Long Wave Ultraviolet Sources for Mineral Collectors

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INTRODUCTION

Mineral collectors are now faced with a choice of three different wavelengths of long wave (LW) ultraviolet (UV) sources. Two of these, which peak at approximately 350 nm and 370 nm respectively, can have quite different effects on fluorescent minerals. This is especially noticeable in the calcite cleavage rhombs from Múzquiz, Coahuila, Mexico. Often lamps are not marked with their emission peak but there is a way that collectors can know whether their lamp is a 350 nm or a 370 nm lamp. Please note that I use "lamps" which is the engineering term; however others call them bulbs or tubes. I would like to propose the terms "LW350" and "LW370" for the two emissions of fluorescent ultraviolet lamps. The third wavelength is also discussed in this article.

Spectral emission scans of the LW350 and LW370 lamps follow, along with charts of most of the different LW lamps on the market. By using these charts and using Mexican calcite as a discriminating test, collectors should be able to tell what wavelength of LW lamp they have. Awareness of the LW350 and LW370 distinction should also help collectors refine their own observations of mineral fluorescence.

Another result of this investigation was the discovery that the Blacklight Blue (BLB) LW370 lamps available, those produced by Philips Lighting have a very low visible light component and are now recommended for fluorescent mineral displays. None of the other BLB lamps made by other manufacturers have the low visible light filters.

LONG WAVE FLUORESCENT TYPE LAMPS

Long wave UV fluorescent tube-type lamps are low-pressure mercury (Hg) arc lamps. They come in two different lamp phosphors. One phosphor has a peak output at about 350 nanometers (nm) (some measure the peak at 351, 352, or 353 nm), and one has a peak at about 368 nm to 371 nm. The 350 nm peak has a very broad bandwidth, while the 368 nm peak has a narrow bandwidth. See Figure A.

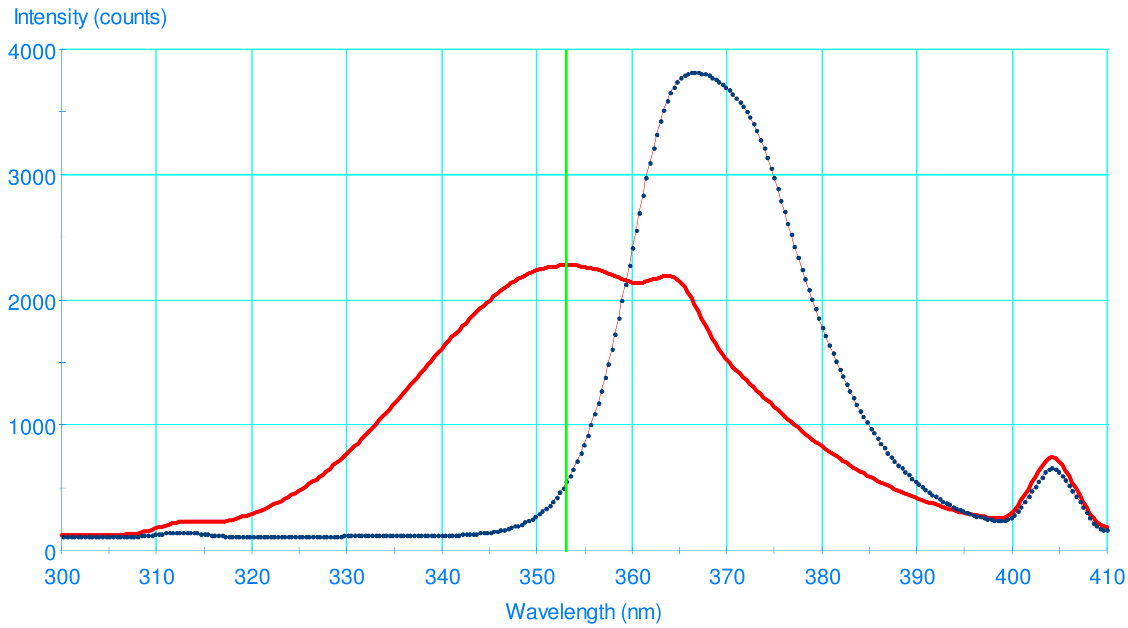

Figure A. Spectral Distributions of two UV SYSTEMS, Inc. TripleBright LW lamps without any LW filters.
Dotted line lamp is a LL-60-368 and the solid line lamp is a LL-60-352.

