

A DIY Long-, Medium-, and Short-Wave Ultraviolet Lamp for Fluorescence Photography

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"I am almost inclined to coin a word, and call the appearance fluorescence, from fluor-spar, as the analogous term opalescence is derived from the name of a mineral."

- George Gabriel Stokes

A Short Primer on UV Fluorescence Photography

Fluorescence is the glow revealed by certain substances when illuminated by light within a certain wavelength range. Most often, the emitted light has a longer wavelength than the wavelength of the radiation used to excite it, and the most familiar type of fluorescence occurs when a fluorescent material is illuminated with invisible ultraviolet (UV) light that causes a very bright glow within the visible spectrum.

The term fluorescence has nothing to do with the element fluorine. Instead, it was coined by Sir George Stokes (1819 – 1903), a mathematics professor at the University of Cambridge, when in the 1850s he noted the color-shifting effects in the mineral fluorspar. In Sir Stokes mind, the property of fluorescence was to fluorspar like opalescence was to the opal stone. Fluorspar melts very easily, so its name comes from the Latin “fluo”, for flow, and “spar”, for a non-metallic mineral.

As shown in Figure 1, UV-induced fluorescence occurs when an atom of a fluorescent material is excited by kicking an orbital electron to a higher energy level as the result of absorbing an ultraviolet photon. A lower-energy photon – with a wavelength commonly in the visible or near-IR range - is emitted when the atom relaxes back to its ground state.

Ultraviolet fluorescence photography is about imaging the visible emissions produced by a fluorescent material while excluding the ultraviolet light used to excite it. As shown in Figure 3, UV sources also tend to produce visible light, so a UV-pass filter should be used in front of the source to minimize illuminating the subject with visible light. This “excitation filter” is typically made of a colored filter glass with characteristics similar to the ones shown in Figure 2. Lower-quality glass than for reflected-UV

photography is perfectly acceptable for the excitation filter since small imperfections don't affect illumination in any meaningful way.

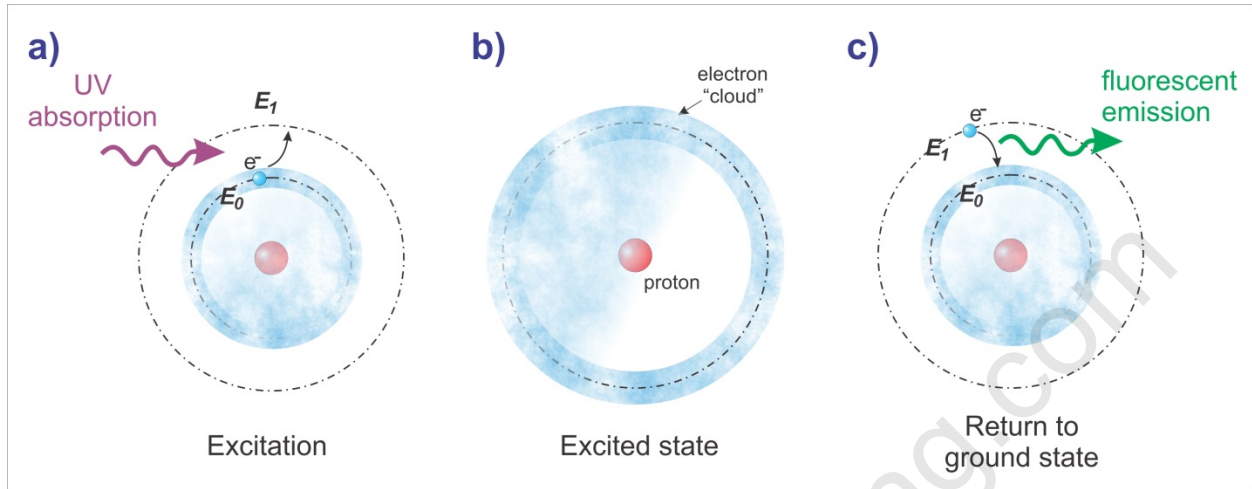


Figure 1 - UV-induced fluorescence occurs when an atom of a fluorescent material is excited by kicking an orbital electron to a higher energy level as the result of absorbing an ultraviolet photon (a). A lower-energy photon is emitted when the excited atom (b) relaxes back to its ground state (c).

