Technology Update-Ultraviolet Light

Ultraviolet light sources for testing gem fluorescence have been a staple piece of gem equipment for decades. Emerging technologies will not only change the way you look at ultraviolet but will eventually redefine our industry standards.

By Bear Williams

When a gemologist is ready to test for fluorescence, they usually reach for their ultraviolet (UV) light. Most of these lamps (Figure 1) will have two buttons for switching between long-wave (LW) and short-wave (SW). The bulb inside this device is a low-pressure mercury tube, developed in 1919. You are possibly reading this article under an overhead fluorescent light right now. These standard, overhead low-pressure tubes are coated on the inside with powdered phosphors that react to the electrical discharge and emit the white light that we observe. On the other hand, the UV bulb, also a low-pressure mercury tube, is coated with nickel oxides to block out the visible wavelengths. Filtering out longer wavelengths in the 400-700 nanometer (nm) visible ranges allows only the higher energy LW and SW UV luminescence. This "black-light" technology saw its main production begin in the late 1920's.

Figure 1

But what could be wrong with this technology as it applies to gemology? If we take a look at the emissions in these types of bulbs one can see some problems that arise. Using a UV-Vis spectrophotometer, you can see the mercury spectrum (Figure 2) of a LW-UV light source. In this graph we can readily see the 365nm line, which is the designated emission for the LW-UV band. However, upon closer examination, it is apparent that other, longer wavelengths are also emitted by most of these types of bulbs. Since other energy is present, which energy is truly activating the fluorescence of a particular stone? Not necessarily the sole designated 365nm line and quite probably the other mercury lines at the 404 and 435nm wavelengths. These other wavelength bleeds are not

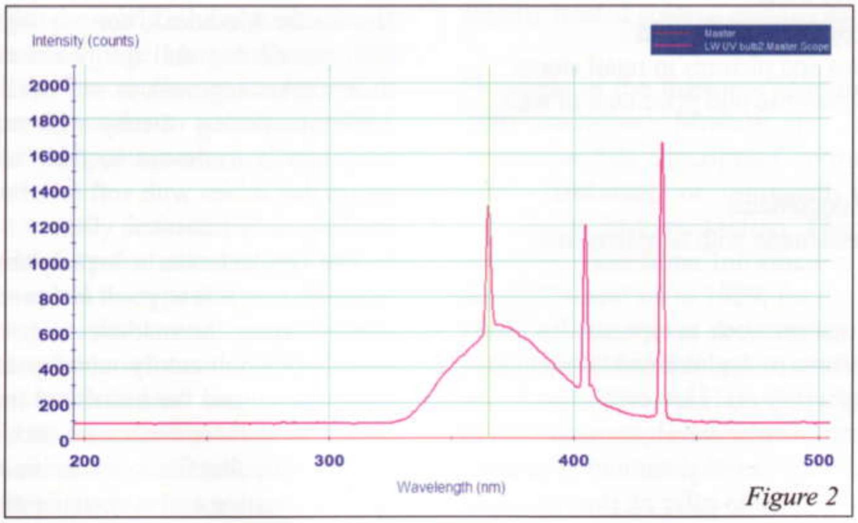


Figure 2

a bad thing in themselves. In fact, the 400-425nm excitations are fantastic energy sources to induce fluorescence, but not if you are under the impression that it is the 365nm energy that is doing it, and not if you are comparing results with someone who has a pure 365nm source.

