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Principal Investigator	Co-Principal Investigator	Co-Principal Investigator (Technical)
Dr. A.K. Gupta Professor and Head, Department of Forensic Science Sam Higginbottom Institute of Agriculture, Technology & Sciences SHIATS, Allahabad	Dr. G.S. Sodhi Associate Professor Forensic Science Unit Department of Chemistry SGTB Khalsa College University of Delhi	Dr. (Mrs.) Vimal Rarh Deputy Director, Centre for e-Learning and Assistant Professor, Department of Chemistry, SGTB Khalsa College, University of Delhi <i>Specialised in : e-Learning and Educational Technologies</i>
Paper Coordinator	Author	Reviewer
Dr. Ravinder Chowdhry Ex-ADVISOR (R&D) Last Cabinet Secretariat, Government Of India, New Delhi	Dr. Ravinder Chowdhry Ex-ADVISOR (R&D) Last Cabinet Secretariat, Government Of India, New Delhi	Ms. Deepika Bhandari Assistant Professor & HOD Department of Forensic Science Institute of Forensic Science Mumbai
Anchor Institute : SGTB Khalsa College, University of Delhi		

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1. Learning Outcomes

After studying this module, you shall be able to know –

- About Ultraviolet and Infrared Photography
- Various radiation sources of ultraviolet rays
- UV photography with Digital and Film Cameras
- Uses of Photography in Forensic/ Law enforcements

2. Introduction: Ultra violet and Infrared Photography

Wavelength of Visible Light

Electromagnetic radiations are light, however we are able to see a small part of radiation—the portion we call visible light. Other part of the spectrum has wavelengths very high or very less and beyond the limit of our visual perception. The Visible White light splits into seven colors of rainbow, having different wavelength when it is passed through prism. Violet Colour shows the shortest wavelength, at 380 nanometers, and Red has the longest wavelength, at 700 nanometers.

Electromagnetic radiation vary is their energy range. Ultraviolet radiation is very active than visible radiation and therefore has a shorter wavelength. To be more precise: Ultraviolet rays has wavelength between 100 nanometers and 400 nanometers approximately whereas visible radiation includes wavelengths between 400 and 780 nanometers.

Ultraviolet spectrum is classified into the following bands:-

- i. Long wave ultraviolet
- ii. Middle ultraviolet
- iii. Short wave ultraviolet
- iv. Vacuum ultraviolet

i. Long wave Ultraviolet:

It extends from 3200 Å to 4000 Å. This is the range transmitted by regular optical glass of which most photographic lenses are made. This range is most practical value in ultraviolet photography.

ii. Middle Ultraviolet:

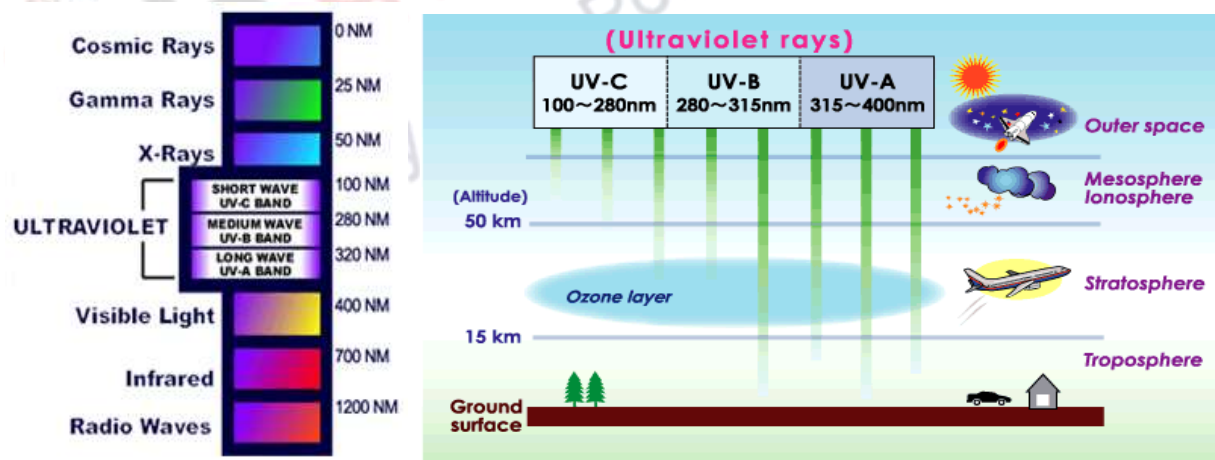
Between 2800 – 3200 Å lies in this region. Middle ultraviolet radiations are not transmitted by even photographic lenses. A lens made of quartz however will transmit these rays and could therefore produce an image using them. Quartz lenses however can also transmit longer ultraviolet.

