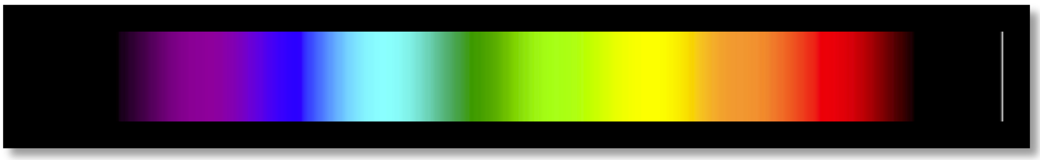
# SEEING THE INVISIBLE – UV AND IR IMAGING WITH THE DCS5

| Ultraviolet | Visible | Infrared |
|---|---|---|
| 10 to 400 nm | 400 to 700 nm | 700 nm to 1100 nm |



In 1903 Prof. R W Wood, an American physicist and inventor, invented the first UV filter to block visible light. The Woods filter is made of Barium sodium silicate glass incorporating 9% nickel oxide. A deep violet, it's opaque to visible light except the longest red and shortest violet. It is transparent in the violet/UV in a band between 320 and 400nm with a peak at 365nm and a broad range of IR and the longest least visible red wavelengths.

**Figure 1 - Prof. R.W Wood**

## FLUORESCENT UV IMAGING

In Forensic applications UV illumination is traditionally used to stimulate fluorescence at a longer wavelength. Typically this is above 400 nm; the point where due to the protein absorption of the human eye, crystalline lens, visibility rapidly falls away. This type of imaging is Fluorescent UV Imaging.

There are however two different types of Ultra Violet imaging, and it is important for the topics discussed here that we are aware of the distinction between the following:-

1. Fluorescent UV Imaging
2. Reflective UV Imaging

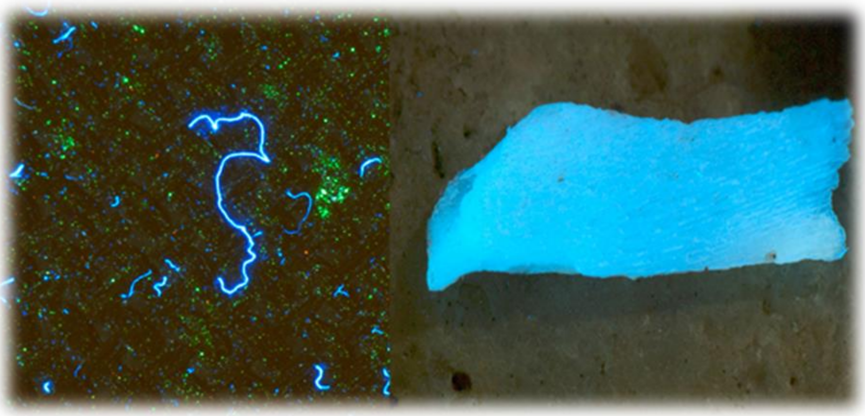


**Figure 2 - fluorescent Ultra Violet imaging: Fibres and bone fluorescing under UV. Some fingerprint powders also fluoresce under Ultra Violet light.**

Because this kind of image creates fluorescence above 400nm, it can be viewed through, and captured with standard cameras.

## REFLECTIVE ULTRA VIOLET IMAGING

There are three kinds of UV Light

1. UV-A: 320–400nm = long wave.
2. UV-B: 290–320nm = medium wave.
3. UV-C: 100–290nm = short wave

The UV that reaches us from sunlight is mostly UV-A (~95%) and a little UV-B. Overexposure to the UV in sunlight or UV from UV-flashes, UV-strobes, UV-bulbs or UV-LEDs can cause *cumulative* skin and eye damage leading to skin cancers, melanoma, corneal sunburn, cataracts and macular degeneration. It is therefore recommended that when using any UV light source you wear eye protection and don't expose your skin directly to the UV light.
Short Wave UV (UVC) destroys DNA. Any short wave UV imaging MUST be undertaken either through a safe enclosure, or by wearing the appropriate PPE.

Traditionally, short wave UV imaging systems are used to exmine latent fingerprints. These systems were developed around the spectral response of film. Film is unable to see IR, and the specialist film for UV imaging was designed to see short wave UV light. These images are usually green in colour, and have a relatively small viewing area. Due to the low levels of light, the systems use image intensifiers. The resulting images are often noisy and difficult to capture.

The introduction of low noise, professional digital cameras, with the capability for 'live' view and a spectral response below 400nm and above 750nm has opened up new Forensic possibilities. It is these possibilities that we will examine in the rest of this document.

## SUPERGLUE FUMING AND FLUORESCENT DYES

Superglue fuming develops fingerprint impressions on non-porous and semi-porous surfaces. The developed fingerprints are usually white, but on some occasions, they are black. Viewing these fingerprints can be difficult if:

1. If a surface is white, the white polymer is almost invisible.
2. If a surface is multi-patterned, or black with a black fingerprint impressions, the mark is equally difficult to see.

For this reason, Fingerprint laboratories apply either powders or liquid fluorescent dyes such as BY40 or Rhodamine 6g, to the superglued surface. When viewed with the correct lighting, the fingerprints will often (but not always) fluoresce, making them easy to find and photograph. However, some surfaces, like latex gloves, printed carrier bags and adhesive tape, will absorb the fluorescent dye. This results in the background and the fingerprint fluorescing, so no fingerprints are visible, and other chemical treatments have to be used.

Most laboratories are very busy environments, and a fast turnaround time, especially for volume crime, is essential. So, whilst fingerprints can sometimes be found by using oblique, white light, the process is both labour intensive, and difficult, making it impractical as the only method for daily use. In general, the recommendation is a quick examination with white light, if you can see a fingerprint, it should be photographed before any dye is applied. The surface is then stained, hopefully revealing more fingerprints. In cases where the background and the fingerprint absorb the fluorescent dye, fluorescence will obscure rather than reveal the fingerprint. For this reason, negative items for fluorescence, must still be examined under white light.

The fluorescent dye process is effective, but presents the following problems.

1. Time consuming, costly and messy.
2. There are debates over which formula to use. Typically, when using the BY40 solution, you can use either Ethanol, or water as a carrier agent. The Ethanol solution is is quickly absorbed into the polymer deposit. However, the use of large quantities presents a significant fire risk, for this reason many laboratories use a water based solution. This is not very effective, and often gives poor fluorescence.
3. A pure alcohol solution can remove any surface printing, and with it the fingerprint.

Recent trials at Foster and Freeman have shown that Long Wave UV (LWUV) imaging (UVA-365nm), with the correct equipment, provides an effective way to view fingerprint impressions developed with cyanoacrylate fuming. When using LWUV combined with reflected and fluorescent IR(Infra Red), most surfaces do not require fluorescent dye. In some of the examples at the end of this this document, you can see how LWUV, Reflective IR and fluorescent IR all work together to obtain the best results.

Long Wave UV, has been shown to have the following benefits:-

1. Faster turnaround times, as no second chemical process is required, and the photography is easier.
2. Non-destructive, no risk that the dye will damage the surface.
3. Reduced costs, especially with the ethanol based formula.
4. Fingerprints can be recovered from surfaces where it was previously impossible to see the developed superglue. For example, latex gloves, adhesive tape, patterned printed plastic bags, freezer bags.
5. Clear plastic bags turn black, leaving the white fingerprint clearly visible.

When compared to traditional short wave (254nm) imaging system, LWUV (365nm) has the following benefits:-

1. Safe to use with the correct PPE.
2. Does not damage DNA.
3. Has a very large viewing area.
4. Is fast and easy to use.
5. Allows the use of intense long wave UV, resulting in low noise images and short exposure times that are easily captured with the correct camera.

If the surfaces fluoresces under LWUV, consider the following:

1. White Polystyrene, treat either with Polycyano, or dye stain the developed polymer.
2. If the surface contains text or images do the following:
   1. Examine under a IR light with selectable wavelengths If all of the background disappears, apply black powder to the fingerprint and illuminated as Reflected IR.
   2. If some of the background disappears, apply Natural 2 Powder and illuminate using fluorescent IR imaging techniques.

## WHAT IS LONG WAVE UV, AND WHAT DO WE NEED TO BE ABLE TO UTILISE THIS TECHNOLOGY?

Visible light contains high photon energy. Ultra Violet photons have more energy than visible light. This causes many surfaces to absorb light rather than reflect it, the shorter the wavelength, the greater the absorption. Because the human eye only sees between 400 – 750nm, we don’t see the shorter wavelengths. But if we use electronic systems like the DCS5, with long or short wave UV, we would be able to see the following:-

**Absorption:** UV light is highly absorbed by many commonly encountered organic materials, yet is reflected by many inorganic materials like stone and metal. If these organic materials are on a surface with higher UV reflectance, the substances will often stand out more strongly than visible-light or near-IR images. The reverse is true as well traces of inorganic materials like salt stand out as bright on a dark organic surface like a wooden table.