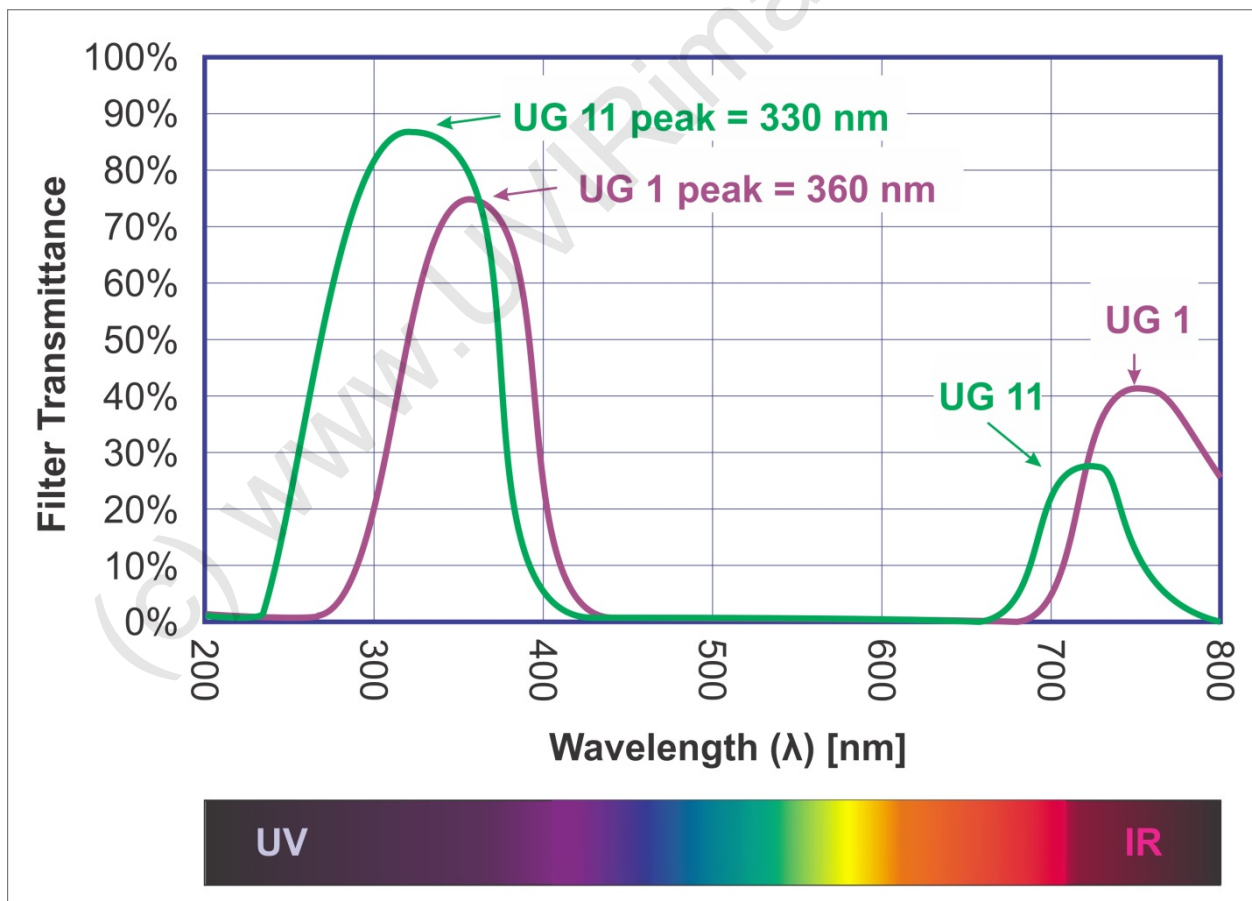


Figure 2 – Transmittance of 1 mm thick Schott UG1 and UG11 glasses.

On the camera side, a “barrier filter” is used to block reflected excitation light and transmit only the fluorescence. Ideally, the spectral properties of the barrier filter should be closely matched to the spectral properties of the excitation light source and expected fluorescence. The barrier filter should be chosen so that it completely cuts off the light coming from the UV source, yet not be so deeply colored that it will also attenuate the fluorescence. A properly matched barrier filter will produce the brightest possible fluorescence, with very strong contrast and no interference from the excitation source.

Standard DSLR cameras are very insensitive to UV, and lens optics are usually very obscure to UV wavelengths, so a barrier filter is not usually needed when the excitation wavelength is outside the visible range and the source includes a sufficiently narrowband excitation filter. However, when using sources close to the camera’s sensitive range (e.g. 390 nm LED lamp), a Kodak Wratten #2A (cutoff at 410 nm) or #2B (cutoff at 395 nm) pale yellow barrier filter may be necessary to eliminate interference from the excitation source.