iii. Short Wave Ultraviolet:

This region lies between 2000 – 2800 Å and is also called ultraviolet. One should never look straight at a source of shortwave ultraviolet radiation. A quartz lens will transmit most wavelengths of short ultraviolet.

iv. Vacuum Ultraviolet:

This region is shorter than 2000 Å and up to 100 Å which is upper limit of X –rays. These radiations pass through vacuum and have no practical value in photography.



UV Rays can be classified into three bands according to their frequencies as given above in the visual.

3. Radiation source of Ultraviolet Rays

1. Sunlight:

Although it would be possible to use sunlight as a source of UV to produce fluorescence, but it is not a practical procedure as it is not followed for forensic photography.

2. Mercury Vapour Lamps:

Mercury vapor lamps, both high pressure and low pressure have applications in reflected and fluorescence photography. All mercury vapor lamps however emit long wave ultraviolet and if the tube is made of quartz, then shorter waves of ultraviolet may also be emitted. A high pressure mercury arc lamp emits a high output of long wave ultraviolet with a corresponding result of intense fluorescence particularly in subjects of small area.

3. Electronic Flash:

Electronic flash lamps are suitable for ultraviolet photography since they emit long wave ultraviolet. One of the difficulties encountered in using electronic flash is that resulting fluorescence is not perceptible during the short flash interval.

The electromagnetic spectrum is invaluable for forensic photography. This comprises wavelengths in the visible spectrum and those that are invisible to the human eye. While we can only see the narrow range of light in the visible spectrum, we can use special cameras to take images of objects, documents as well as human body using ultraviolet and infrared wavelengths, which allows us to gain even deeper insights.

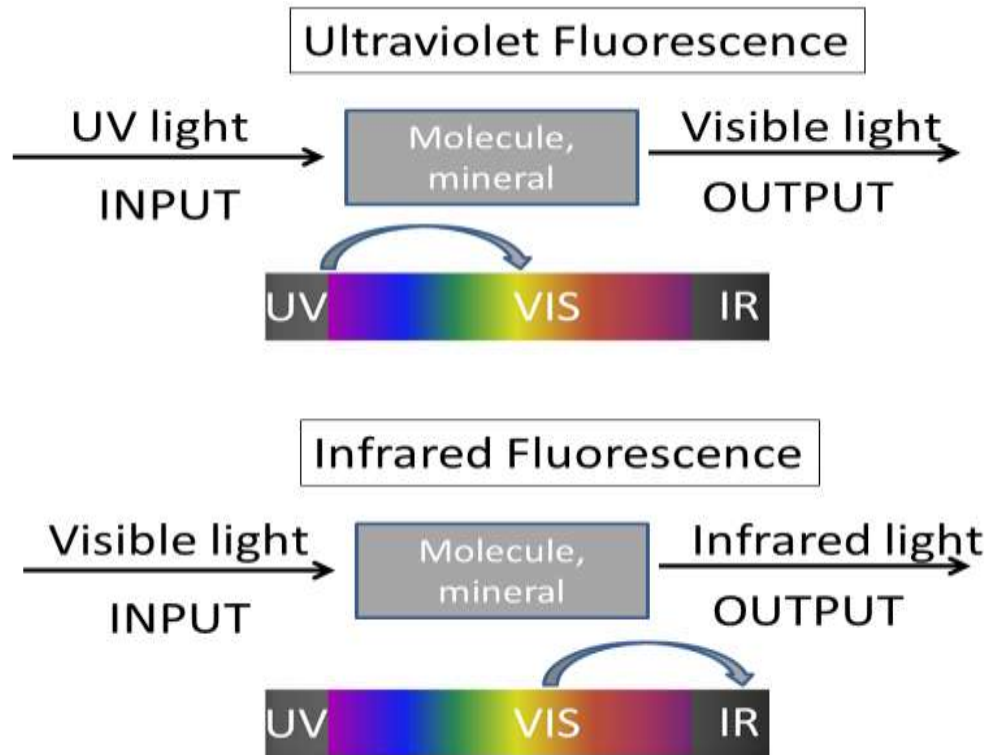
By responding to ultraviolet and infrared light, the camera reveals information that is otherwise concealed from the human eye.