Note that even though these two phosphors produce UV with different emission peaks and heights, the total UV energy they generate is the same if you integrate the energy under the curves. These fluorescent lamps with both types of phosphors (peak at 351 nm or 368 nm) come in two different models, Blacklight (BL) and Blacklight Blue (BLB). The Blacklight lamps appear white when off but bright blue-white when lit. For fluorescent mineral applications, the BL lamps require an external LW UV filter to block the visible light that they generate. The Blacklight Blue lamps have an integral filter built into the bulb wall of the tube lamp. These BLB lamps appear black when off but deep blue when lit. The BL and BLB lamps come in different lengths, and wattages. Most of the common wattages along with the corresponding lighting industry lamp numbers are shown in Table 1.

Table 1 – BL and BLB, wattage, length, diameter, and industry part number.

Nominal Lamp Wattage	Lamp Length in inches	Lamp Diameter in inches	Industry part no. for Blacklight “BL” lamps	Industry part no. for BlacklightBlue “BLB” lamps
4 W	6 in.	5/8 in. Dia.	F4T5/BL	F4T5/BLB
6	9	5/8	F6T5/BL	F6T5/BLB
8	12	5/8	F8T5/BL	F8T5/BLB
15	18	1	F15T8/BL	F15T8/BLB
20	24	1 1/2	F20T12/BL	F20T12/BLB
25	18	1	F25T8/BL	
30	36	1	F30T8/BL	F30T8/BLB
40	48	1 1/2	F40T12/BL	F40T12/BLB

The “F” stands for a fluorescent lamp; the next number (i.e., 6, 8, or 15) stand for the electrical wattage; the “T” stands for tubular; the next number stands for the number of one eights of an inch in diameter (the T8 is one inch in diameter and the T12 is 1.5 inches in diameter). The phosphor color used is usually the last letters in the part number, for example; WW = Warm White, CW = Cool White.

HIGH-PRESSURE MERCURY ARC UV LAMPS

High-pressure Hg arc lamps are sometimes used with fluorescent minerals. These Hg arc lamps, with screw-in bases, come in several wattages, but the most popular are the 100 W, 175 W, and 250 W sizes. They have a monochromatic output that is primarily at one UV wavelength, 365 nm. As with fluorescent type lamps, these Hg lamps require a ballast. These Hg arc lamps were used as streetlights for many years, but now have mostly been replaced by “golden” color high-pressure sodium arc lamps. Because the Hg arc lamps produce so much visible light, a special very dense external LW filter is required for fluorescent applications. However, when this LW filter absorbs all of the visible light, this energy has to go somewhere: and it does - it turns to heat. In fact, the LW filter gets so hot that it can burn your hand if you touch it. Because the filter gets so hot, it has to be made of a special heat-resistant glass so it will not crack. Because they need to be so dense and heat-resistant, these LW filters (usually molded round and called “roundels”) are usually very expensive.

OTHER LW SOURCES.

Other LW UV sources are lasers, xenon arc lamps, and UV Light Emitting Diodes (LED’s). Some so called “blacklight” LED’s have a deep blue light that peaks at about 390 nm, which is technically not in the UV-A range but in the visible [visible light extends from 380 to 780 nm]. However, a discussion of these UV sources is beyond the scope of this paper. Although incandescent lamps do produce some UV, they are very inefficient. Sometimes incandescent lamps with integral LW filters are sold as "blacklights" in novelty shops, however, because they have very little UV energy, they are not recommended for fluorescent minerals.

FLUORESCENT LAMP MANUFACTURERS

There are several lamp manufacturers of fluorescent LW lamps. Their lamps are **not** all the same. The big three companies are: General Electric, Sylvania – Osram, and Philips Lighting. And there are several companies in Japan that make some of the UV lamps such as Sankyo Denki, NEC, Ushio, WKO, with many other companies in Taiwan, South Korea or China. In fact, for many years now, all the 4, 6, and 8 watt fluorescent lamps were made in Japan or other countries in the Orient, even if they said GE, Sylvania, or Philips on the lamp. However, recently Philips began selling their BLB Holland-made lamps here in the USA. Repeating a previous point, even when they have the identical industry lamp number, the lamps made by different manufacturers are **not** all the same.