As an interesting aside, while long-wave-UV is not harmful to our eyes or skin, it causes the lens in the eyes (as well as some eyeglasses) to fluoresce during exposure which interferes with viewing fluorescent specimens. Wearing UV-blocking goggles while viewing specimens under LW-UV is thus recommended to enhance visual contrast. Of course, UV certified goggles must be used as the minimum level of protection when working with midrange and shortwave-UV.

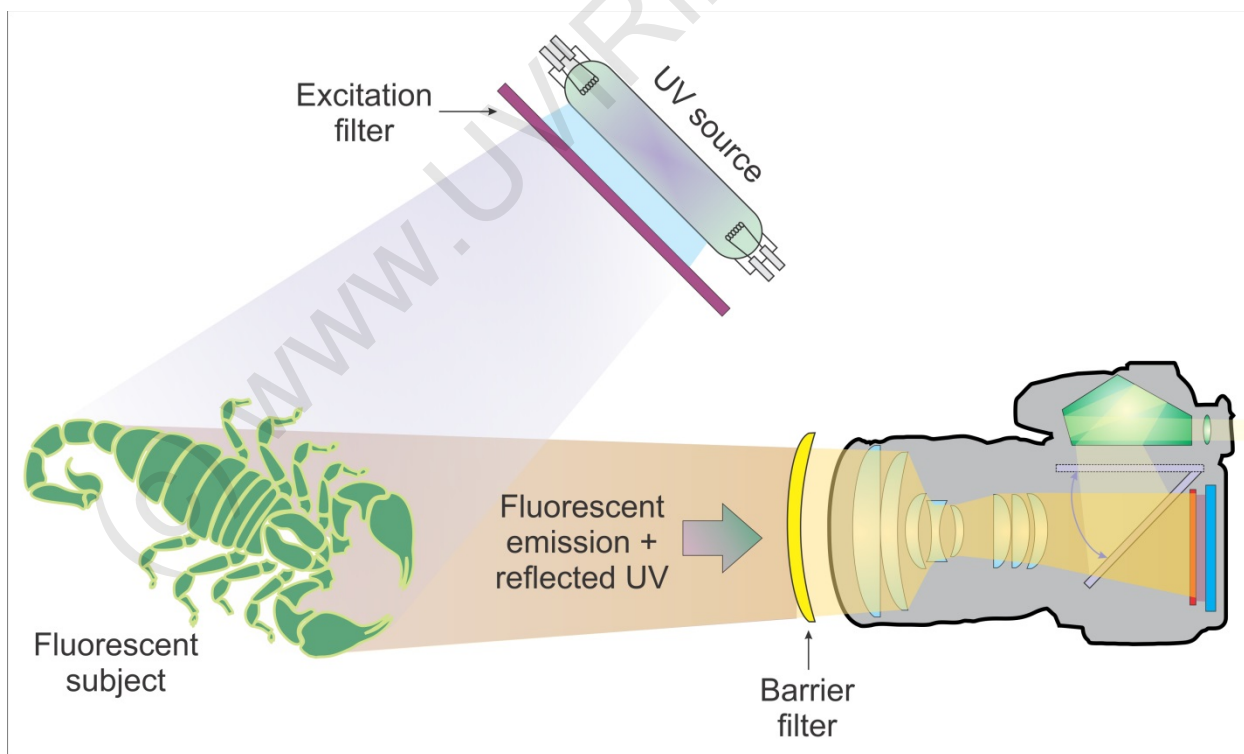


Figure 3 – In UV fluorescence photography, the UV-pass filter is known as the “excitation filter”, and is placed in front of the UV source to transmit only those wavelengths of the illumination light that efficiently excite fluorescence. A so-called

“barrier filter” (also known as an “emission filter”) eliminates reflected UV light and very efficiently transmits the fluorescence emitted by the specimen.

UV Lamps for Fluorescence Photography

Almost all UV sources used in fluorescence photography work are based on mercury vapor lamps with external filters to narrow down their emissions to one of the ranges shown in Table 1. Different materials respond to different wavelengths differently, so a single wavelength lamp does not usually suffice to explore the field of UV fluorescence photography. Most commonly, enthusiasts would have a lamp for Long-Wave (LW) and one for Short-Wave (SW) use, or alternatively a dual-wavelength LW and SW lamp with individual power control. More advanced users also have a lamp that can emit Medium-Wave (MW) UV because a few materials respond very distinctly to its wavelength. The selection depends on the user’s specific interest – 85% of fluorescent minerals glow under SW-UV light, but LW-UV should be used for all live specimens because of the biological damage that would be caused by shorter wavelength UV. Figure 4 shows the three lamps that I use most often.