Multispectral imaging can also be used to read & record faded or burnt manuscripts - even from carbonized and damaged fragments. We can recover washing off the original ink & overwritten with new text. These *washed out inks* can still be read using the appropriate wavelength of light. The UV range (400-360nm) produces ultraviolet fluorescence images (UVF) and ultraviolet reflected images (UVR). The infrared electromagnetic radiation most close to the visible range (1100-780nm) can be detected by a special camera/attachment, which is used to collect infrared CCD images (IRCCD) and infrared false color images (IRFC). More sophisticated cameras can detect infrared light even further down the range (1100-1700nm), producing infrared reflectography images (IRR).

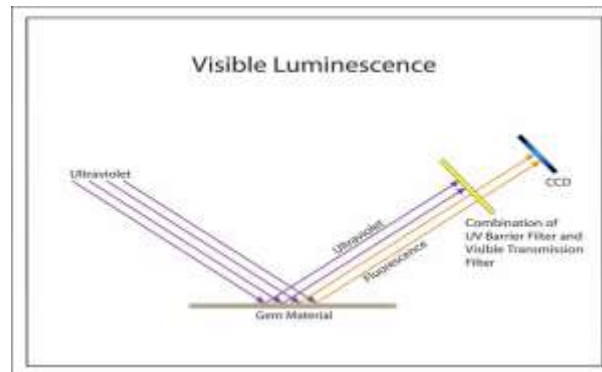


There are two kinds of photography that should not be mixed up: Fluorescence and UV-reflected photography.



LUMINESCENCE	FLUORESCENCE	PHOSPHORESCENCE
<p>When certain materials (solids, liquids or gases) are subjected to short wave electromagnetic radiation, they will emit another radiation of longer wavelength very often in the visible spectrum.</p> <p>This phenomenon of induced light emission is called luminescence and there are two distinct types – fluorescence and phosphorescence</p>	<p>If the luminescence ceases in a very short time (10^{-8} seconds) after the exciting radiation is removed, the phenomenon is called fluorescence.</p>	<p>There are some substances which continue to emit luminescence for some time, even hours after removal of the exciting stimulus (e.g. TV screen, Oscilloscope, certain chemicals and living organisms.)</p>

The first, fluorescence photography, involves illuminating the subject with UV (“black”) light and the subject returns this radiation with lower wavelength, inside **the visible spectrum**, being photographed with conventional photography.



UV Fluorescence imaging:

UV illumination stimulates fluorescence at a longer wavelength than the UV excitation source. The resulting fluorescence is typically in the visible band. A color camera with a UV-blocking filter is used to record the fluorescence image.

Photoluminescence –

SWUV excited LWUV fluorescence probably not a common form of fluorescence photography as it requires a very controlled SWUV excitation source, typically narrow band. A barrier filter that transmits LWUV and blocks SWUV is necessary for the lens. Unfortunately, most photographic lenses will fluoresce to some degree resulting in a foggy image. Lenses specially designed for reflected ultraviolet photography should fare much better. It is not possible to use a readily available SWUV lamp in this application as they also emit some LWUV light.

Visible excited visible fluorescence –

This is very similar to visible excited infrared, except of course the fluorescence occurs in the visible region of the spectrum. The excitation is typically blue or green light and the fluorescence red. However, fluorescence can be green, yellow or orange as exhibited by many "fluorescent" dyes and inks. Capturing visible fluorescence excited by visible light can be very challenging and often requires narrow band excitation sources and sharp cut-off filters. It is also important to exclude infrared from the excitation source or the environment.

4. UV Photography with Digital Cameras

Digital sensors are sensitive to a wide and undesirable spectrum of radiations, from near UV to the IR. Camera manufacturers try to avoid these undesirable side-effects that affect the quality and sharpness of the photographs.

Usually all cameras have built-in filters of the so-called “Hot Mirror” type that eliminate totally the UV from the photographs. CCD and CMOS image sensors of digital cameras incorporate strong UV and IR filters to achieve good color accuracy with standard visible-light subjects. Normal Digital-SLR cameras are not very sensitive in the UV, but very much to IR ranges.

5. Chemical Photography and Films

All photographic films (color negative and slides, black-and-white, infrared) are sensitive to ultraviolet radiation (because silver halide crystals are sensitive to it). There is no significant advantage to using color film for reflected ultraviolet photos because only the blue layer of the tri-color pack will be exposed by the ultraviolet (the integral yellow filter of the film effectively preventing exposure of the red and green layers). The typical film photography method starts with a panchromatic film like Kodak T-Max 400 which has good response to UV. The photographer has to use a special UV-pass filter that blocks visible light from reaching the film, but this black glass filter also prevents the photographer from composing the shot or focusing it properly while it is installed.