DIFFERENCES REVEALED: MEXICAN CALCITE “RHOMBS”

For almost 40 years, the big three companies made their BL and BLB with the two different LW phosphors. Most of the FMS members never knew the difference since our fluorescent minerals did not look that different under the two wavelengths (350 nm or 368 nm). Then the transparent rhombohedron fluorescent calcite from Mexico hit the market in the late 80's. These "rhombs" were labeled from "Challengers Cave" or Nueva Leon, but their actual location is near Múzquiz, Coahuila, Mexico. They would fluoresce similarly to the Terlingua, Texas calcite; that is bright blue short wave (SW) with a bright blue afterglow and usually pink under LW, with dim afterglow. However, in September 1993 a discovery was made in connection with the Denver Show, the FMS had a meeting at Earl Verbeek's house. Earl, Doug Mitchell, Bill Mattison, and I were examining some of that Mexican calcite under different LW UV lights, when we found out that it would fluoresce a different color under each of the lights. With a 4 W F4T5/BL lamp (with an external LW filter) made by one manufacturer, the calcite would fluoresce a salmon or "straw" color, while with another manufacturer's 4 W lamp it would fluoresce the typical Terlingua pink color. A photograph of some of this Mexican calcite can be seen at web site: www.uvsystems.com. Go to "Photo", then "Mineral Specimens" to see an example of the different fluorescent colors. It turned out that those two different lamp manufacturers used different LW phosphors in their lamps. It was determined that most of the Mexican "rhombs" would fluoresce the "straw color" (some call it pale yellow) under the 350 nm wavelength, but it would fluoresce the pink color under the 368 nm wavelength. The LW phosphor with the emission that peaks at about 350 nm is usually a Barium Silicate:Pb, or $BaSi_2O_5$:Pb phosphor, [:Pb means that the Barium Silicate is doped with Lead] while the LW phosphor with an emission that peaks at about 368 nm is usually a Strontium Fluoroborate:Eu, or SrB_4O_7F:Eu phosphor. Sometimes, however these LW 368 nm lamps use a Strontium Europium Borate, or SrB_4O_7:Eu phosphor. I now use that Mexican calcite and what color it fluoresces to determine what wavelength phosphor is in a LW fluorescent lamp. If "straw" then it is a 350 nm peak phosphor (LW350); if pink, then it is a 368 nm peak phosphor (LW370). Figure B and C show the two different phosphors with and without an external LW filter. Both graphs are plotted in the same scale so you can compare the outputs and see how the LW filters absorb some of the UV but block the visible 405 nm Hg emission line.