Table 1 – Wavelength ranges used in fluorescence photography along with the internationally-recognized ranges according to standard ISO 21348 (2007) “Space environment (natural and artificial) — Process for determining solar irradiances”.

Ultraviolet Range	ISO 21348 (2007) Designation	ISO 21348 (2007) Range	Common Mercury Lamp Wavelength
Long-wave UV (LW-UV)	UVA	315 nm to 400 nm	365 nm
Mid-wave UV (MW-UV)	UVB	280 nm to 315 nm	312 nm
Short-wave UV (SW-UV)	UVC	100 nm to 280 nm	254 nm



Figure 4 – Some popular UV lamps used by fluorescent mineral enthusiasts include the Versalume LW/SW (front), Spectroline MinMAX SW (middle), and pro-grade Way Too Cool 18 W LW/MW/SW filtered UV sources.

WARNING: Mid-wave and short-wave ultraviolet radiation can cause permanent eye and skin damage. Do not look directly at MW or SW UV radiation, even for brief periods. Take appropriate precautions with pets and other living organisms that might suffer injury or damage due to UV exposure at these wavelengths.

A DIY Professional-Grade LW, MW, and SW UV Lamp

Quality filtered lamps tend to be expensive, but their price is often justified not only because of the cost of tubes, but also because of the high cost of filter glass – especially the one for the shorter wavelengths. A more economical proposition is to build your own lamp, and you may follow the schematic of Figure 5 as the basis for a professional-quality 18W lamp that covers the full range of wavelengths.

The tubes that I use are made by Philips and can be purchased online with ease (for around \$20 to \$25 each). My choices are:

- Long-wave tube: Philips PL-L 18W/10/4P 18 Watt Actinic Blacklight Lamp
- Mid-range and short-wave tubes: Philips PL-L18W/TUV 18 Watt Germicidal Lamp

These are 8.5" long folded tubes that operate at a voltage of 60V and consume 18W. They have a 4-pin type 2G11 base, so you will need three mating lamp receptacles.

I use Lightwave model EB-1005/GPH793 electronic ballasts to run the lamps from the AC powerline. These ballasts can drive lamps of up to 40W, and start the lamp by heating the lamp's filament and then applies a relatively low strike voltage across the lamp electrodes to start the discharge across the mercury gas.

The LW lamp is originally made for electronic fly killers and produces 3.5 W of UVA radiation at 18 W electrical input. Its spectrum has been optimized by Philips to match the eye sensitivity of the housefly. They have virtually no UV-B output, so they are safe to use without protection. A long-wave UV filter needs to be used in front of this tube to eliminate its strong turquoise-blue visible emissions.

Another lamp model is used to produce SW and MW UV. It is originally designed by Philips for use in professional water and air disinfection units. It features an almost constant UV-C power output of 5.5W at 18 W electrical input over its complete lifetime, making it a great choice for consistently illuminating samples when performing publishable-grade research.

MW light is produced from the SW lamp with a dedicated phosphor sheath for downconverting and filtering the lamp's output to a broadband distribution centered at 312 nm. An alternative is to use a narrowband UVB phototherapy tube made for treating skin diseases such as psoriasis, atopic dermatitis, and vitiligo. For example, Philips' PL-L36W/01 – in a package that is twice as large as the 18 W lamps - emits 6.2 W of UV-B radiation in a narrow band between 305 and 315 nm with a peak at 311 nm while drawing 36 W of electrical power.