Some materials will absorb ultraviolet, while others will reflect these radiations. Some have partial reflection. These effects can be recorded photographically using ultraviolet radiation. Black-and-white films are sensitive to most wavelengths of ultraviolet. By using a filter that absorbs all visible light but passes ultraviolet, it is possible to make a photographic exposure with just ultraviolet.

6. Requirements for UV light Photography

UV Source:

Any Flash with UV Filter or any other UV light source. Instead of a UV source, flash can be used. A high output studio flash will emit a fair bit of UV.

UV Sensitive Camera:

Specialist cameras converted to be sensitive only to UV, however the cheapest commercial option is to simply use black and white film. Black and White Film has sensitivity to UV however the images may undergo reduced contrast.

UV Transmission Filter:

A Filter such as the Kodak Wratten 18A (which leaks a little IR) or Baader Venus 1.25" Ultraviolet Transmission Filter.

Tripod:

Exposure times can be long therefore a tripod is necessary.

Light Meter:

Although fairly useless, this might help sometime.

The lens we use may be good or bad for UV — lenses often contain coatings to block UV — so a little experimentation is required. Alternatively, a quartz lens can be used (Nikon used to make a UV-Nikkor but very costly).

7. Focusing and Exposure

Focusing has to be done for visible light and then shooting for maximum depth of field to get the correct focus. Accurate focus and exposure for ultraviolet photography requires test exposure. The ISO of film will be much different for ultraviolet photography. A film with a speed of ISO 400 for visible light may have an effective speed of ISO 10 for ultraviolet photography.

8. Uses in Forensic/Law Enforcement

- Ultraviolet photography has to be used after visible light techniques and infrared light techniques fail (questioned documents, security documents etc.)
- Fingerprints on multicolored surfaces (dusting with fluorescent powder or ninhydrin is necessary).
- Body secretions such as urine, semen and perspiration often glow when illuminated by ultraviolet light.
- Money and other valuables can be dusted or marked to identify thieves.

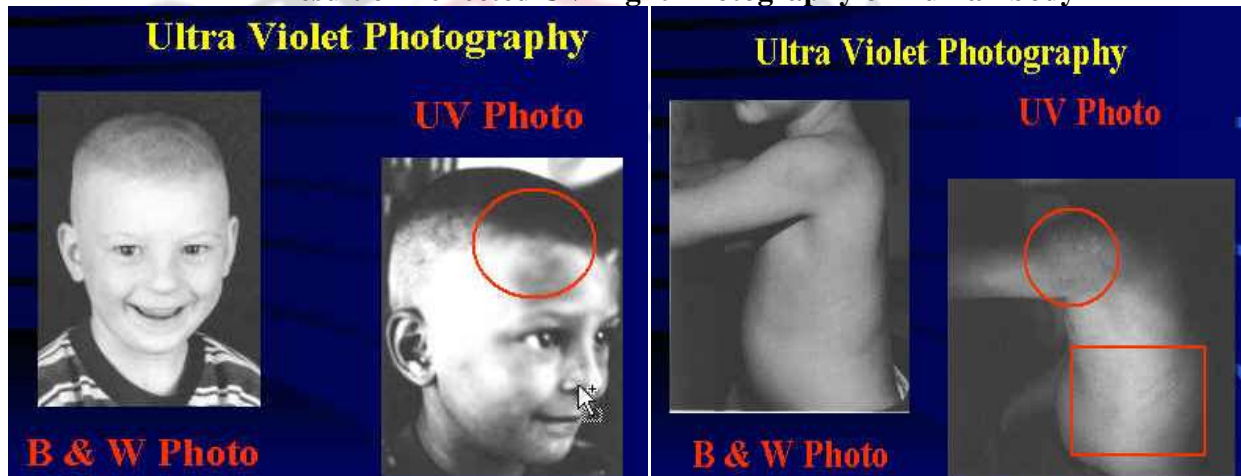
9. Photographic Necessities for Reflected UV Radiation

- i. In a situation when we are taking photograph of an object by illuminating it with a radiation source that emits ultraviolet. The subject has to be illuminated proportionately from at least two sides.
- ii. All visible light has to be excluded from the camera by placing over the lens a filter that transmits only UV.
- iii. The image has to be recorded in the camera on the film.