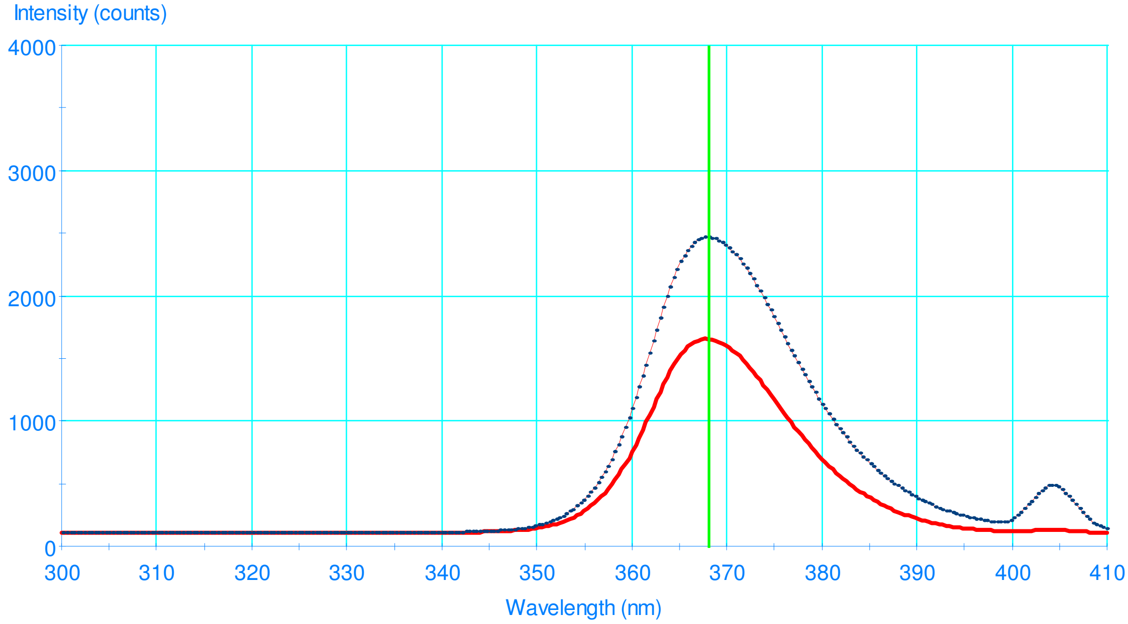

Figure B. Spectral Distributions of a UV SYSTEMS, Inc. SuperBright LW lamp with and without the FL-20 LW filter.

Top curve is a LL-16-368 and the bottom is the same lamp but as measured through a FL-20 LW filter. The scale is the same as Figure C.

DIFFERENCES IN OTHER LW FLUORESCENT MINERALS

The fluorescence of other minerals, in addition to Mexican calcite, is affected by these two LW phosphors. When looking at the same mineral specimens using a UV SYSTEMS, Inc., SuperBright 2020LW with a standard LL-16-351 lamp (LW350) and a SuperBright 2010LW with a special LL-16-368 lamp (LW370), I found out that some corundum specimens fluoresce brighter red under LW370 than under LW350. Both lamps (LL-16-351 and LL-16-368) have the same arc loading, meaning that they are similarly powered. Also some hackmanite (including the newly available Afghanistan hackmanite crystals) will fluoresce brighter orange under LW370 than under LW350. On the other hand, the LW fluorescence of hardystonite from Franklin, NJ is a much brighter deep blue under LW350 (it usually is brightest under SW) than under LW370 where it appears almost non-fluorescent. The same is true for agrellite from Kipawa, Canada; it is brighter under LW350 than under LW370. I am sure there are many other fluorescent minerals out there just waiting to be observed fluorescing different colors or intensities under the two different LW phosphors.

At present there have been very few differences in hue (fluorescent color) observed in any fluorescent minerals between LW lights using a high-pressure Hg arc UV light at 365 nm and a LW fluorescent lamp at 368 nm (LW370). This might change as more observations are made in the future. The major reasons that very few differences have been noted is most likely because (a) the wavelength difference between 365 nm and 368 nm is very small, and (b) the UV intensity of the 365 nm lamp is so much brighter that it makes it difficult to make comparisons. Even if the Hg arc wavelength is monochromatic at 365 nm and the fluorescent lamp peaks at 368 nm in a bell-shaped (Gaussian) distribution, differences in fluorescent mineral colors should be observable if the wavelengths caused the difference. Note that with the high UV output of the Hg arc lamp vs. the fluorescent lamp, a fluorescent specimen might appear to look different because it would be brighter under the Hg arc lamp; however, the hue (color) will most likely not change.