**Lack of penetration**: UV light does not penetrate even very thin layers of materials, making surface topology more apparent, since normally translucent surfaces appear opaque. The high energy of UV photons makes them interact strongly with the electronsin atoms and molecules. Many materials look very dark when imaged with UV light.

**Highly scattered UV waves:** UV light waves have a short wavelength, which means that they are scattered much more readily by small surface imperfections on a smooth surface than either visible or near-IR light. Scratches and dust are much more apparent, which is why the optics industry uses UV imaging to inspect lens surfaces, for example. Some of the texture imaging can be accomplished by raking-illuminated visible-light photography, though UV has advantages over raking light.

To view the effect of Long Wave UV, we need:

1. A digital camera where the internal UV/IR blocking filter has been removed and replaced with quartz of the correct density.
2. A professional digital camera with 'low noise' capability in 'live view'.
3. A high quality quartz lens with extension tubes and a wide viewing area.
4. A filter to transmit UV and block IR.
5. Long wave 365nm light source that can be moved to different angles.

## MODIFYING THE DIGITAL CAMERA

Since early 2000, camera manufacturers have placed UV and IR blocking filters and colour balance filters in front of the camera sensor. (Some early cameras such as the Nikon d70 can be used for UV imaging with no modification, as the blocking filters were not very effective) Modifying the camera involves removing both of these filters, and any other filters, such as anti aliasing filters, and glass added for camera sensor cleaning.

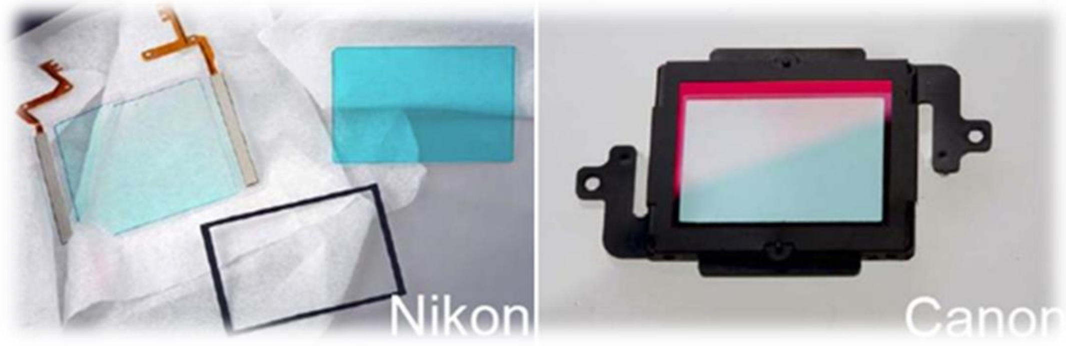
Not all cameras are suitable for modification, and the UV sensitivity (not published by the manufacturer) varies from camera to camera. Sometimes the filters are permanently fixed to the sensor and cannot be removed. In other cases the shutter mechanism uses IR light to check the shutter speed. This sends an IR flare across the sensor resulting in IR contamination.

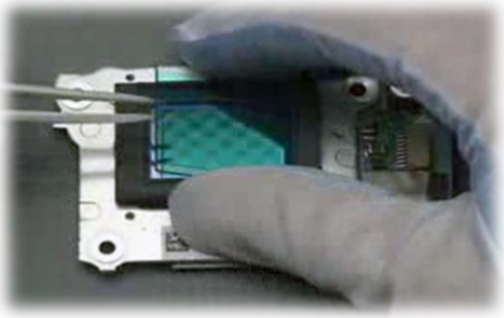
### REMOVING THE CAMERA'S INTERNAL FILTERS

All camera have two filters in front of the sensor, these filters are:

1. Block UV and IR
2. Colour Balance.

The images below illustrate the IR + UV cut, and Colour balance filters in Nikon and Canon cameras.



Once the filters are removed, a piece of quartz, of the same size, thickness, and refractive index is placed in front of the sensor. If this is incorrect, the TTL and auto focus will not work correctly and the camera will require re-calibration. Only specialist technicians should complete this process.

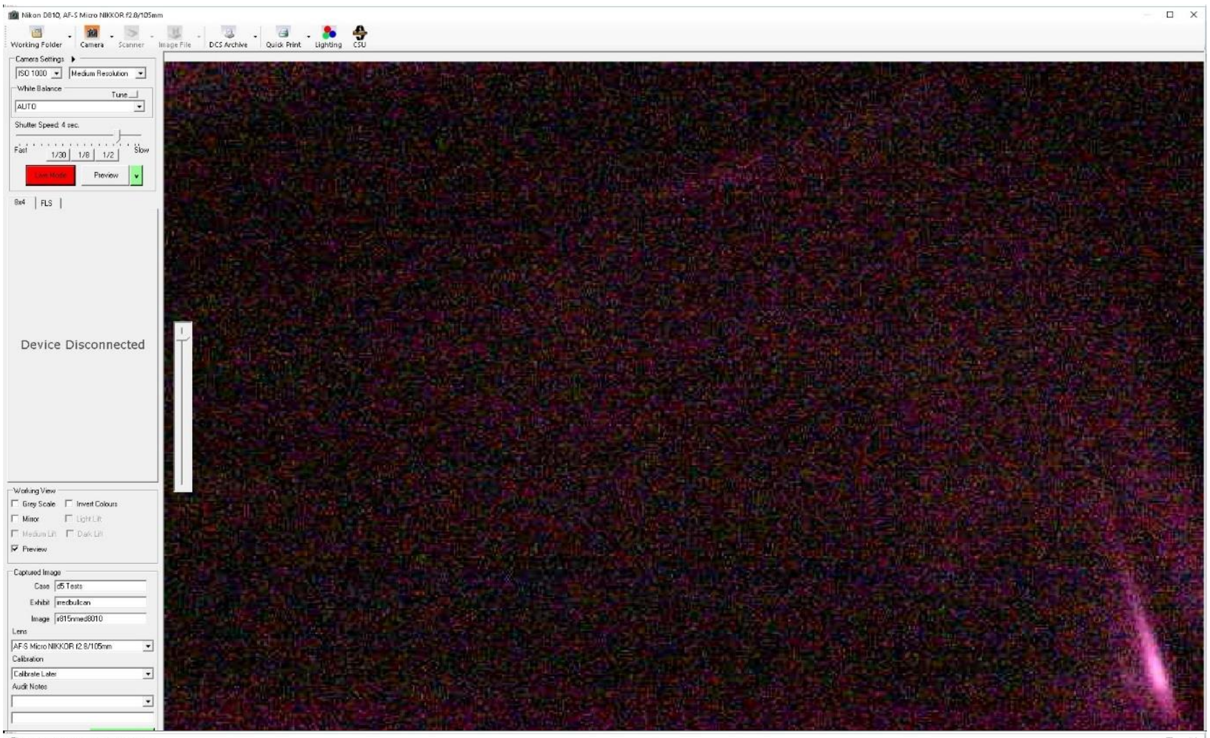
If UV +IR cut and Colour balance filters are placed onto the camera lens, the camera can be used for normal photography.

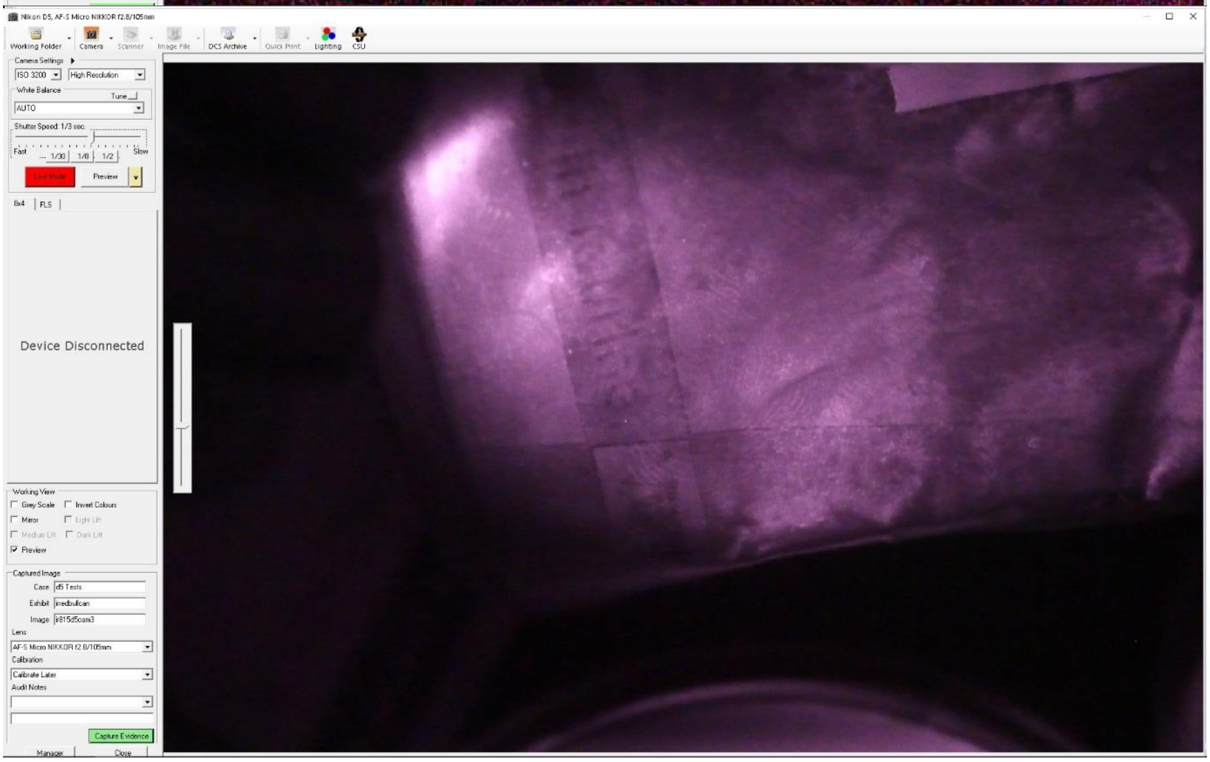
## VIEWING THE DEVELOPED FINGERPRINT

The human cannot see below 400nm, therefore the camera must become our 'eyes.' It is therefore very important that the camera has very low noise 'live view'. However not all cameras are equal, and high pixel count cameras are often 'noisy' at low light levels, making them unsuitable as a search tool for fingerprint impressions.