- iv. We have to take necessary precaution like increasing the contrast in the following situation

Blood	In situation where its Colour blends with surroundings
Documents	Erasures, forgeries & faded documents Inks & printer ribbons-since pigments vary in the absorption and reflection of ultraviolet
Invisible stains	Various body secretions such as: urine, semen, pus, perspirations etc. as they often emit a particular fluorescence.
Clothing	White clothing particularly may fluoresce an intense white blue because dyes are used in laundry detergent makes them look brighter & white. The use of UV light under water has been suggested as an aid in locating human bodies because of these common fluorescence in clothing.
Fingerprints	On multicoated backgrounds, shiny or concave objects, organic matter (all using fingerprint powder).

Result of Reflected UV Light Photography on human body



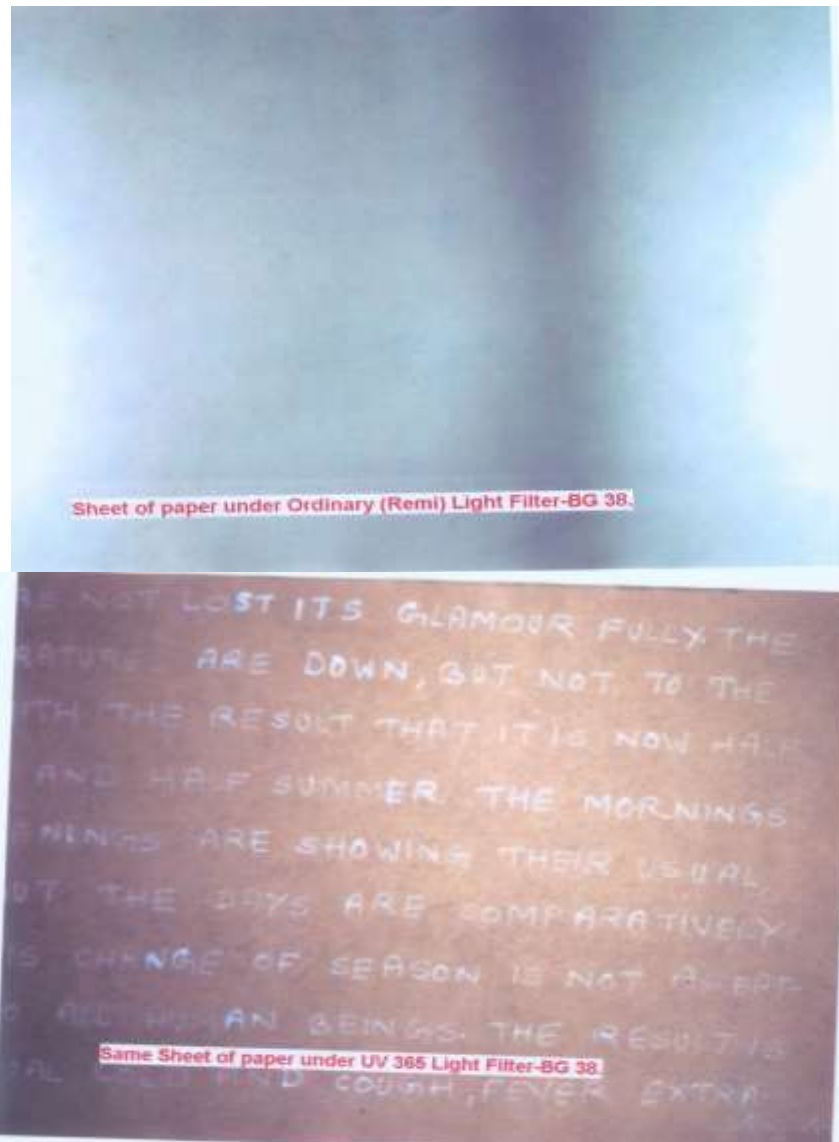


This baby was photographed in normal light and UV light. She had very minimal exposure to the sun, and always with sunblock, thus there is no evidence of sun-induced hyper pigmentation. In the UV reflected photograph on the right, the mark on her cheek is a scratch.

The burn on the subject's thigh was caused by burning kerosene. The oil-producing cells in the skin are damaged, so the skin appears lighter in the UV band, since skin oils absorb UV. Severely sun-damaged skin will appear lighter as well.



100 Euro bill UV security features under UV light



10. Infrared Photography

Sir Frederick William Herschel, a German-born British astronomer, discovered infrared light on 11th February 1800. While using a variety of colored filters to view sunlight, he observed that some colors passed more heat than others. Herschel hypothesized that the colors themselves may have actually produced different temperatures and set out to test his theory.