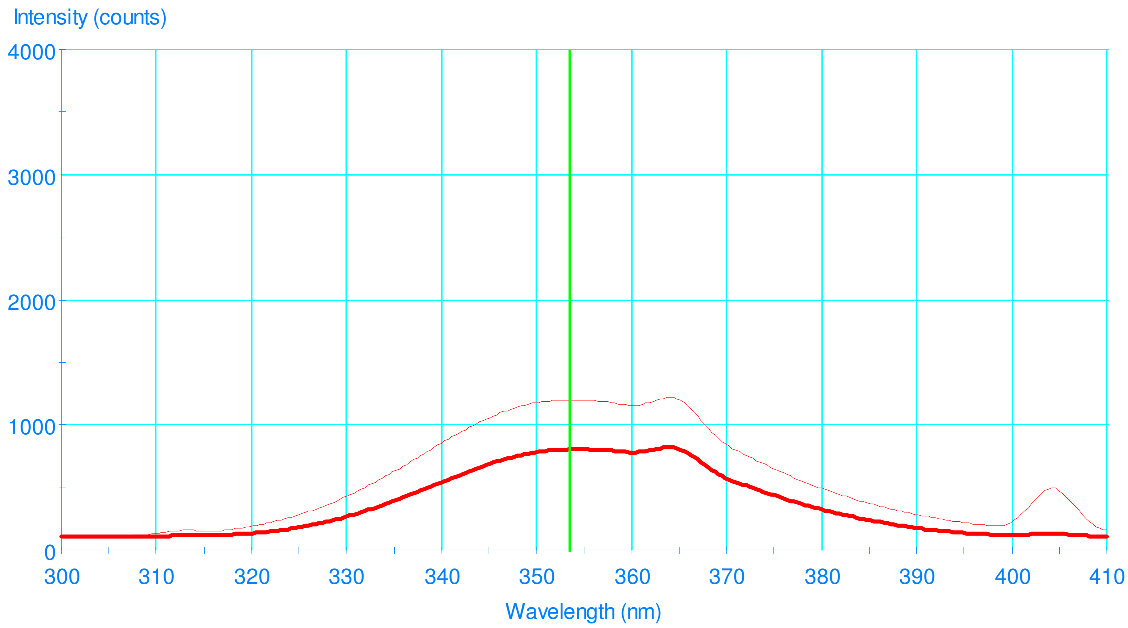

Figure C. Spectral Distributions of a UV SYSTEMS, Inc. SuperBright LW lamp with and without the FL-20 LW filters.
Top curve is a LL-16-351 and the bottom is the same lamp but as measured through a FL-20 LW filter. The scale is the same as Figure B.

HOW SHOULD WE IDENTIFY LW PHOSPHORS?

The fluorescent mineral community and the scientific community both use the same abbreviation for "SW", Short Wave UV. And even though there are many different medium wave (mid-wave) lamps presently manufactured, each with a different emission, no big difference in the fluorescent response of minerals has been observed between the different MW lamps (at least so far). Now MW is a standard term used for Medium Wave or Mid-wave. But LW has these three wavelengths! It takes too long to keep saying "LW at 350 nm" and "LW at 368 nm". Or to say "LW from a mercury arc lamp (or bullet lamp)".

LW350, LW365, and LW370

I propose that we refer to the two different LW phosphor wavelengths as LW350 and LW370 and call them "long wave three fifty" and "long wave three seventy". The 350 would of course refer to 350 nm (or 351 or 352 or 353 nm), and would cover a range of wavelengths within + or – 3 nm of 350 nm. And the 370 would refer to the 368 nm, also within + or – 3 nm. We can also add the monochromatic 365 nm as LW365 "long wave three sixty-five". We could then refer to all of the wavelengths that are presently being used for fluorescent minerals as: SW, MW, LW350, LW365, or LW370 -five abbreviations for wavelengths, not just two that we have had. What do you think?

WHY NOT JUST LABEL THE PHOSPHORS BY THEIR EXACT PEAK WAVELENGTHS?

It is very difficult to measure the exact peak wavelength of fluorescent lamp phosphors. The measurement of the phosphors is usually done by spectroradiometer or by spectrometers. In these instruments many things can effect the accuracy and repeatability of wavelength measurements, as the slit width, scan interval, type of sensor (photomultipler tube [PMT] or charged coupled device [CCD]), diffraction grating, measurement procedure (if the instrument is designed to measure fluorescent lamps), and the optics of the device. Some lamp manufacturers list their LW370 phosphor peak at 371 nm while others list it at 368 nm. It is not certain whether these stated differences are meaningful or which one is the more accurate. By using the approximating labels LW350 or LW370, I am not suggesting that the value indicates the correct exact peak wavelength. I am just conveying the idea that the LW350 label designates LW phosphors that peak in the range of 350 to 353 nm (the $BaSi_2O_5$:Pb phosphor), and the LW370 label designates phosphors that peak at 368 to 371 nm (the SrB_4O_7F:Eu or SrB_4O_7:Eu phosphors).

THE FMS LOWSTAND COMMITTEE

For several years now the FMS has had a committee working on the identity problem of LW fluorescent lamps. It seemed to us that the manufacturers should identity their lamps so an owner could tell what LW phosphor was in his lamp. Right now two different manufacturers can use the same lighting industry standard part number on their lamps but have different phosphors inside.