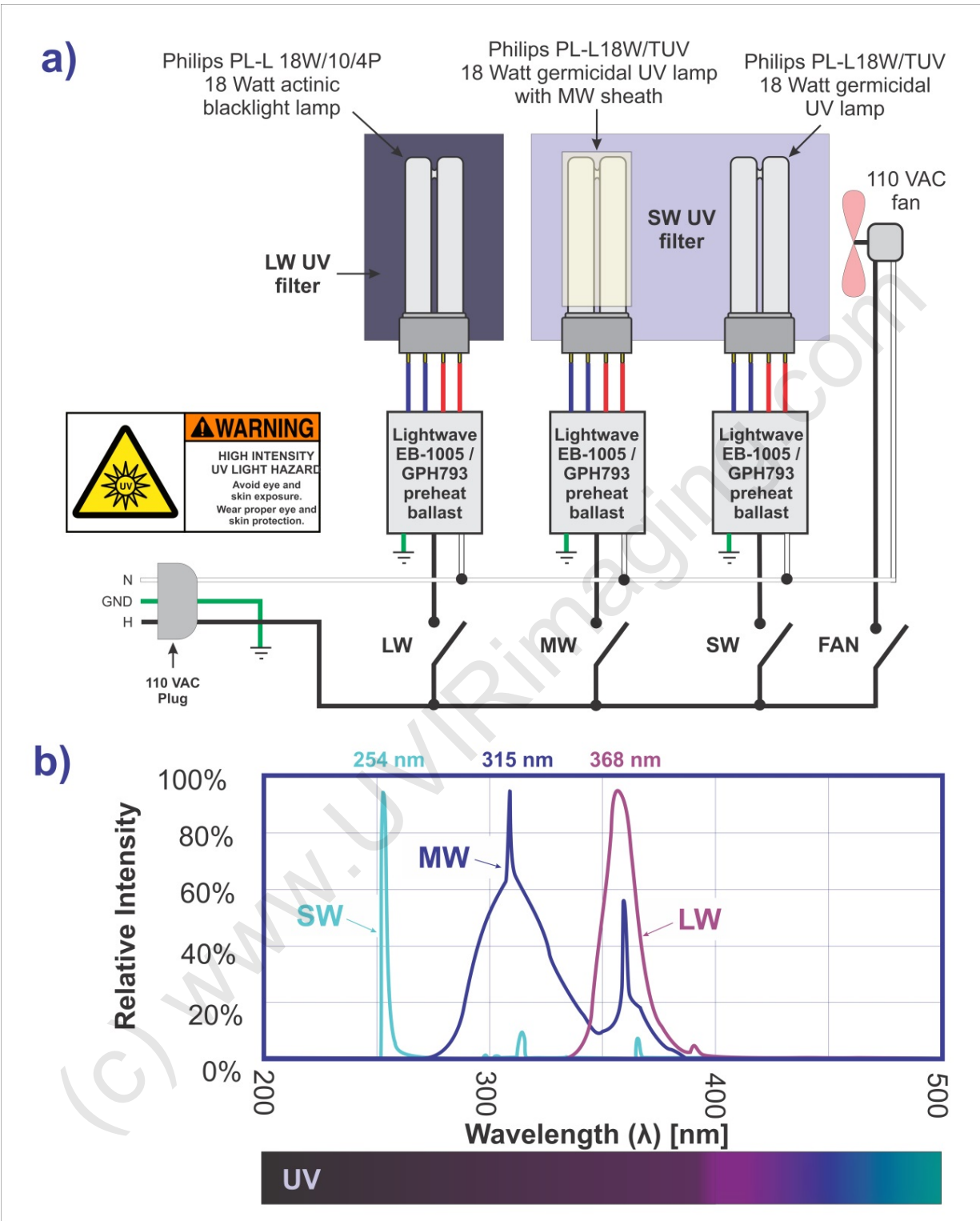


Figure 5 – An 18 Watt longwave, midrange, and shortwave UV lamp for mineral fluorescence work can be built from three Phillips UV tubes. a) The long-wave tube is originally made for attracting insects for fly killers. The other two tubes are UV germicidal lamps. b) The individual lamps are all low-pressure mercury vapor, so they share mercury’s emission lines, but the use of phosphor, type of envelope glass, and filters shape their respective output spectrum.

LW and visible emissions from the MW and SW lamps should be reduced using a smooth, polished pane of SW-UV-transmitting filter glass, such as Hoya U-325C. Large panes of filter glasses can be purchased from UV Systems Inc. – a high-quality UV lamp manufacturer that caters to fluorescent mineral collectors. While a piece of rippled LW filter glass for this lamp should cost around \$15 to \$20, you should expect the SW filter to be significantly more expensive – probably in the \$400 range for a 4" × 8" × ¼" pane. Because of this cost, always make provisions to protect the filters while in use. For example, the filters could be recessed inside the enclosure, and a protection barrier made of chicken wire mesh could be placed on the outside to prevent any object from hitting the filter.

Lastly, a fan to cool down the lamps, as well as to vent ozone produced by the two germicidal lamps should be assembled onto the enclosure.

Photographing Fluorescent Minerals Illuminated by the DIY UV Lamp

Some 15% out of the approximately 3,600 known mineral species that have been identified fluoresce when excited by UV light. However, it's uncommon for a mineral to fluoresce in its pure state. Trace amount of ionic impurities are required to make most fluorescent minerals produce their glow. These doping materials are known as "activators", and they work by creating inhomogeneities in the mineral's crystal structure where fluorescent emission can take place when atoms are excited by UV light.