Herschel conducted an experiment measuring the difference in temperature between the colors in the visible spectrum. He placed thermometers within each color of the visible spectrum. The results showed an increase in temperature from blue to red. When he noticed an even warmer temperature measurement just beyond the red end of the visible spectrum, Herschel had discovered infrared light!



A typical television remote control uses infrared energy at a wavelength around 940 nanometers. While we cannot "see" the light emitting from a remote, some digital and cell phone cameras are sensitive to that wavelength of radiation.



Infrared lamps heat lamps often emit both visible and infrared energy at wavelengths between 500nm to 3000nm in length. Heat lamps can also keep small animals and reptiles warm or even to keep eggs warm so they can hatch.

The *infrared* range begins at wavelengths of 700 nm (at the red end of the visible spectrum) and extends toward longer wavelengths. Both sunlight and incandescent light sources contain large amounts of infrared. The sensors used in digital cameras are very sensitive to *near-infrared* (700-1200 nm). Virtually all digital cameras use infrared-cut filters sandwiched on top of the sensor, in order to reduce or eliminate IR light. Many of these filters let usable amounts of IR pass (up to about 900 nm), and these cameras can be used for IR photography. The built-in IR-cut filters are of varying construction and effectiveness, which makes different camera brands and models more or less suitable for IR photography. Among Nikon DSLRs, the D70 and D70s are reported to be particularly suitable for IR photography.

Radiation source for Infrared photography

Sun Light: Sun Light contains a high percentage of I.R. radiations and therefore a very useful natural source of infrared radiations.

Hot Bodies: All sources which emit or generate heat also emit I.R. radiations in various proportions. Even the human body emits I.R. radiations. This fact has been used in detecting military installations, human beings and animal life in complete darkness with the help of I.R. photographs and I.R. detecting devices.

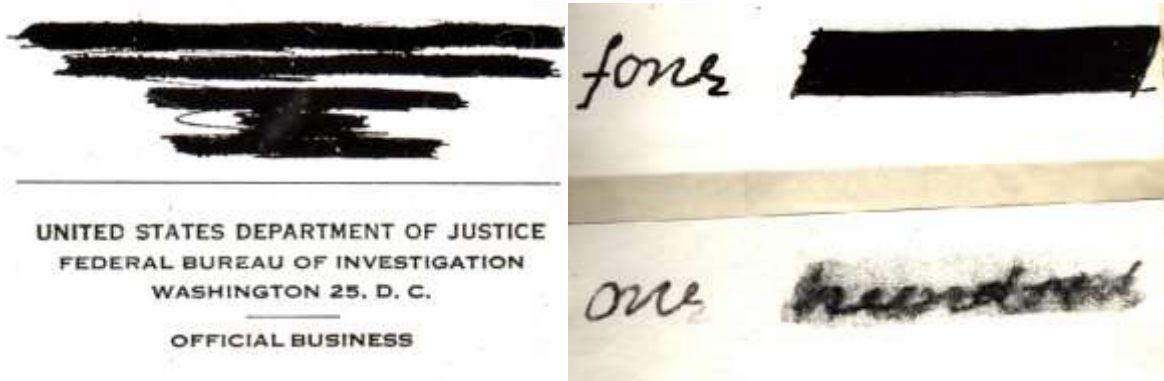
Tungsten lamps: In laboratory, tungsten filament lamp is the most commonly used source of I.R radiations. The various types of tungsten filament lamps are 500 or 1000 watts like the photoflood lamps and halogen projection lamps. I.R lamps coated with graphite are available which are specially made for I.R. photography since the visible light may be opaque to graphite and only I.R radiations are emitted.

Photoflash Lamps: It is practical to coat a dark red, infrared transmitting envelop over photoflash.