The FMS committee is called LOng Wave STANDardization (LOWSTAND) Committee and is made up of FMS members Dr. Ronald J. Baker, Richard C. Bostwick, Dr. Jacek Chrostowski, Axel Emmermann, William Mattison, Dr. Earl Verbeek, and myself. In June of 2000, letters were written to the big three lamp manufacturers and three other UV light manufacturers asking if it would be possible to label their lamps with some identification. We only received one answer, and that was from a UV light manufacturer that said he did not think it would ever happen.

In June of 2002, Axel Emmermann and I met with the business manager of UV lamps for Philips Lighting in Roosendaal, Netherlands. We discussed the problem of the lamp manufacturers adding some identification to their lamps. He also did not think it would happen. He believes there could actually be a competitive advantage by NOT identifying which phosphor is in each lamp. LOWSTAND has not given up, but we are not “holding our breath” either.

My company, UV SYSTEMS, Inc. has identified all of its LW lamps. The last three part numbers refer to the peak wavelength of that lamp. And the catalog sheets have the peak wavelength of every lamp listed.

Sylvania-Osram is the only lamp manufacturer that presently identifies its BL or BLB lamps. All Sylvania-Osram lamps are marked with, “350BL” or “350BLB” meaning that they use the LW350 phosphor.

BLB LAMPS

The phosphor differences I have been describing apply to BLB as well as BL lamps. As I said earlier, all LW lamps are not the same; there can be a difference depending on the lamp manufacturer. All BLB lamps are also not the same. UV SYSTEMS, Inc. now has an Ocean Optics UBS2000 spectrophotometer that can also be configured as a spectroradiometer. This device can measure and plot the UV output versus wavelength (also called spectral distribution) of UV lamps (see Figures A, B, C, D, and E). I have measured the UV wavelength of most of the common fluorescent lamps used by fluorescent mineral collectors, allowing me to confirm the LW phosphor that is used in each LW lamp. I have also measured the UV output of these same lamps to determine how effective the integral bulb wall LW filter is on those BLB lamps. However, it should be noted that while my specific Ocean Optics (OO) spectrophotometer can measure the peak wavelength within + or – 3.1 nm, other OO systems can measure them to within less than ½ of a nm., and spectroradiometers made by other companies can be even more accurate.

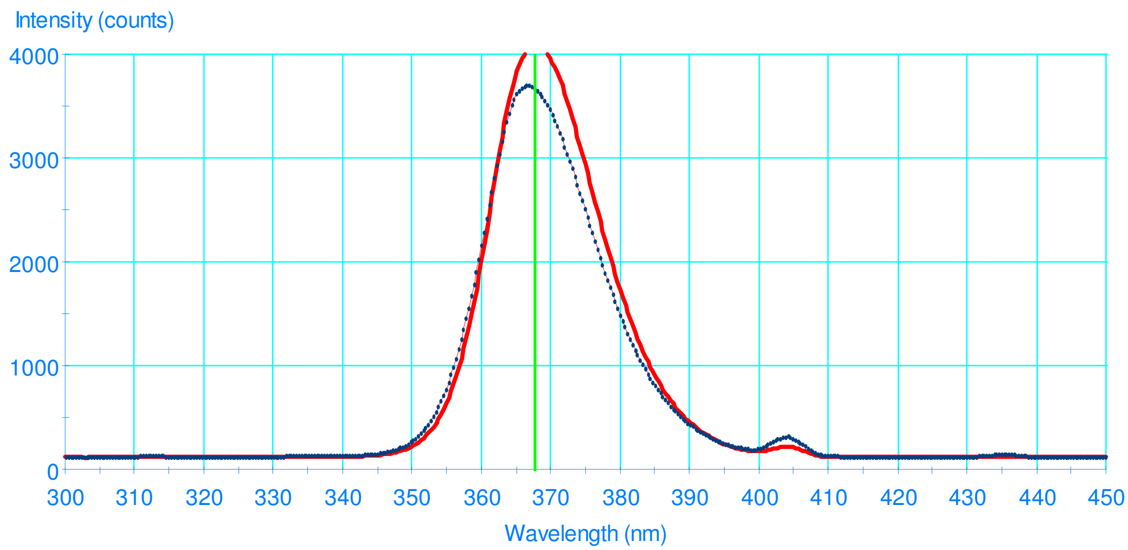

Figure D. 300 to 450 nm Spectral Distributions of a Philips and GE BLB LW370 lamps.