Below are two images. Both images are screen shots of 'live view' in two different cameras. The first image is taken on the Nikon D810 a 36mpixel camera. The second is a Nikon D5, a 21 megapixel camera. Both are taken using the same lighting at the same wavelength. The Nikon D5 shows much lower noise, the D810 has an unacceptable 'noise level'.

The Nikon D5 can output a 'live' HDMI image, the D810 will only output usb. This D5 produces a stable, exceptionally clear, easy to focus image, but the image from the D810 fluctuates, and is difficult to focus.


Nikon D810, AF-S Micro NIKKOR f2.8/105mm
Working Folder
Camera
Scanner
Image File
DCS Archive
Quick Print
Lighting
CSU
Camera Settings
ISO 1000
Medium Resolution
White Balance
Tune
AUTO
Shutter Speed: 4 sec.
Fast
Slow
1/30
1/8
1/2
Preview
Device Disconnected
Working View
Grey Scale
Invert Colours
Mirror
Preview
Captured Image
Case
d5 Tests
Exhibit
Image
Lens
AF-S Micro NIKKOR f2.8/105mm
Calibration
Calibrate Later
Audit Notes


Nikon D5, AF-S Micro NIKKOR f2.8/105mm
Working Folder
Camera
Scanner
Image File
DCS Archive
Quick Print
Lighting
CSU
Camera Settings
ISO 3200
High Resolution
White Balance
Tune
AUTO
Shutter Speed: 1/3 sec.
Fast
Slow
1/30
1/8
1/2
Preview
Device Disconnected
Working View
Grey Scale
Invert Colours
Mirror
Preview
Captured Image
Case
d5 Tests
Exhibit
Image
Lens
AF-S Micro NIKKOR f2.8/105mm
Calibration
Calibrate Later
Audit Notes
Capture Evidence
Manager
Close

## LENS SELECTION

The next crucial part in reflective UV imaging is the choice of lens. Whilst a few older lenses allow some UV to be transmitted, best results are always obtained with a fused Quartz lens. This is because:-

1. Modern lenses are multi-coated to reduce interference from UV light.
2. Quartz transmits much more UV than standard glass.
3. Focus shift.

Focus Shift is where when you focus in visible light, but then photograph UV, the image will be out of focus. Manufacturers do have markers on the lens to indicate the correct focus point, but this is rarely accurate enough for forensic imaging.

## QUARTZ LENS

These lenses are silica in a non-crystalline form. They differ from glass because they contain no other ingredients. Standard glass includes other ingredients such as aluminium and titanium, which are added to lower the melt temperature. Because silica is pure, it has a high working and melting temperature producing superior optical and thermal properties when compared to conventional glass. It has superior UV transmission to any standard lens. Quartz lenses have no focus shift, enabling you to view and focus the image live, giving high quality, sharp images.

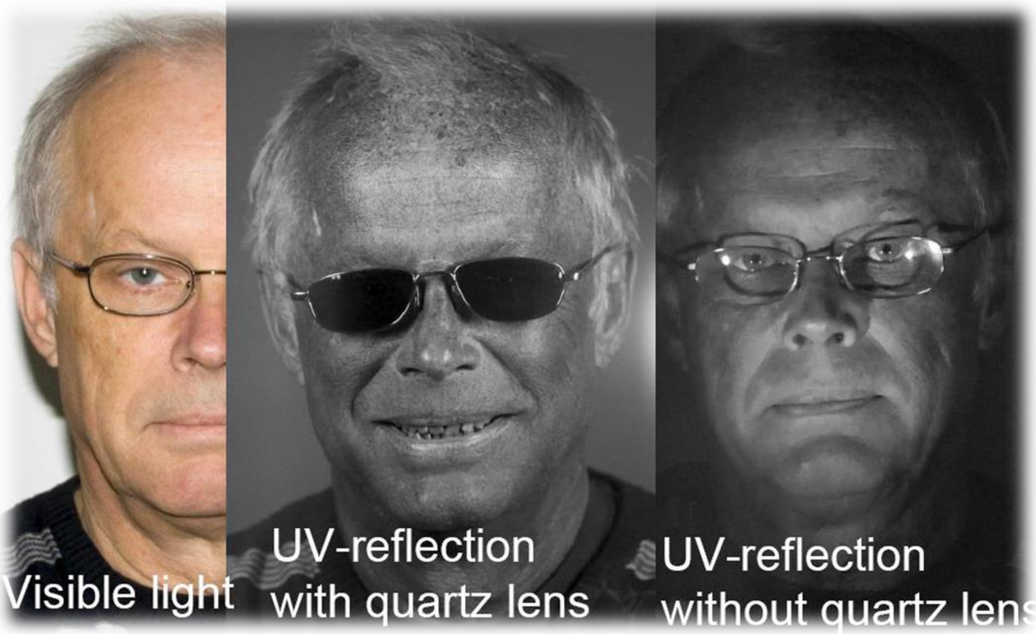



**Figure 3 - Comparison showing how a Quartz lens captures long wave UV.**

## HOT SPOT

With macro photography on a Quartz lens, as you reach the maximum focus position, you may see what is known as an image 'hot spot'. Essentially a 'hot spot' is a ghost image of the aperture spot created by two ghost reflections. These reflections can occur between any two lens surfaces, so it can be a reflection of the sensor or cover glass followed by a reflection from a lens surface. It is only noticeable when you focus the lens as close as possible, and then only on certain surfaces. There is however a solution.

If extension tubes are added to the lens (usually the 12mm is sufficient), the lens position can be set slightly further away, yet the image will be larger in the frame and the ‘hot spot will have vanished.

## IR LEAKAGE – WHICH FILTER FOR DIGITAL 365NM UV IMAGING

Whilst the Wratten 18A Filter was used for film, it is not suitable for digital cameras. This is due to light leakage in the IR. Film cannot see IR, digital cameras can. The filter used by Foster and Freeman transmits the UV, but blocks the IR

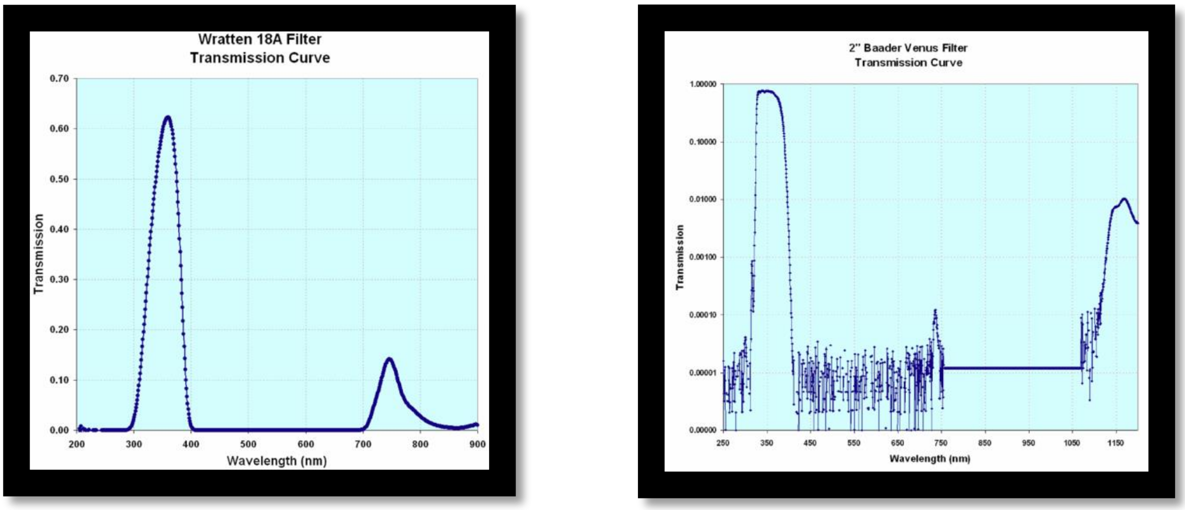



**Figure 4 - Wratten 18A Filter transmission and Baader U Filter transmission**

## TESTS WITH LWUV

Over a period of several months, we have examined numerous items. All vary in their surface types. Some are porous, others semi-porous. We have experimented with surfaces that are not traditionally treated with cyanoacrylate, and have examined items where it has been difficult to obtain any fingerprints at all. Two items of particular interest were latex gloves and adhesive tape. Neither are usually treated with cyanoacrylate, yet in tests, both produced excellent results under LWUV.