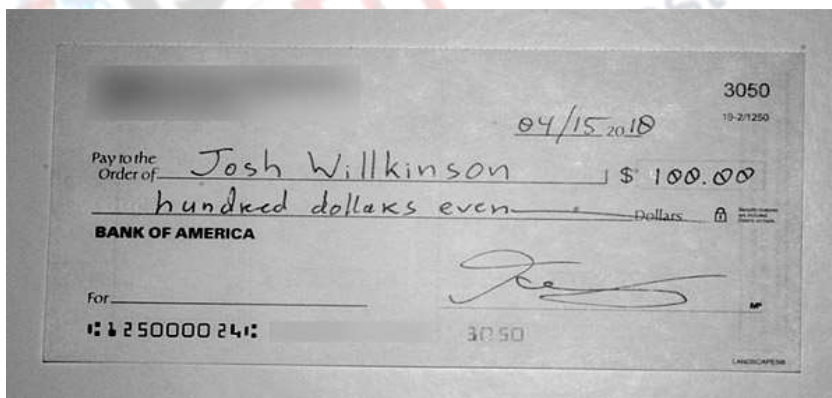
Electronic flash units: Electronic flash units have many advantages in the photography of living subjects. Their benefits of coolness and short exposure time are extendable to infrared photography. Another advantage of these units is that they are more readily obtainable with compact reflectors than the tungsten photoflood equipment.

Infrared photography has found several applications in criminological investigations of faded, erased, burnt, worn, dirty or altered documents, the differentiation between pigments, dyes and inks which may appear indistinguishable to the eye. Infrared photography also helps in examination and identification of cloth, fibers and hair, detection of secret writing and variety of other applications. Infrared can decipher printings or writings underlying the obliterating ink which although black to naked eye in visible light happens to be transparent to infrared.

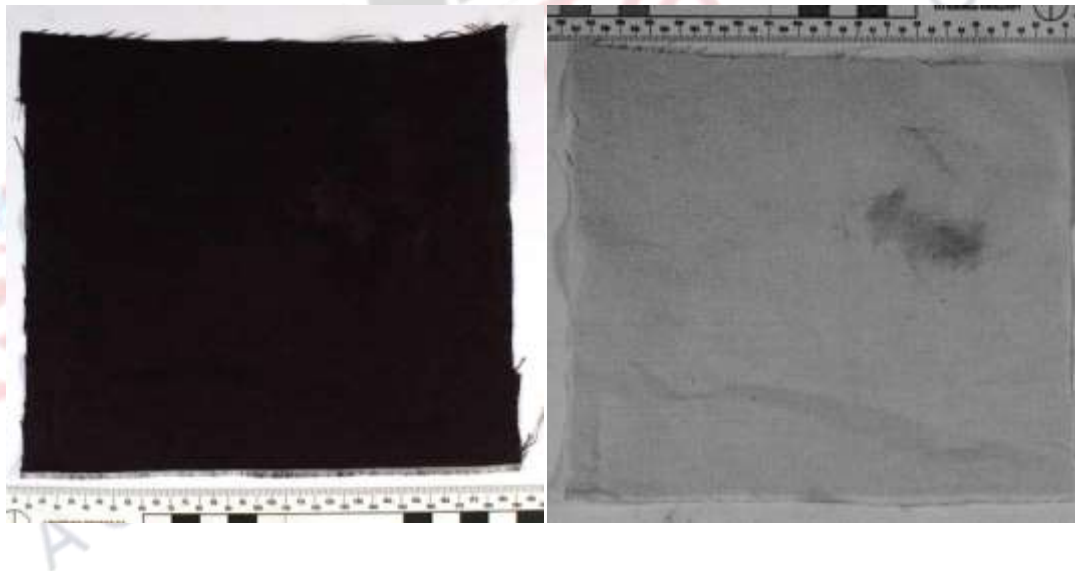
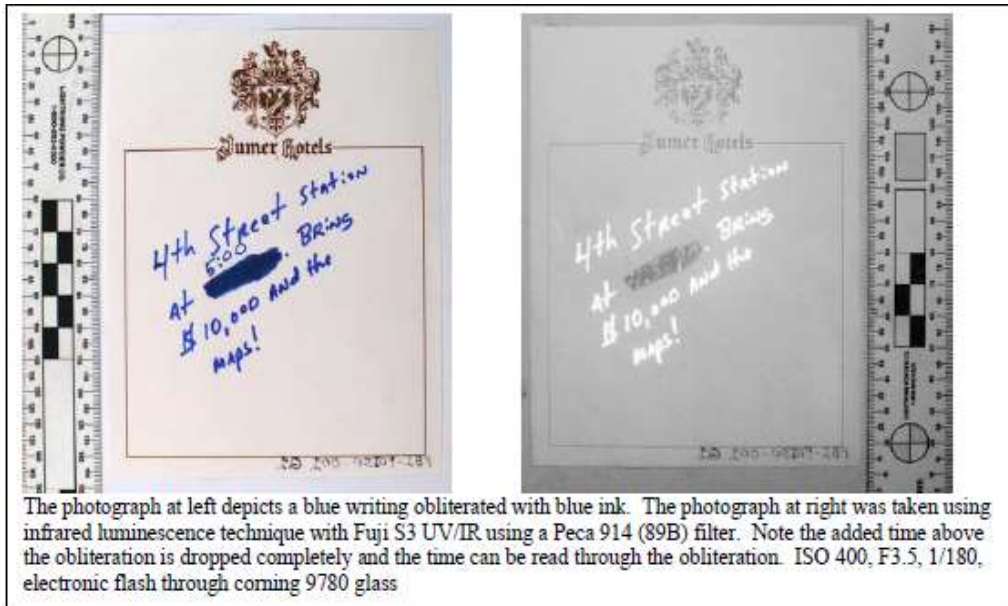
Mechanical or chemical erasure can sometimes be determined even if over written, provided of course the overwriting is an ink transparent to infrared.