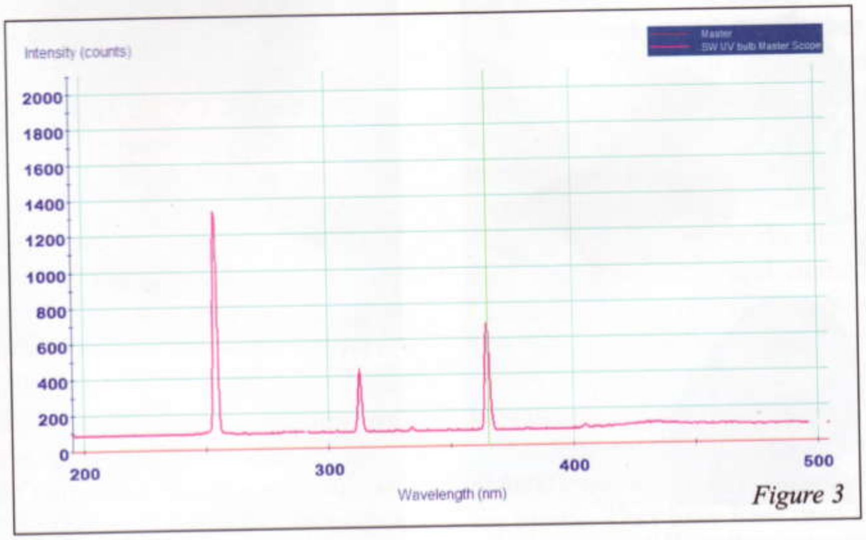


Figure 3

Looking at the second graph (Figure 3) we see a very troubling anomaly with these bulbs. The visible results are readily apparent, and in the SW mode we see its 254nm emission peak. While the 254nm is the designated emission, please draw your attention to the 365nm line simultaneously emitting. This is a LW component. Though it is only half the amplitude of the 254nm line, its existence there could lead to what is often interpreted as the stone "weakly fluorescing in SW," when in fact it is probably induced by the leaking LW component.

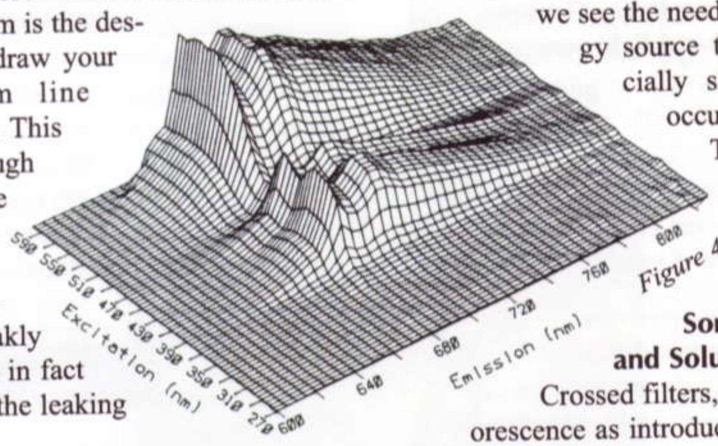


Figure 4

There is no need to be vague with this. We can see the need to precisely identify the source of energy that is causing the excitation. It may be called SW or LW, but when they have several energy levels that bleed or overlap each other as we have plainly seen, it is not an exact science. In multiple tests made in various jewelers' gem labs, *all* the UV lights tested as having the LW UV bleeding through their SW tube style testing lights. Solutions are on the horizon, but first let us discuss some basics.

Stokes Law

Fluorescence begins when the absorption of visible or UV radiation raises the atoms to an excited state. The electrons absorb this quantum energy and jump to a higher energy orbit. The subsequent return of these electrons to their ground orbit is when the energy is released as radiation, mostly as visible light or near infrared. According to Stokes Law, this emission occurs at a longer wavelength (lower energy level) than the energy source used to excite the stone.

A very interesting study using excitation and their respective emissions was performed (Hoover & Theisen, 1993) that gave a gradation of energy sources ranging from 250-600nm in 5nm increments and their emission responses (Figure 4). This was laid out in a 3D graph and showed the interesting fact that many gems have little if any response whatsoever to UV radiation of wavelengths shorter than 300nm, most being inert to shorter wavelengths. Again we see the need for proper definition of energy source to fluorescent reaction, especially since most of the excitation occurred from visible light ranges. The graph shows the excitation wavelengths and the resulting emissions of a natural Alexandrite.

Some Alternatives and Solutions

Crossed filters, a technique for observing fluorescence as introduced by Basel Anderson, uses a visible blue light source without the need for UV. In Figure 5 we can see the use of a blue light-emitting diode (LED) and red selenium glass as a filter, which clearly shows the bright glow of a fluorescing ruby, without the use of a UV light source.

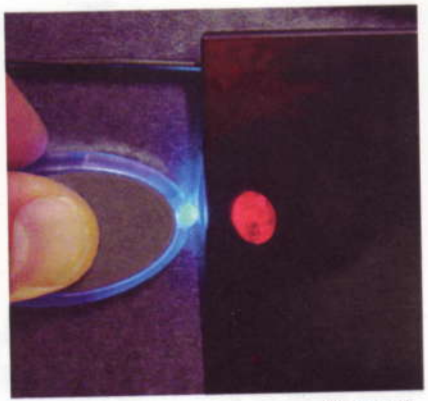


Figure 5

In various testing it is noted that even slight variations in energy levels (392nm vs. 404nm) significantly affect the luminescent response. This is where *and how* we can make our fluorescent readings a more exact science. Harding (1994) and Hoover-Williams (2005) in "Crossed Filters Revisited" caution in their observations that different illuminants can greatly increase the value


Figure 6

of fluorescence in diagnostic testing. When considering this and the Hoover-Theisen ex/em models, all authors note that the longer the wavelength of excitation light used, the stronger the emission. Gemmologist Sylvia Gumpsberger of the Canadian Gemmological Association even uses various red light sources for her fluorescence observations.