Some surfaces will fluoresce under LWUV, and others, such as labels on bottles will fluoresce in small sections. So, part of the marks will be visible under the LWUV, but other parts will contain background interference. In these instances, we found that we could apply the Natural2 powder. The powder adheres exceptionally well to the white polymer. The powder fluoresces in the IR, and when viewed the resulting fingerprints will no longer contain background interference. A good example of this is shown below.

## CIF BOTTLE

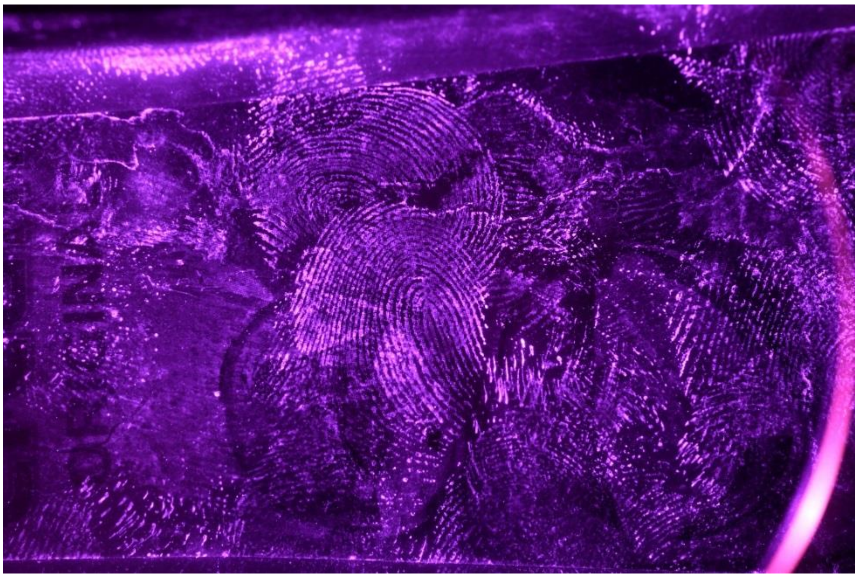
This sample has been treated with cyanoacrylate fuming.

The top image is under white light.

The second image shows LWUV reflection. Part of the background is fluorescing, resulting in interference with the fingerprints.

The last image has , had Natural2 powder applied to the superglue, when examined under IR, the fingerprints are clearly visible and the background interference has been removed.





Conclusion

Based on the many samples I examined, I wold recommend the following procedure for examining evidence treated with cyanoacrylate fuming.

1. Examine with LWUV using the Nikon D5 in ‘Live mode’ with a HDMI feed. A high quality, calibrated monitor and capture software is essential.
2. If part of the background fluoresces, and the background is smooth, apply Natural2 powder, and examine under 780nm with the correct sharp cut filter. Black powder can be applied after the Natural2, but Natural2 cannot be applied after black powder.
3. If the background fluoresces, examine under IR light. If the background goes totally white, apply black powder to the fingerprint and photograph under IR light.
4. If the background does not fluoresce and there is still some interference, use reflected IR light. This requires a IR light above 750nm, best results are achieved when the exact wavelength is selected.
5. Polystyrene will not work with this process, best results on polystyrene are obtained with Polycyano, or cyanoacrylate and fluorescent dye.

The pages below contain a small sample from the many items we examined.

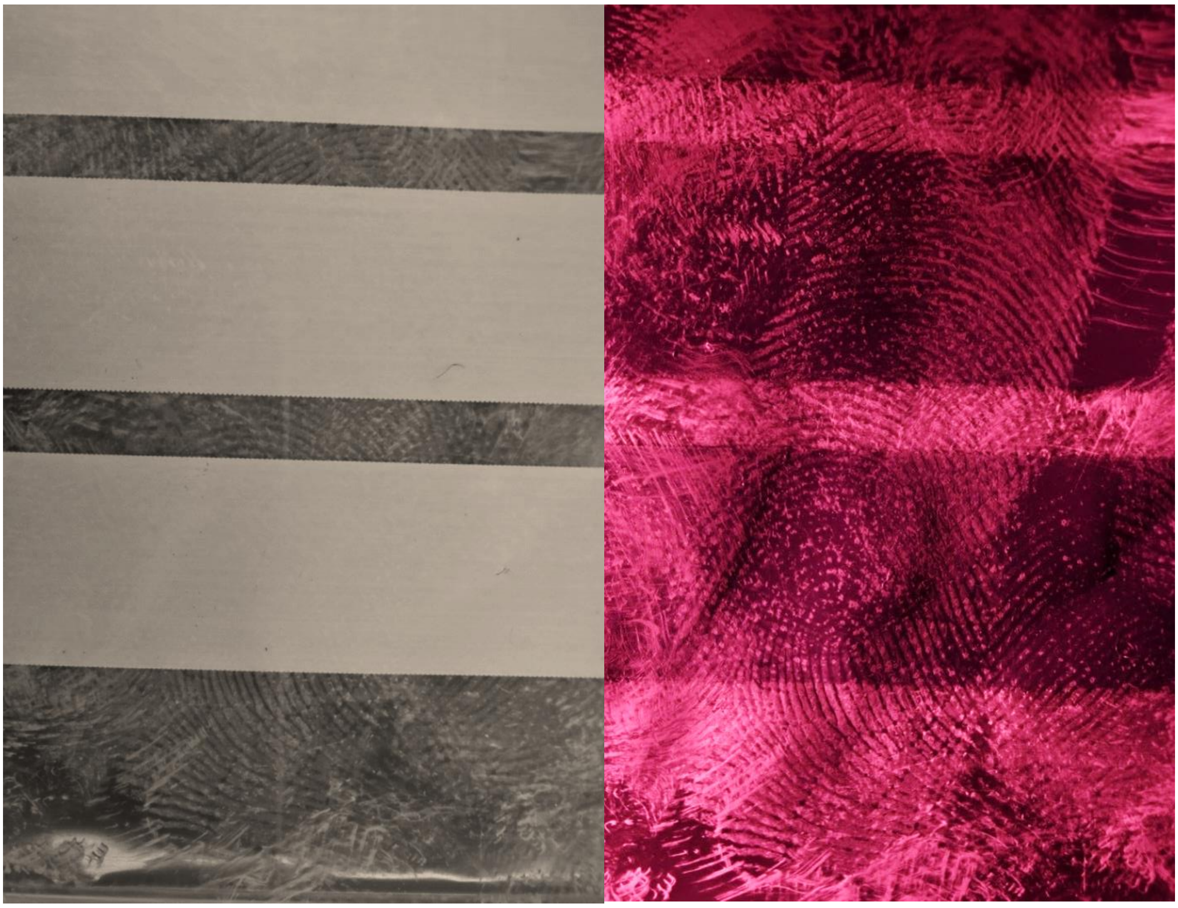


**Figure 5 - White Light, and LWUV Light.**

Cyanoacrylate on a freezer bag with semi-porous white bars. A fluorescent dye will be absorbed into the white bars, making both the fingerprint and the background. Fluoresce. Any ridge detail on the white bars will be very difficult to visualise. However, when viewed under LWUV, the fingerprint is visible on the clear and the white surface of the bag

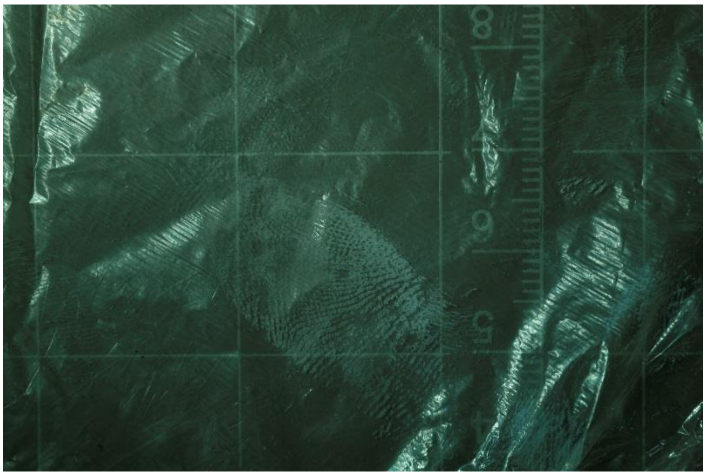
.