Top curve is the Philips 20 W F20T12/BLB lamp, and the bottom curve is the same lamp only made by GE. Both curves are made to the same scale.

In 1983, I wrote an article in the ***Journal of the FMS*** entitled, "Almost Everything That You Would Want to Know about Long-Wave BLB Lamps" (Vol. 12, No. 1, and pages 27 – 39). My latest test results contradict that original article's conclusions that BLB lamps should not be used for fluorescent mineral displays. My present tests show that Philips Lighting is now using a new, very dense, filter in all of their BLB lamps. See Figures D and E. This means that less of the visible blue light is transmitted through their integral filters. This also means that you can now use Philips BLB lamps for your fluorescent mineral displays without having that excessive visible blue light transmitted through the bulb wall integral filter! Only Philip Lighting BLB lamps have that denser LW filter -not General Electric, Sylvania – Osram, Sankyo Denki, or other lamp manufacturers.

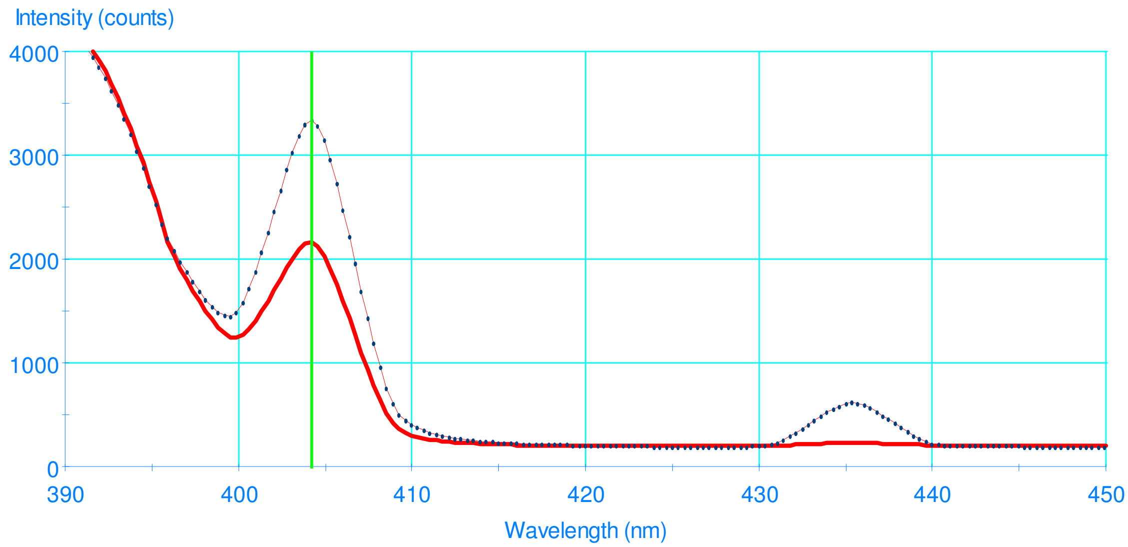

Figure E. 390 to 450 nm Spectral Distributions of a GE vs. Philips F20T12/BLB LW370 lamps.

Top curve is the GE 20 W BLB lamp, and the bottom curve is the Philips 20 W BLB lamp. The curves show just the visible light that is emitted from the lamps. Both curves are made to the same scale.

As a practical matter, the different diameter lamps result in different integral bulb wall filters (because of the different tubing diameters). Therefore the Philips T5 lamps are somewhat different than their T8 and T12 BLB lamps. However, all appear to transmit less of the visible blue than do those of the other manufacturers. Of all of the lamps I tested the T12 lamps measure (and also appear) to be the densest with the least amount of visible blue light emitted. See Figure E. Philips makes two sizes of their T12 BLB lamps: the 20 W F20T12/BLB, is 24 inches long, and the 40 W F40T12/BLB, is 48 inches long. The Philips BLB lamps only come in the LW370 phosphor (peaks at about 368 nm).