Activator ions include tungsten, molybdenum, lead, boron, titanium, manganese, uranium and chromium. However, the presence of activator ions can be dampened or "quenched" by impurities of iron or copper which can dramatically reduce or completely eliminate fluorescence. Paradoxically, fluorescence is also undermined when the concentration of activator ions exceeds a certain trace amount. The color and degree of fluorescence of a specimen are related to the type and concentration of activators and quenchers, so different specimens of the same material may reveal very different fluorescence, especially if they come from different geographical locations.

In my view, the bible on mineral fluorescence is "Ultraviolet Light and Fluorescent Minerals: Understanding, Collecting and Displaying Fluorescent Minerals", which was published by the late Thomas S. Warren [1999] - the founder of founder of Ultra-Violet Products, Inc. (now UVP, Inc.). Chapters in this book were contributed by recognized experts on fluorescent minerals from the mines in Franklin, NJ – an area known as the "Fluorescent Mineral Capital of the World" because of its rich ore body containing 357 minerals, 91 of which have fluorescent properties.

The last working underground mine in the Franklin area, and in fact in all of New Jersey closed in 1986 before it was turned into the Sterling Hill Mine Tour and Museum of Fluorescence. Iron and zinc were extracted at this site, and its flagship ore was franklinite $ZnFe^{3+}_2O_4$. Franklinite is not fluorescent, but it commonly occurs with willemite, which fluoresces very brightly in green under ultraviolet, as well as calcite, which glows red under short-wave UV (Figure 6).

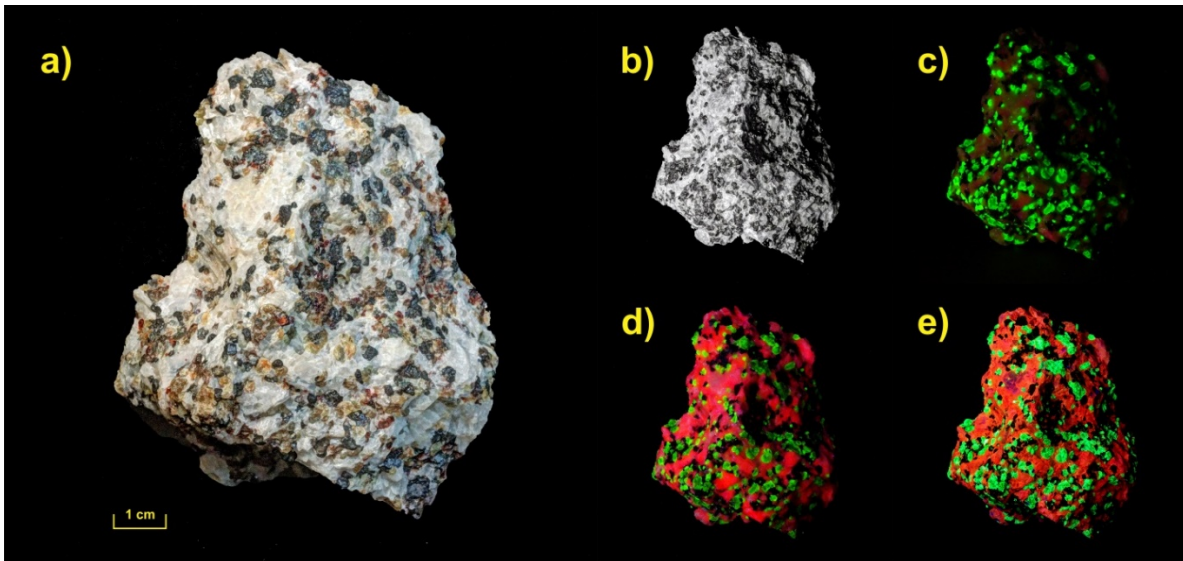


Figure 6 – A composite sample of franklinite, willemite, zincite, and calcite from the Sterling Hill Mine in Ogdensburg, NJ: a) White light photograph; b) reflected near-UV with Baader-U and long-wave illumination; c) fluorescence with long-wave UV excitation; d) fluorescence with mid-wave UV excitation; e) fluorescence with short-wave UV excitation.