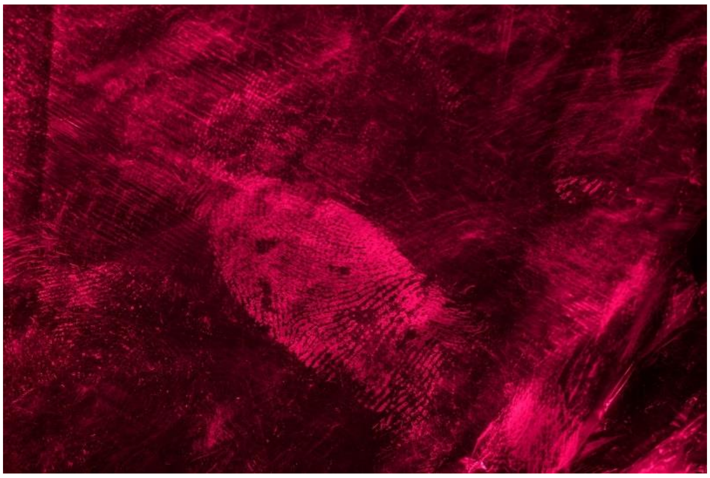
## CLING FILM

Typically, a difficult surface to develop fingerprint impressions. The first image is cyanoacrylate fuming under white light. As the surface is thin, light is reflecting, and the mark is difficult to see.

In the second image, under reflective LWUV, the background turns black, the reflections disappear, and the fingerprint is clearly visible.

The final image shows the enhanced fingerprint.





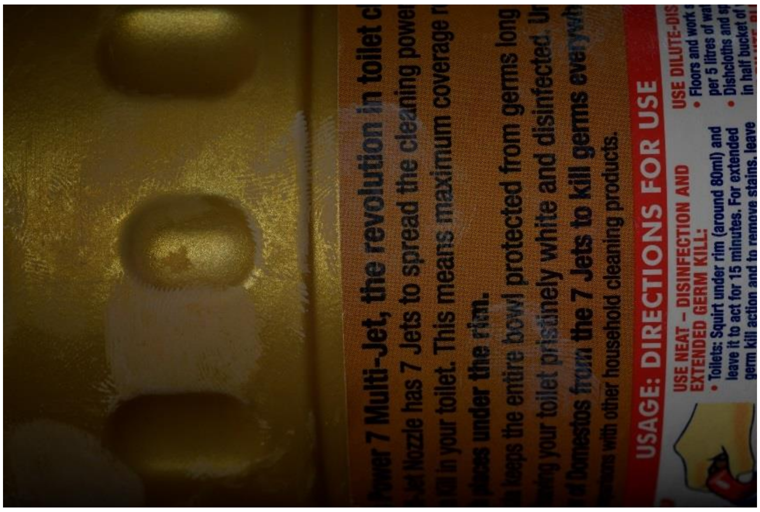
## PLASTIC BOTTLE CLEANING FLUID

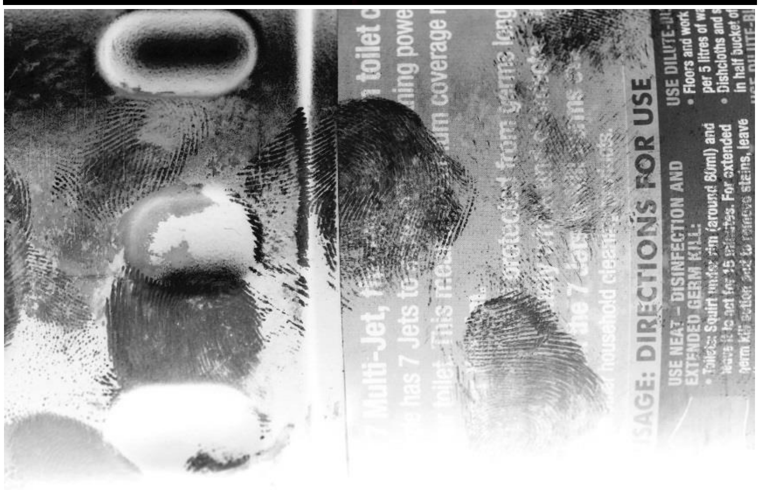
This bottle has a textured plastic surface, and a printed label that runs around the surface. It has been treated with cyanoacrylate fuming.

In the first image, when examined under white light, the patterned surface makes it difficult to see the fingerprint. If Fluorescent dye was added, it would enhance the fingerprint on the plastic, but it may be absorbed into the label.

When examined under LWUV, the fingerprints are clearly visible, and the background interference is removed.

The final image shows the enhanced fingerprint under LWUV.



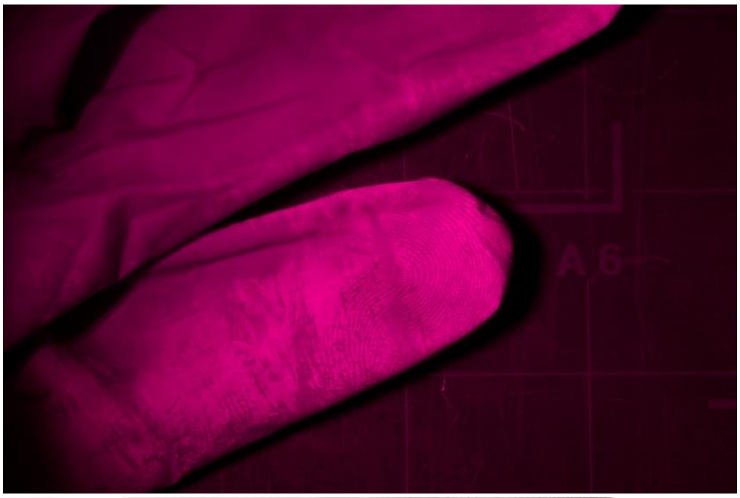



## LATEX GLOVES

Traditionally it is very difficult to obtain fingerprint impressions from latex gloves. As the superglue is white, it is almost impossible to view white polymer with white light. The surface is also semi porous, and when stained with BY40 or any liquid dye, it will absorb the dye, resulting in the staining of the entire surface and the fingerprint. Any developed fingerprints will be impossible to differentiate from the background.

We have now tested numerous latex gloves, specifically looking for fingerprints on the inside surface. Whilst not all gloves produce fingerprints, many now do. It was interesting to note that low cost, latex gloves produced the best results. The higher quality latex and nitrile did not produce as many fingerprints.

When viewed directly under LWUV, the fingerprints are clearly visible.

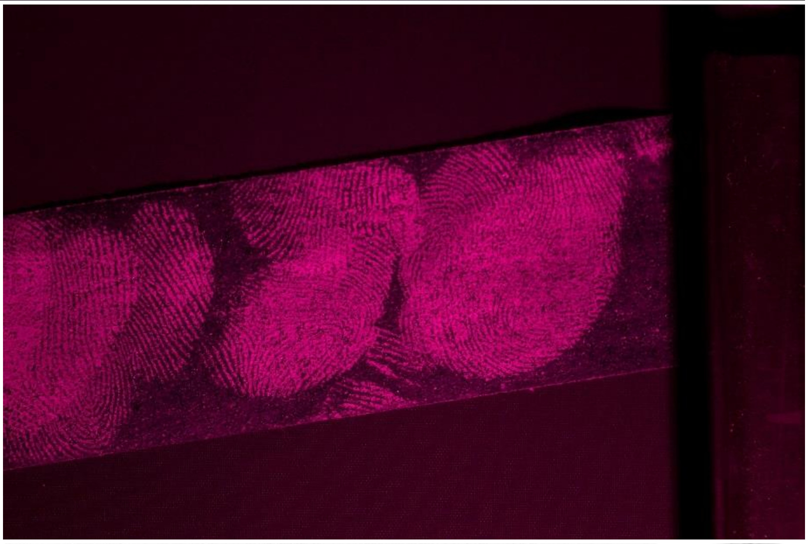

## MASKING TAPE

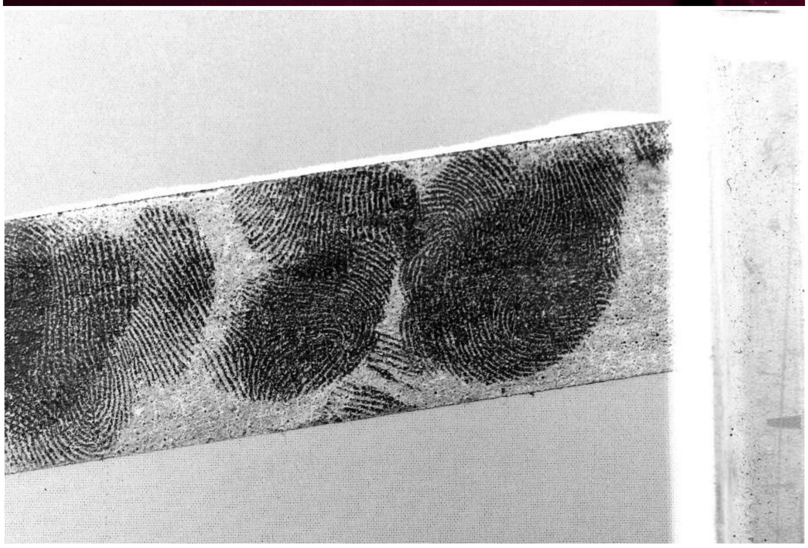
This tape is paper backed and adhesive. The most commonly used processes for this kind of surface are Ninhydrin or Suspension Powders.