Show Your True Colors

As gemologists we rely on our eyes for observing visible fluorescence. What then is the best energy source to use? No need to deal with a SW UV if its only going to have a secondary energy bleed and confuse our readings. Why not a purer energy source that is quick and easy to use, as can be provided by light-emitting diode (LED) technology?

Pictured are a variety of commonly available LED light sources (Figure 6) that range from 392 to 645nm. From left to right in the accompanying graph (Figure 7) you can see their emissions superimposed as overlays according to their light color. Is there bleed or extraneous illumination caused by LEDs? No, each produces a singular, pure light range. It will inevitably be what we want to use in all our future gemological testing. As an example, we may note something like, "The stone did not fluoresce @ 255nm, but showed a whitish yellow at 365nm and a bright orange at 404nm." This may be the first step for our gemological community to discuss in their varied standardization group meetings as we re-equip ourselves during the 21st century.

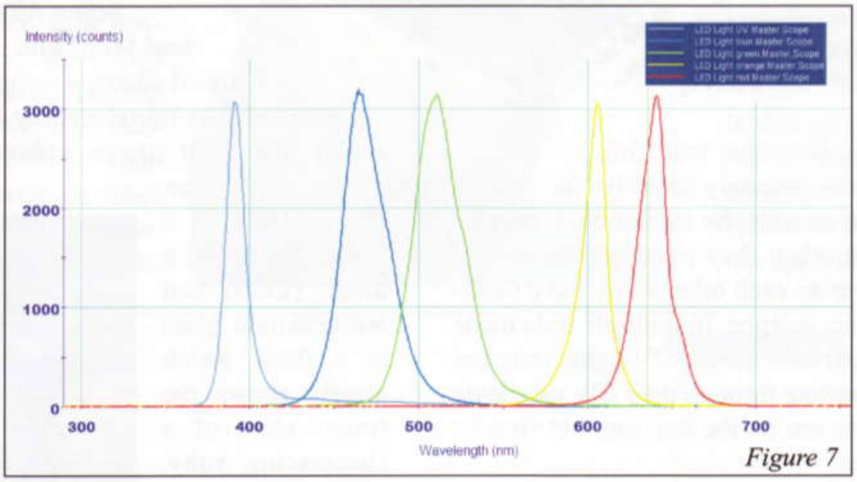


Figure 7

We need a pure SW UV energy source, and Sensor Electronics in Columbia, SC, utilizes nitride technology to produce SW UV LEDs that are available from 247 to 365nm in 5nm increments. These emit in the same clean emission as the above pictured hand lights. Keep in mind that all LED light sources have well-defined wavelengths. Since we have established the SW designation at 254nm, then we could obtain similar results with a single source LED at 255nm. NTT Basic Research Labs, in Asugi, Japan, has created aluminum nitride LEDs that produce a far UV (210nm) radiation. This will open great potential in gemological research.

In her paper "LED Light Sources for Gemmologists," Sylvia Gumpsberger notes that due to the nature of the tighter wavelengths the white LED sources are not suitable if you are using it for the spectroscope or other full spectrum needs. Currently, the manufacturers are looking for methods of broadening the spectrum on the whites. Also of note is the use of the yellow LED, which gives a good monochromatic source that is excellent for refractive index readings.

If you are thinking of updating your laboratory with the latest technology, you can expect different results than the textbooks–and you will not be wrong. It is not just UV LEDs that we can benefit from. As previously mentioned, blue lights can give us fluorescence through crossed filters, but many of these light ranges that are in the violet to ultraviolet, specifically in the 390-415nm range, can give surprising results.

