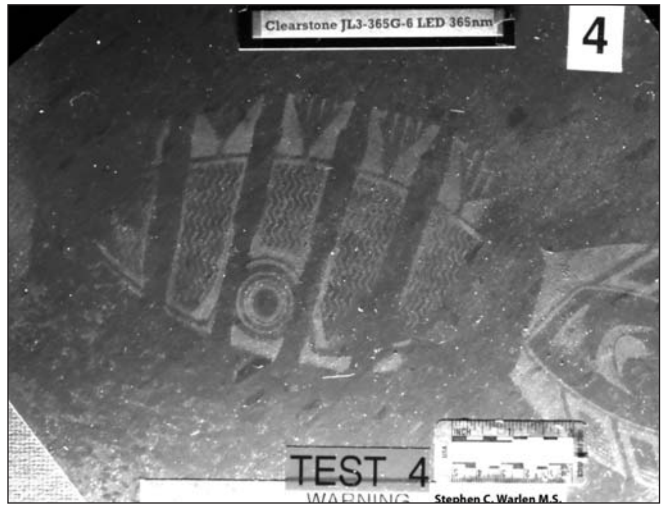


Figure 4a and Figure 4b*—The potential evidence here is a dusty shoe impression on a vinyl floor tile. In the color photo (Figure 4a), there is very little to be seen except for the tile. But the UV generated photo (Figure 4b) as described in the accompanying article reveals good details of the footwear. (Photos courtesy of Stephen Warlen, Kansas City (Missouri) Police Department)*

based longwave UV sources to find evidence, although it has two built-in, low-power longwave UV illuminators that can also be used. The UVScanner cannot image latent fingerprints as efficiently as the RUVIS can. It does, however, image dusty shoeprints and bloody fingerprints well, with the advantage that the longwave UV radiation it requires can be produced in very high quantities in a highly directional beam with electronic brightness control. Best of all, the longwave UV radiation is much less hazardous to exposed skin relative to shortwave UV and will not produce ozone. UV-blocking clear safety glasses (plastic or glass) and SPF 15 or higher sunscreen on exposed skin provides sufficient protection.

Suppliers such as Clearstone Technology and Rofin have produced longwave UV sources based on high-intensity LEDs that have tremendous advantages over gas-discharge lamps. These sources can put out multiple watts of 365 nm radiation, all radiating from a much smaller aperture than any conceivable gas-discharge lamp solution. These sources can light a large area of a crime scene such as a floor, where the radiation strikes the surface at a very low angle, just skimming along the surface. This very low illumination incidence angle enhances the contrast between the substrate surface and certain types of trace impressions on the surface. Once evidence has been located and marked, it can be processed using EDPLs, or photographed at high resolution with a Fujifilm camera system set up for UV.

A good example of this low-angle illumination combined with longwave UV imaging is shown in *Figures 4a and 4b*. This scene is illuminated with a Clearstone Technologies 365 nm light source at a low incidence angle. The source has 5 watts of optical power at 365 nm. The vinyl floor tile has a shoe impression on it that is composed of concrete dust. The dust particles scatter the longwave UV radiation up into the camera (a Fujifilm IS Pro), while the vinyl surface


Figure 5a and Figure 5b*—Here is another example of what can be found with longwave UV procedures. The car shown above has had its driver's side front fender replaced. Under longwave UV imaging (Figure 5b), the difference is obvious. (Photos courtesy of Austin Richards)* absorbs the energetic UV radiation, making the surface look very dark. The result is a high-contrast image relative to what the eye sees.

Another use for a longwave UV imaging device is to image paint on vehicles to see if the vehicle has recently been repainted.

In hit-and-run cases, suspects whose vehicles have suffered body damage will often have the damage repaired immediately after the incident. Fresh paint absorbs longwave UV radiation more readily that older oxidized paint.

For example: The white Toyota Prius in *Figures 5a and 5b* has had its driver's side front fender replaced. In this instance, the illumination source is the sun, which emits copious amounts of longwave UV radiation, and the camera is an Oculus Photonics UVCorder, a variant on the company's UVScanner. A RUVIS device operating in the shortwave UV band cannot image using sunlight as an illumination source, since there is virtually no solar shortwave UV radiation at ground level. It is all absorbed by oxygen in the atmosphere at high altitude.

Summary

Longwave UV imaging of crime scenes is a very useful technique that has been historically underutilized because of the lack of key technology. The technique makes certain types of evidence very easy to identify and document. Investigators needed a longwave UV viewer and a bright, portable source of longwave UV illumination, and these devices now exist.

The UVScanner is a handheld longwave UV imaging device based on a special CCD camera that gives the forensic investigator "UV vision" to find and mark evidence.

Forensic LED-based light sources with multiple watts of 365-nm output make it possible to quickly and more effectively search a wide area with the UVScanner in a way that is much harder to achieve with the shortwave UV RUVIS systems.

About the Authors

Austin Richards is a physicist and systems engineer. He founded Oculus Photonics in 2006. He also works as a research scientist at FLIR in Santa Barbara, California, where he develops infrared imaging systems and technology, and is the holder of four patents. Richards has written articles for the Journal of Forensic Identification*, most recently with Rachel Leintz, and has conducted training in forensic ultraviolet and infrared photography for the Miami-Dade (Florida) Department of Public Safety. Richards can be reached at this e-mail address:*

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