However, when treated with cyanoacrylate and examined under LWUV, the developed fingerprints are clearly visible. These fingerprints are on the adhesive side of the tape.

We have examined numerous different kinds of tape, including, selloptape, different colours of electrical tape, brown packing tape, duct tape. On every surface, and every colour, the LWUV produced excellent results.

On many of the tapes that we examined, we were able to develop fingerprint impressions on both the adhesive and non-adhesive side of the tape.



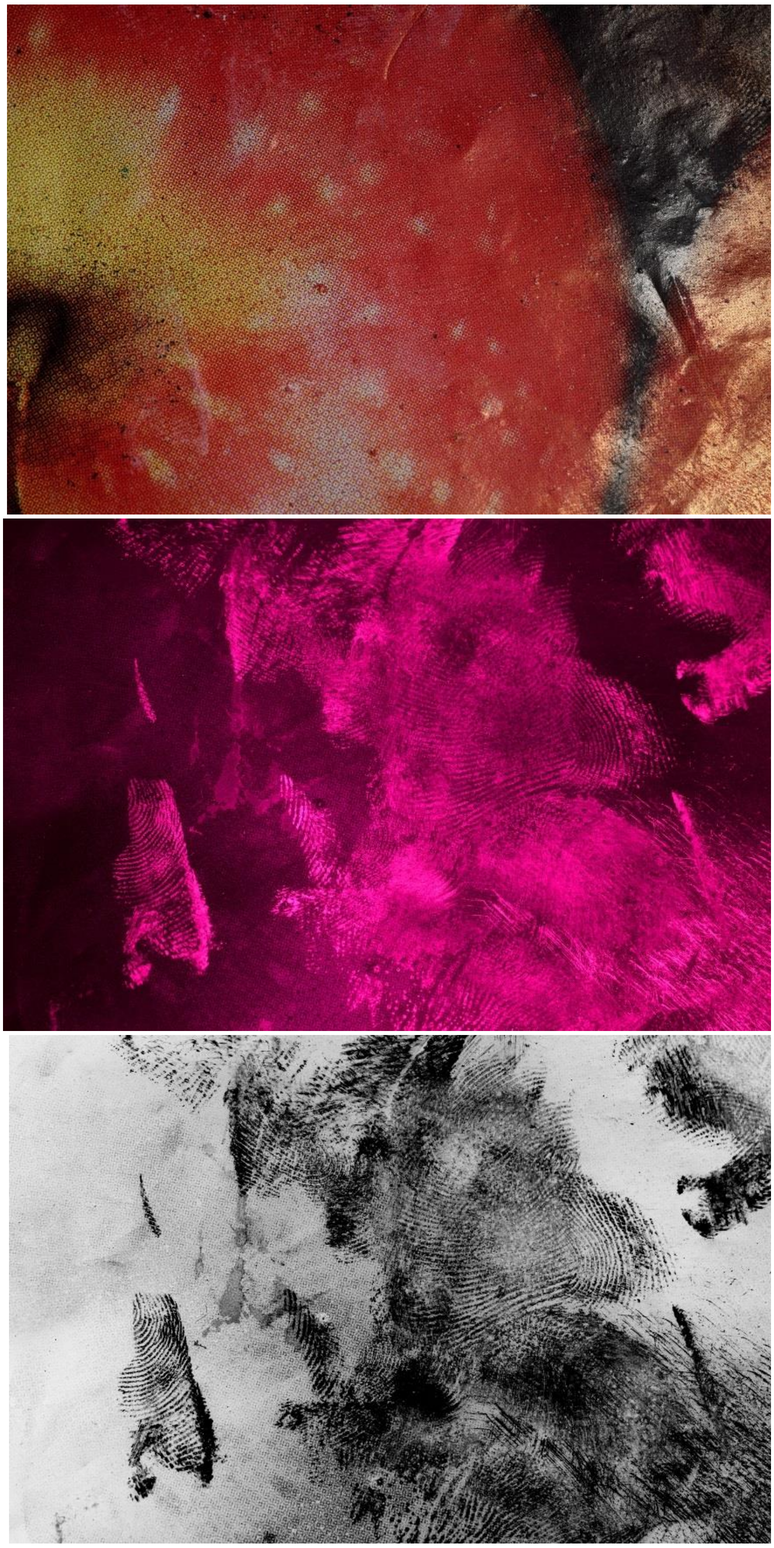


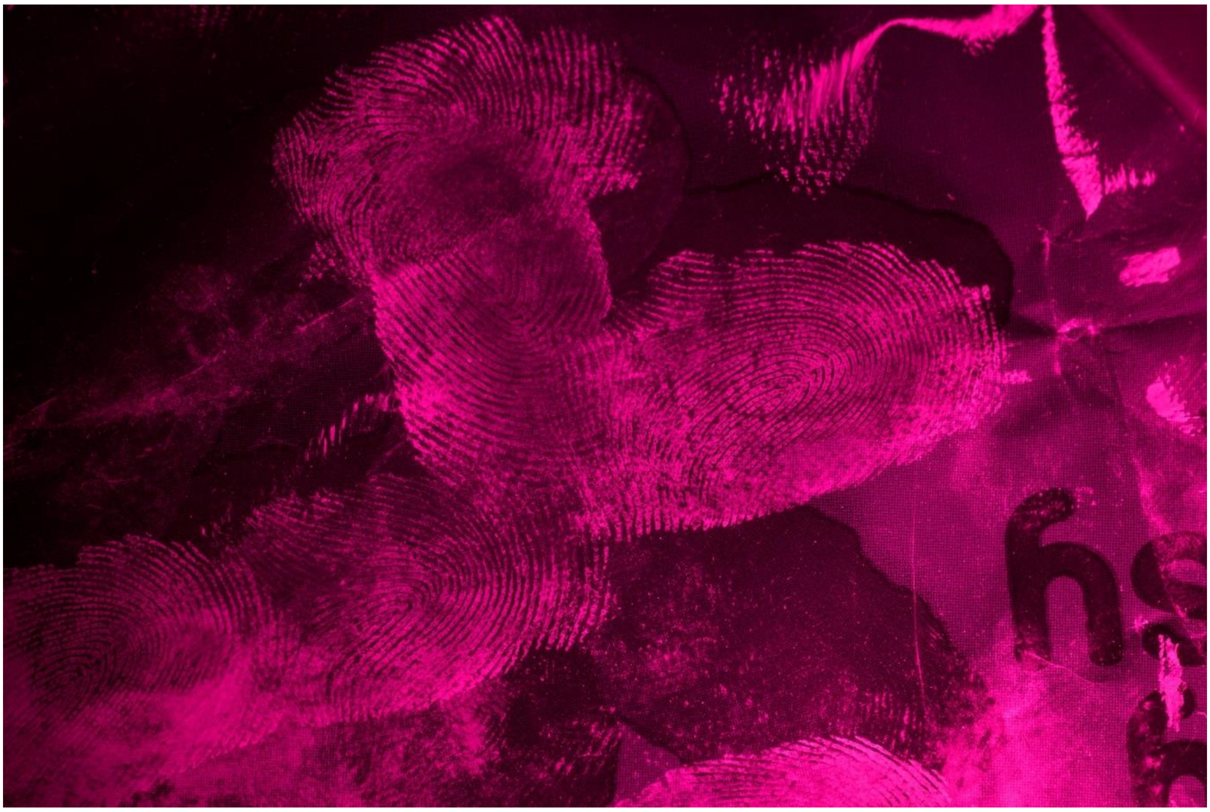