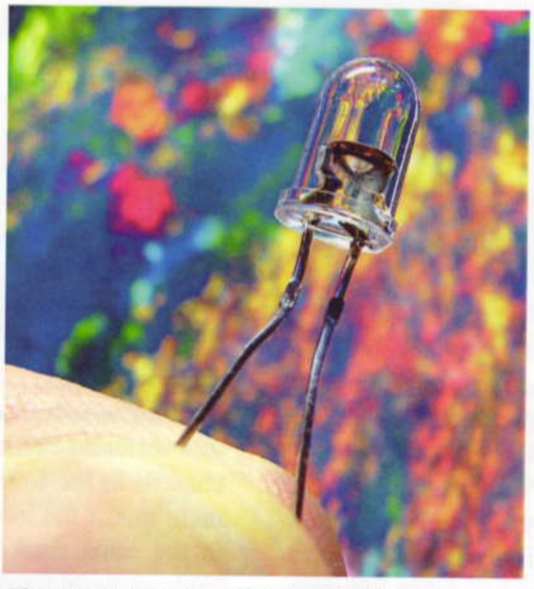
These penlight style LW UV LED lights are readily available in today's market and have no problem fitting in a pocket. They are being discovered in a variety of retail locations. The sub-UV ranges in wavelength induce strong fluorescence even in stones previously thought inert to fluorescence, like garnets. A large variety of different garnet species like spessartite, malaya, and tsavorite (Figure 8) have proven to fluoresce very nicely when using a 402nm LED. Oddly enough, fluorescence in some garnet is overlooked because they fluoresce in their own body color.

Summary

With mercury UV tubes we could see things that were not visible with incandescent light bulbs. Now with LED

Top: Figure 8A; Bottom: Figure 8B

light we can generate exclusive wavelengths that the older tubes cannot. While it is not the purpose of the author to dispute the validity of current or past UV light sources, there is a definite and pressing need for the industry to set new and accurate gemological standards based on better technology, with which we can begin to compile a new body of reference data.



The mighty but tiny LED light bulb.

A Major Light Switch

As far as the rest of the world? They are already converting to LED technology. The new Boeing 787 luxury passenger jet has LED illumination throughout the entire interior cabin. Most automobile makers have already utilized LEDs as their interior lights, brake and signal lights, and are currently working on switching over their main headlights. By 2010, all traffic signals will be working with LED. No need for the expensive, heavy, energy hogs of today, the new traffic lights will be only a single light that changes to the three colors.

Other benefits of LED lighting are greatly reduced energy consumption and longevity. The usual life span of an incandescent light bulb is 750-1000 hours. An LED bulb will last about 100,000 hours. Incandescent bulbs have wire filaments encased within a glass bulb. They only emit 5% of their energy as visible light; the rest is wasted as heat, another hidden energy hog.

As reported in the September 23, 2006 *Economist Magazine* "Technological Quarterly," "Fluorescent bulbs are about four times more efficient than incandescent." But LED greatly rivals even fluorescent lighting in energy consumption and does not require the use of mercury, a notorious contaminant. The *Economist* goes on to explain, "Worldwide, about 20% of electricity is used for lighting. Several studies show that eventually LEDs would cut that consumption in half. That would save billions of dollars in electricity bills, greatly reduce energy demands and significantly save us from the greenhouse gas emissions."

Another aspect of this new technology is the use of organic materials (OLED) made with a thin sheet of glowing plastic. They have been used in a variety of electronic devices and in the small green night-lights that use every bit of nine cents a year in energy, but only if you leave them on 24 hours a day. In the not too distant future imagine curtains or entire walls that can be illuminated at not only different intensities according to the mood, but also with the ability to change the color to your heart's desire.

Commenting on the eventual demise of our current lighting systems, Dr. Jerry Simmons, Director of the Solid State Lighting Program of Sandia National Laboratory sums things up nicely. "We're on the brink of a new lighting revolution. Ultimately, incandescent light bulbs will end up in a museum, just like vacuum tubes did for electronics."

With lights that can be directed toward the areas of use instead of radiating in all directions, LED systems increase their efficiency even more dramatically, while cutting down on extraneous light pollution. Large cities might even be able to see the stars again. ◆

Further Reading Hoover-Williams, Crossed Filters Revisited, Journal of Gemmology, Winter 2005

Sylvia Gumpsberger Pocket LED Light Sources for Gemmologists Canadian Gemmologist, Autumn, 2003

Hoover-Theisen, Fluorescence Excitation-Emission Spectra of Chromium Containing Gems. Australian Gemmologist, May 1993

About the authors: *Bear Williams, with his wife Cara operates Bear Essentials Inc., a colored stone house. Utilizing their in-house laboratory, Stone Group Labs, they can engage in their research and continued passion for gemology.*