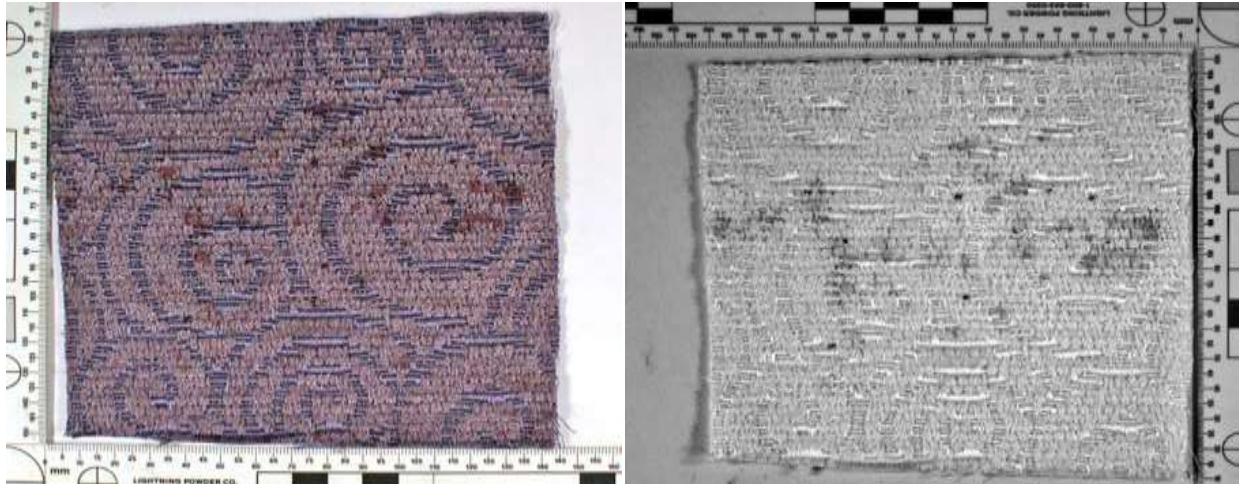
In visible light the check looks to be written for \$400 dollars.



In 830nm (Deep BW) Infrared light you can clearly see the original



The photograph at left depicts black cotton fabric with a bloodstain. The photograph at right was taken using infrared reflected with the Fuji S3 UV/IR digital camera with Peca 900 (18A) filter. The black cloth is rendered white and the bloodstain readily visible. ISO 400, F16, 1/750, Tungsten cross lighting



The photograph at left depicts synthetic upholstery with a bloodstain. The photograph at right was taken using infrared reflected with the Fuji S3 UV/IR digital camera with Peca 906 (87A) filter. The fabric is rendered white with pattern neutralized and the bloodstain readily visible. ISO 400, F16, 1/20, Tungsten cross lighting.



11. Summary

1. Ultraviolet radiation is more energetic than visible radiation and therefore has a shorter wavelength.
2. A lens made of quartz however will transmit these rays and could therefore produce an image using them. Quartz lenses however can also transmit longer ultraviolet.
3. There are some substances which continue to emit luminescence for some time, even hours after removal of the exciting stimulus (e.g. TV screen, Oscilloscope, certain chemicals and living organisms.)
4. All visible light has to be excluded from the camera by placing over the lens a filter that transmits only UV.
5. The *infrared* range begins at wavelengths of 700 nm (at the red end of the visible spectrum) and extends toward longer wavelengths.
6. Infrared photography has found several applications in criminological investigations of faded, erased, burnt, worn, dirty or altered documents, the differentiation between pigments, dyes and inks which may appear indistinguishable to the eye.