## PLASTIC BAG

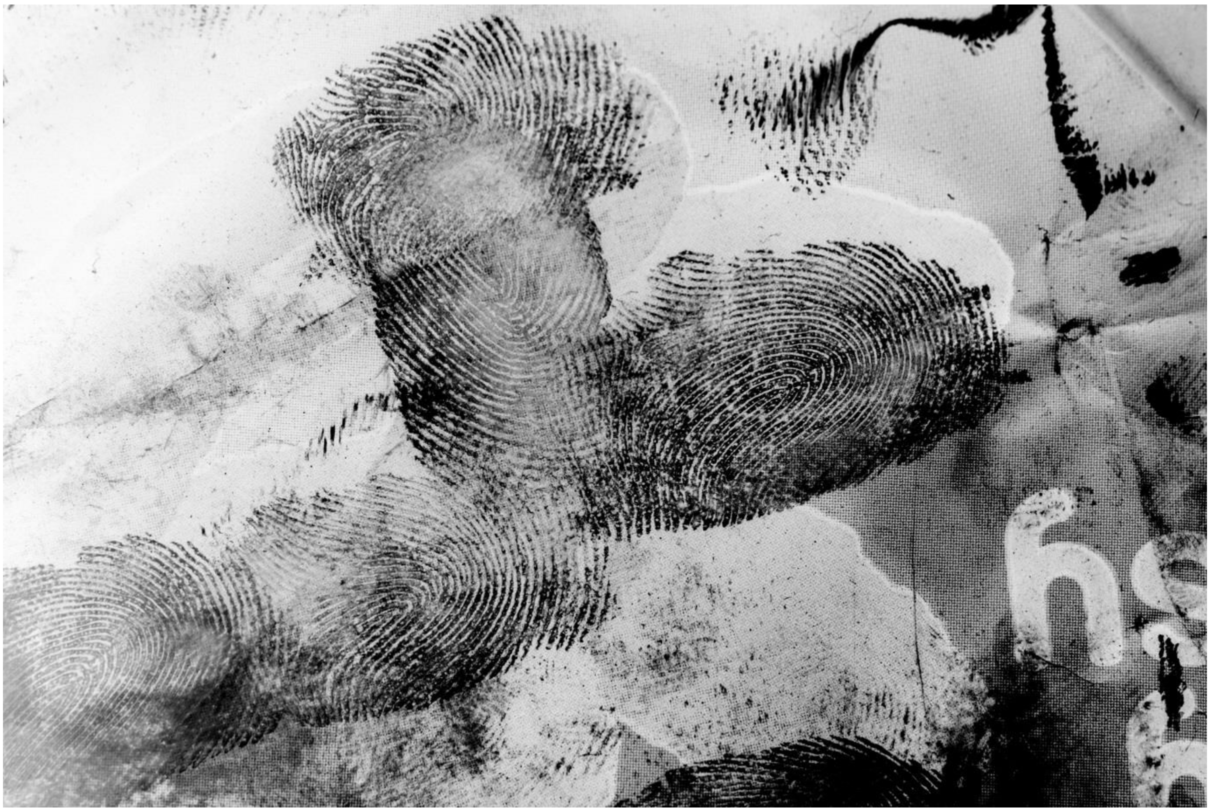
This is a heavily printed carrier bag that has been subjected to cyanoacrylate fuming. If post treated with an alcohol based dye, the printed surface will be removed, taking any fingerprints with it. The only available process would be a water based, or half water, half alcohol based dye.

Visually it is impossible to see anything on the surface, but when examined with LWUV, the fingerprints are clearly visible.

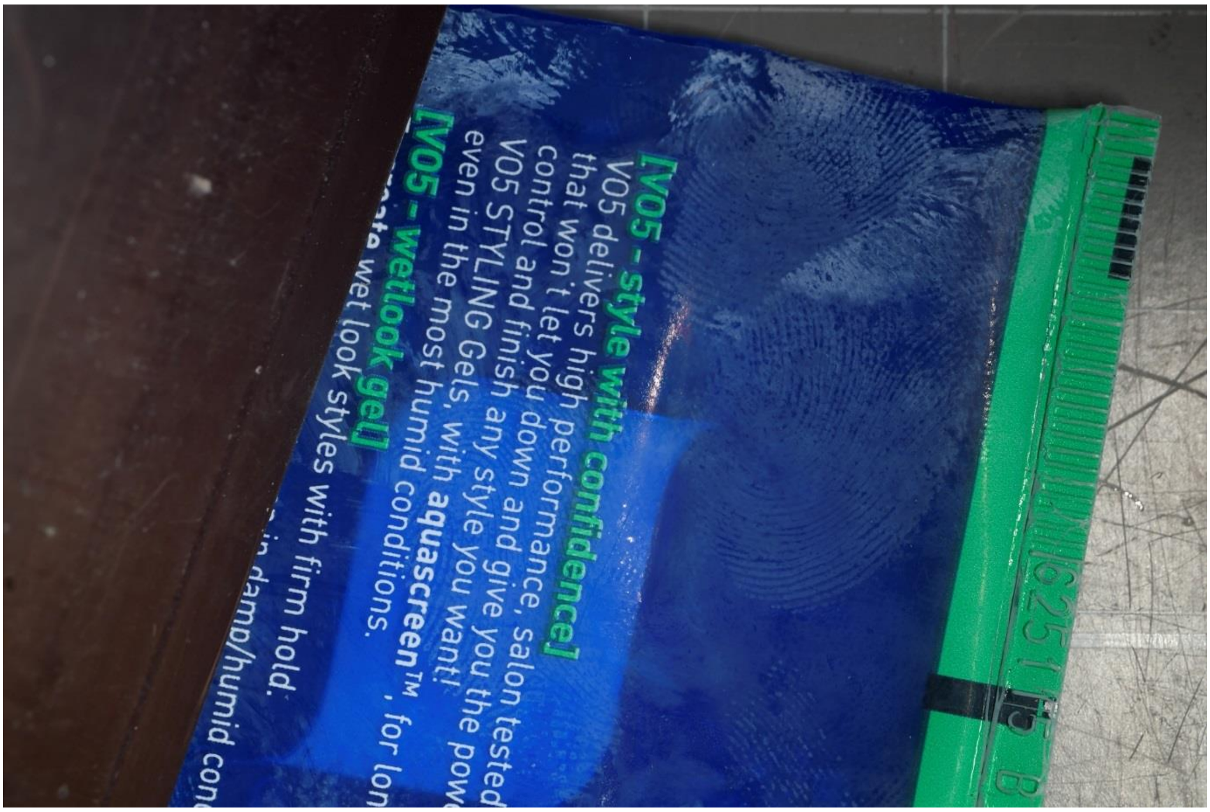
When examining this item with LWUV, you can quickly and easily search for marks with no dye being required.