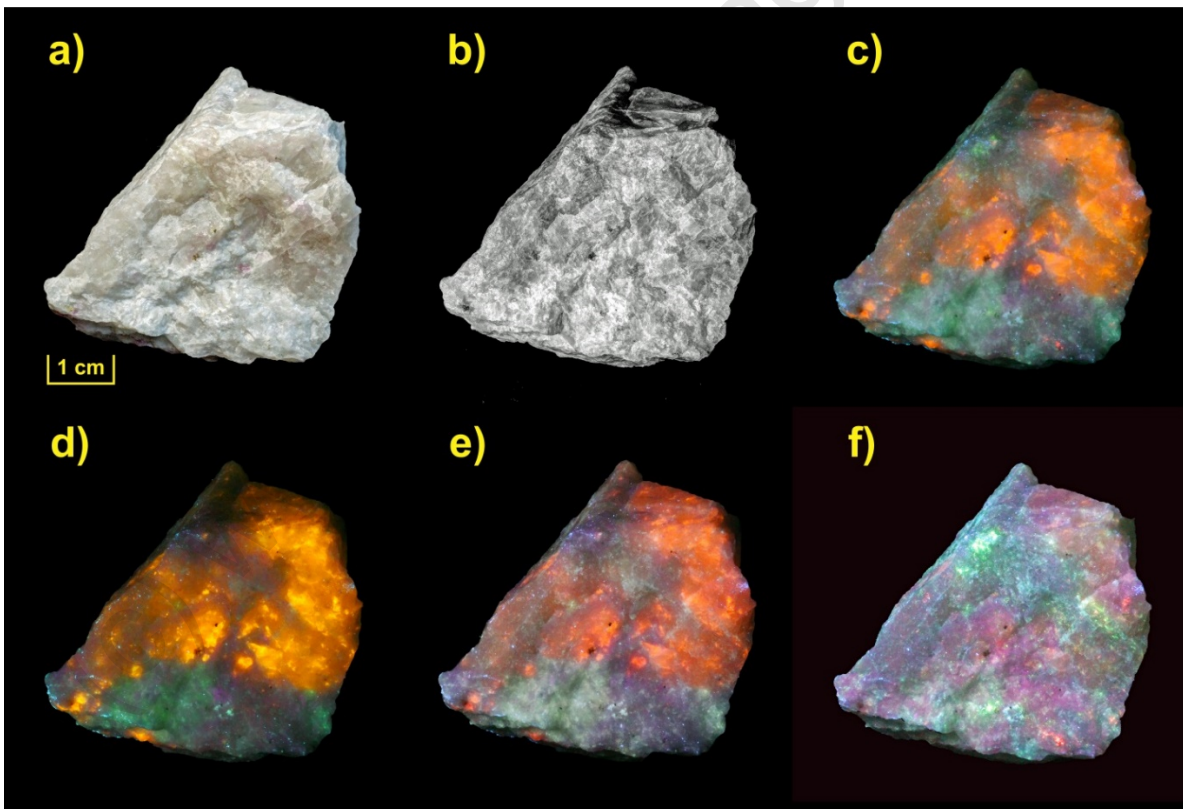


Figure 7 – Hackmanite from Bancroft, Ontario, Canada: a) White light photograph; b) reflected near-UV with Baader-U and long-wave illumination; c) fluorescence with wideband (LW, MW and SW) excitation; d) long-wave UV excitation; e) fluorescence with mid-wave UV excitation; f) fluorescence with short-wave UV excitation.