RECOMMENDATION

For collectors who are just starting out and want to have an inexpensive LW fluorescent display, I would suggest that they consider using the Philips Lighting 20 W F20T12/BLB UV lamps for their display.

SUMMARY

I propose that the LW fluorescent lamps be referred to as LW350 if they have the 350 to 353 nm LW phosphor in them, and that LW370 be used for the 368 to 371 nm lamps. And LW365 if the lamps are the high pressure Hg arc lamps. This would mean that we have five abbreviations for wavelengths that we use with fluorescent minerals: SW, MW, LW350, LW365, and LW370.

I believe that fluorescent BLB lamps that are manufactured by Philips Lighting can be used for LW370 fluorescent mineral displays without any excessive visible light being emitted by their lamps. The Philips F20T12/BLB has an exceptionally dense LW filter in the bulb wall. Other BLB lamp manufacturers do not use that dense LW filter.

APPENDIX

Below is a table of some of the most common BL or BLB lamps (as of Jan. 2003) that are manufactured. An "X" means that the lamp is manufactured, blank squares means no such lamp is made:

Table 2. Manufacturers of LW350 and LW370 BL and BLB lamps.

Lamp # LW350 (phosphor peaks at approximately 351 nm)	Lamp manufacturer Sylvania-Osram	Lamp manufacturer Sankyo Denki	Lamp # LW370 (phosphor peaks at approximately 368 nm)	Lamp manufacturer General Electric	Lamp manufacturer Philips Lighting
F4T5/BL		**X**	F4T5/BL	**X**	
F4T5/BLB	**X**	**X**	F4T5/BLB	**X**	**X**
F6T5/BL	**X**	**X**	F6T5/BL		
F6T5/BLB		**X**	F6T5/BLB		**X**
F8T5/BL	**X**	**X**	F8T5/BL		
F8T5/BLB	**X**		F8T5/BLB		**X**
F15T8/BL	**X**	**X**	F15T8/BL	**X**	**X**
F15T8/BLB	**X**	**X**	F15T8/BLB	**X**	**X**
F25T8/BL	**X**		F25T8/BL		
F20T12/BL	**X**	**X**	F20T12/BL	**X**	**X**
F20T12/BLB	**X**		F20T12/BLB	**X**	**X**
F30T8/BL	**X**		F30T8/BL		**X**
F30T8/BLB			F30T8/BLB		**X**
F40T12/BL (also labeled as F40T10/BL instead)	**X**	**X**	F40T12/BL	**X**	**X**
F40T12/BLB (also labeled as F40T10/BLB instead)	**X**		F40T12/BLB	**X**	**X**

Note some compact BL and BLB fluorescent lamps are not listed.

ACKNOWLEGMENT

I wish to thank the people who helped me with this article. Those include my wife, Alma Newsome, and especially FMS members Richard Bostwick, Robert Fendrich and Don Halterman,

TECHNICAL NOTES

All the graphs of spectral distributions use the following spectrometer and set up:

The Ocean Optics Fiber Optics Integrating Sphere (FOIS-1) was on the table exactly 18.0 inches from the front surface of the LW filter or LW lamp.
Black felt paper was on the table to block reflected external light from getting into the FOIS-1.
Fiber optic cable P1000-2-UV/VIS was between the FOIS and the Ocean Optics USB2000 spectrometer.
A LW TripleBright or SuperBright 2010LW as required was used as the light source.
A Dell Inspiron 5000e laptop computer using Microsoft Windows 2000 Pro operating system was used with the Ocean Optics OOIBase 32 software ver. year 2001.

Scan setting

Wavelength range is from 300 to 410 nm.
Integ. Time = 12 for Figures A, B, and C.
Average = 30
Boxcar = 6
Flash Delay = 6

Figure D has a wavelength range of 300 to 450 nm, and the Integration Time (which is the gain of the spectroradiometer) was = 40. All other parameters are the same as Figure A, B, and C.

Figure E shows just the visible light emitted from the lamps and it plotted from 390 to 450 nm. Note that the Integration Time (gain) was turned up significantly so it = 700. All other parameters are the same as Figures A, B, and C.