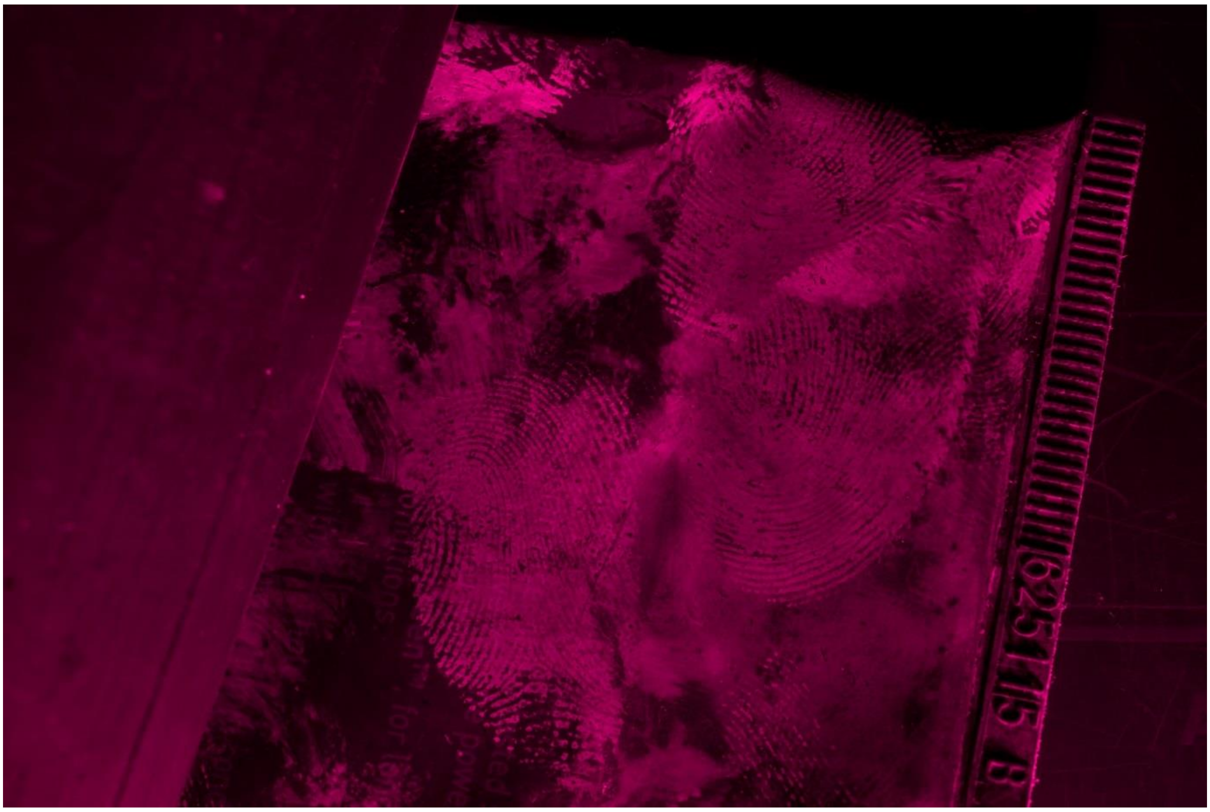


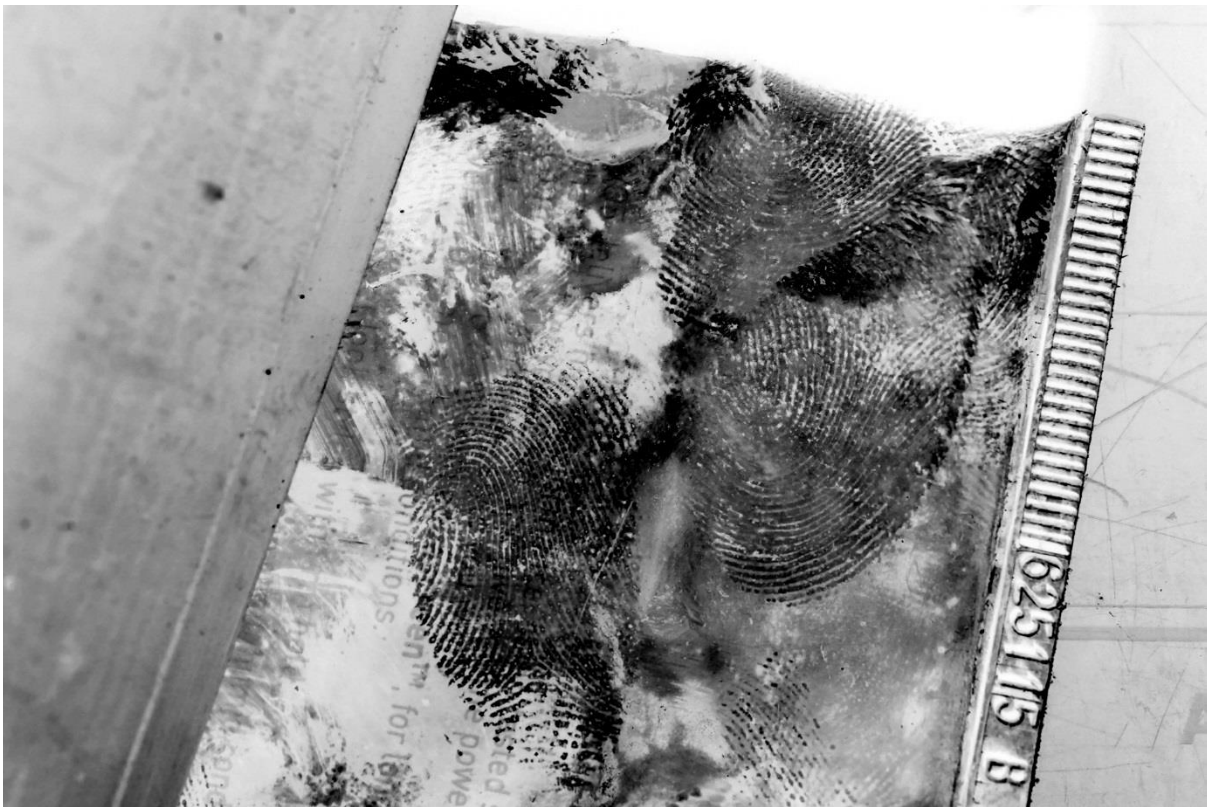




The images above are on a thin plastic, printed wrapper for packets of snack food. This surface will stain well with basic yellow, or Rhodamine. When examined under LWUV, with no dye stain, fingerprint impressions are clearly visible. There is no need to apply a fluorescent dye stain.


[VO5 - style with confidence]
VO5 delivers high performance, salon tested
that won't let you down and give you the
control and finish any style you want!
VO5 STYLING Gels, with aquascreen™, for
even in the most humid conditions.
[VO5 - wetlook gel]
wet look styles with firm hold.





These fingerprints are developed on soft plastic, hair products container. It is interesting to see that the fingerprint on the plain blue background is easily visible under white light, but the fingerprint under the text is completely invisible. Under LWUV, all of the fingerprint impressions are clearly visible.

## LATENT FINGERPRINTS

Fingerprints that are completely invisible to the human eye may on occasion be visible with LWUV, but you are more likely to get good results if you can see something. Visible fingerprints on surfaces like clear glass should always be photographed prior to any chemical treatment, as the chemical process may sometimes delete the visible mark. The fingerprints in the following images are latent prints on a drinking glass. The prints were not deliberately placed there, instead this was a used glass, taken and photographed. The additional point of interest here is that under LWUV, the fingerprints can be view on the clear glass and across the black transfers.

**Figure 15 - white light**

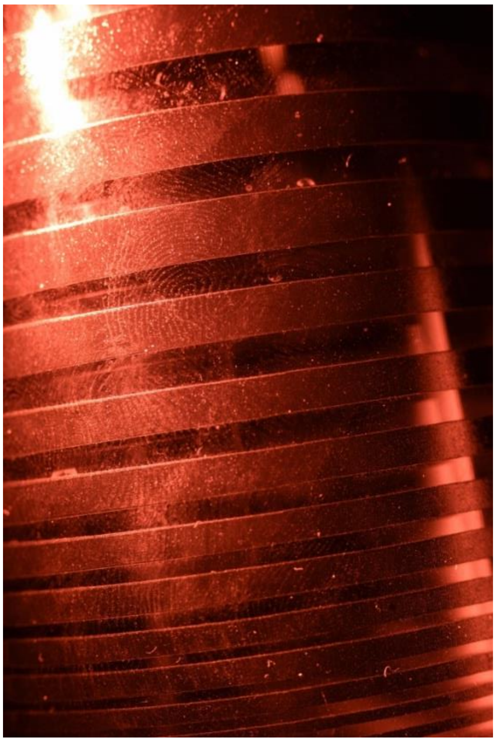


**Figure 16 - UV light**

**Figure 17 – Digitally enhanced LWUV light**

## COMPARISONS USING LWUV, FLUORESCENT IR AND REFLECTIVE IR

### LWUV & FLIR

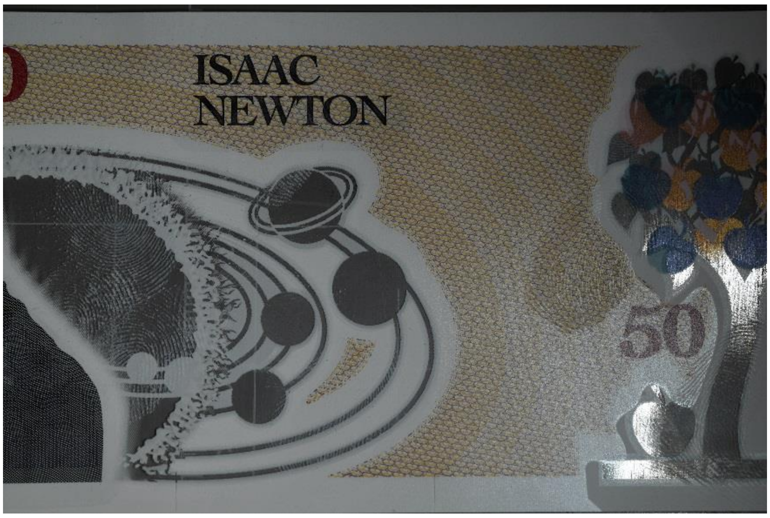
These images show a comparison between the use of LWUV and Fluorescent IR on cyanoacrylate fuming on a bank note.

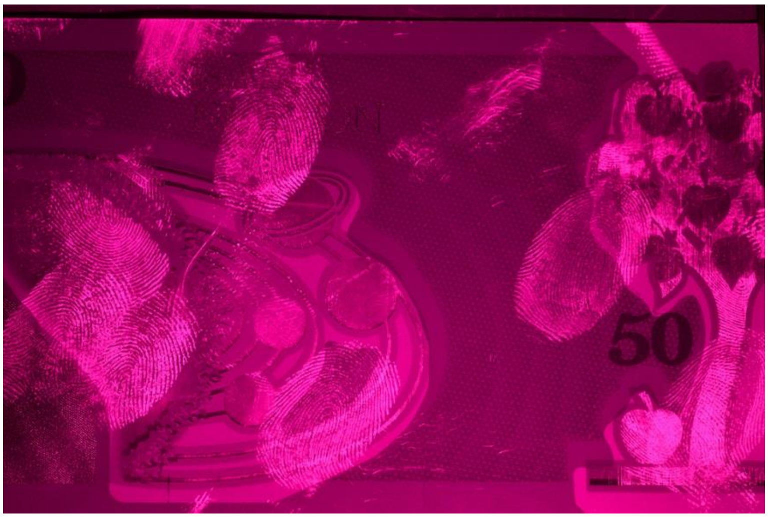
The top image is white light.

The middle image is LWUV

The bottom image is FLIR

On the middle image the word Isaac Newton has disappeared, making the corresponding fingerprint clear, but on the FLIR image the wording remains, but other fingerprints are clearer here than they were on the LWUV.




## WHITE PATTERNED BACKGROUND, PROCESS COMPARISSONS

In this sequence of images, we can see the difference between LWUV, Fluorescent IR, and black powder under reflected IR.

Whilst the image is good under LWUV, there remain some background interference. The same is true with the Natural2 powder. Applying black powder and examining under reflective IR, and then applying some digital imaging, produced the best result.