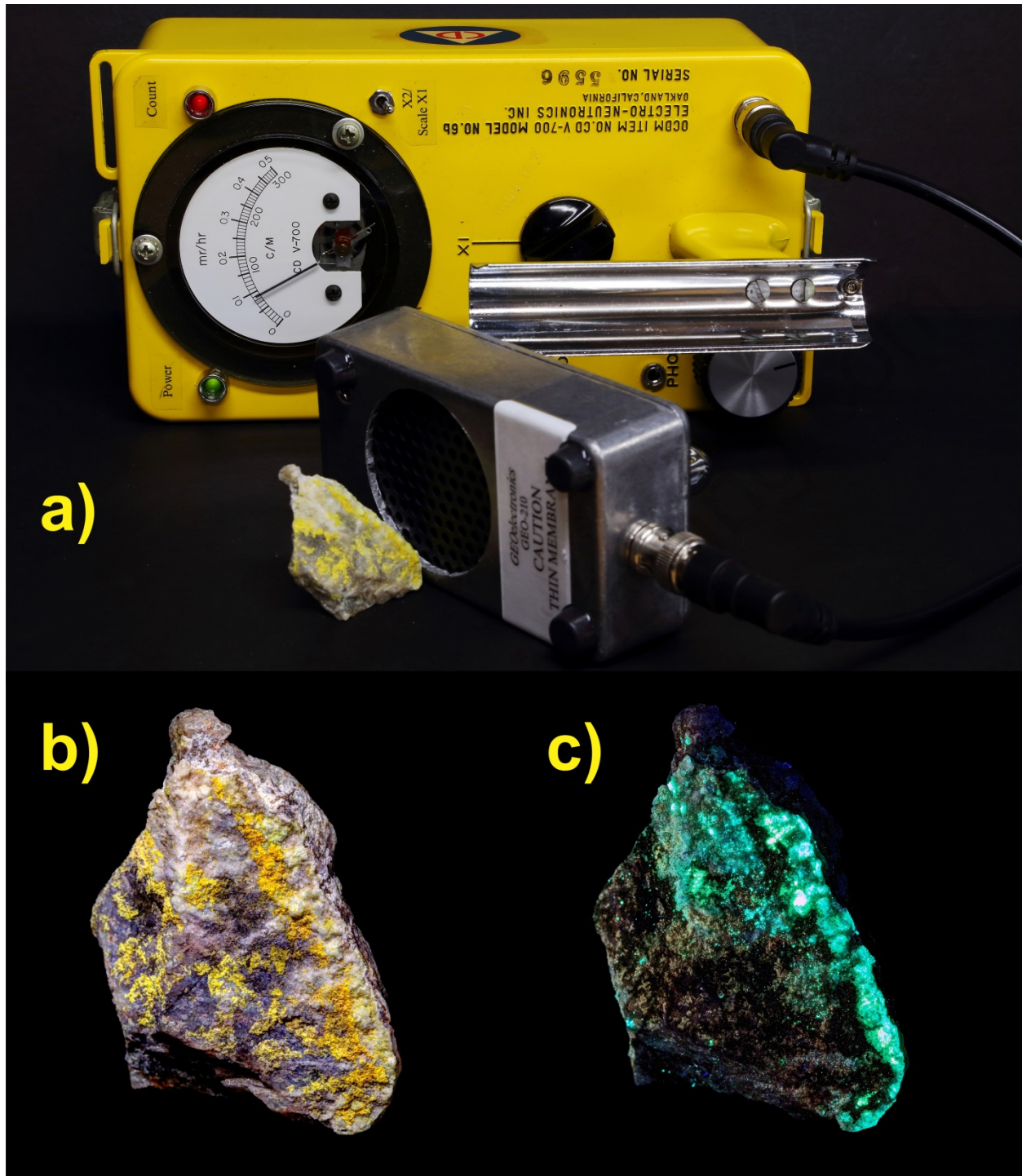


Figure 8 – The yellow patches in this sample from the Schwartzwalder Mine in Jefferson, CO are liebigitte - a uranium carbonate mineral that is commonly found in uranium-bearing ores. a) The uranium salt is radioactive. b) The translucent yellow-green liebigitte crystals c) fluoresce under LW, MW, and SW-UV light.

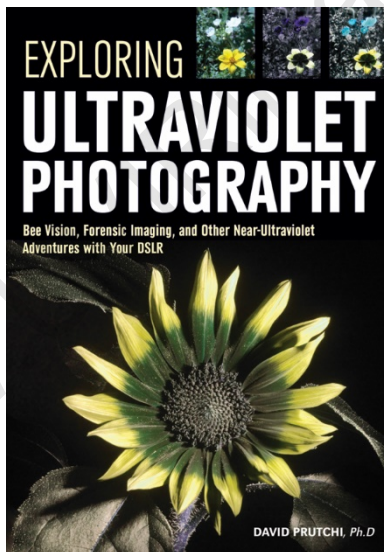
Specimens from the Franklin area are inexpensive and easy to find at online mineral stores and on eBay®. Their fluorescence is so bright that low-powered filtered UV lamps suffice to produce great pictures. Less common and more expensive are tricolor specimens that also contain esperite which

fluoresces in yellow under SW-UV. Another inexpensive mineral that produces beautiful results is hackmanite from mines in Bancroft, Ontario, Canada (Figure 7).

There are a few minerals that will fluoresce when pure. These are called "self-activated" minerals, and include scheelite (an important ore of tungsten), powellite (a calcium molybdate mineral), and several uranium minerals. The latter are mildly radioactive (Figure 8), making them doubly-interesting for science enthusiasts.

If photographing fluorescent minerals interests you, then you should explore the website of the Fluorescent Mineral Society at www.uvminerals.org which has a wealth of practical information on collecting, displaying, and photographing these specimens.

More UV photography and imaging projects are also available in my book "[Exploring Ultraviolet Photography: Bee Vision, Forensic Imaging, and Other Near Ultraviolet Adventures with Your DSLR.](#)"



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