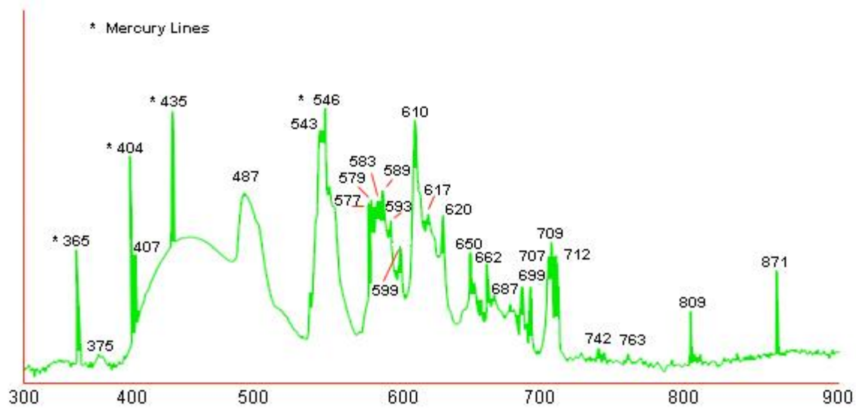
Understanding Spectral Distribution Graphs

Spectral Distribution Graphs (SDG) represents a graphic depiction of the light intensity (power) for the various wavelengths the lamp emits in a plotted format. Buyers without a formal understanding of this information will often mischaracterize the information assuming both positive and negatives that are not actually representative the SDG. We are going to introduce an example SDG and describe how to interpret it.



Philips 48" F32T8 - natural sunshine fluoresent light - Spectrum

Note: This example Spectral Distribution Graph was chosen only because it is a good an example for this discussion as it has a nice mix of both spiky peaks and smooth broad bandwidth areas. It is not intended to be a review of this Philips product nor is it an endorsement non recommendation of the product. This image was lifted off of Wikipedia.

Interpreting a Spectral Distribution Graph

1. You might that interpreting a SDG is no big deal but there are a lot of points that can lead to confusion as to exactly what it is you are seeing. The first thing to look for on an SDG is the labeling of the Y (vertical) axis.

   a. In this example none was give so we should assume the "y" values to be relative radiant intensity in Watts not µMol/S. Since it is a relative rating it is actually unit less, but would have been based on intensity in Watts.

   b. Some SDGs will be labeled in mW/nm of µW/nm, meaning that the value shown for a particular nm position has that amount of intensity power for that 1 nm wide sliver. In this case the lamp will be of a specific Wattage rating

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c. Another way of seeing the "y" axis is as a 'normalized' value shown in mW/nm per lamp Watt. This is a nice way of presenting the SDG as you simply multiply the values based on the lamps Wattage rating. This method also makes it easier to compare different lamps SDGs **if they are normalized the same way.** Normalizing is adjusting the data points evenly such that the total area under the curve adds up to a predetermined value.

d. We have also seen SDGs expressed in relative intensities based µMol/S or as µMol/S per nm. **You must be very careful if you are comparing 2 different SDGs and 1 is based on µMol/S and the other on Wattage. This is not a 1 to 1 comparison as photons of different wavelengths have different energies**.

2. Analyzing the difference between spikes and broad non spiky regions;

   a. First, for a fluorescent based lamp you will always have visible Hg (Mercury) spikes at 365, 405, 436, 546 and 580 nm. These are unavoidable if the lamp is Hg based. There can be some variation in the relative heights of the spikes which will be discussed later.

   b. The main difficulty with SDG analysis is interpreting the spikes. The user has a tendency to see these tall spikes and associate a high percentage of the output intensity to be at these values.

   c. The proper way to determine the net intensity in a particular region is to take the total area under the curve in that region. This is where SDGs shown in mWatts/nm are very straightforward: You can view each of the point heights of the curve nm by nm and simply sum each value to get the total value in the region. The sum of all of these silvers will nicely approximate the area under the curve.

   d. Let's take a look at our example SDG, at 546 nm we have our highest peak, this is a result of the 546 nm Hg spike coupled with the 543 spike of the standard green component of a tri-phosphor blended lamp. While there may appear to be a lot of intensity at this point, it may not be as much as we think. Remember it is the area under the curve that sums to the total intensity for a particular region of the SDG. If I were to define the general region of this green spike to be about 540 to 575 nm, you can easily see that the regions to both the left and right have a greater area under the curve and therefore the net quantity of green light may not actually be that excessive.

3. Another item to look at on an SDG are the void areas or regions where there is no light intensity. On this example there are no serious void areas shown. This is actually fairly unusual for this type of phosphor blend and may be a result of some measurement equipment noise. Numerous and large void areas tend to be more of an issue with lamps that have very high or low Kelvin temperatures as they tend to lean heavily toward the blue or red regions. Looking at the SDG in this example we see no significant voids, this would be an indicator of a good broad spectrum lamp with a very high CRI. I would estimate a Kelvin temperature of about 5000 to 5500K and a CRI of 85 to 90. The actual specifications from Philips were a color temperature of 5000K and a CRI of 82. Our over estimation of

the CRI may be a result of being fooled by the lack of void areas that may have resulted from measurement equipment noise.

4. A quick estimate of this SDG to our recently defined V-C-F measurement technique resulted in a V of 43.6%, C of 29.4% and F of 27.0%. Just looking at the VCF values would rate this as a fairly broad spectrum lamp with a high CRI. While it was made to be a visual lamp it likely would do a reasonable job as a grow lamp, no problem vegetative, but it would likely need some help for fruiting and flowering.

5. Also worth noting on this SDG is the presence of significant energy both below 400 nm and above 700 nm. While this light energy is still useful to a plant most all PAR or quantum meters will not measure it, but as earlier stated this may be measurement equipment noise.

Contributing elements to the distribution of this SDG

The following are the likely phosphors used in this particular lamp along with as many of the peaks that we could identify and the likely source of the peak.

1. **Hg Mercury spikes**: 365, 405, 436, 546, and 579 nm
2. **$BaMg_2Al_{16}O_{27}:Eu^{2+}$ (most likely) (aka BAM)**: 452 nm peak with ½ height bandwidth of 51 nm, accounts for most of the contribution 400 to 510 nm.
3. **$CeMgAl_{11}O_{19}:Tb^{3+}$ (most likely) (Green tri-phosphor component):** Main peak at 544 nm, minor peaks at 488, 577, 579, 584, 617, 621 nm
4. **$Y_2O_3:Eu^{3+}$ (Red tri-phosphor component):** Main peak at 611 nm, minor peaks at 589, 593, 600, 650, 663, 688, 694, 707, 709, and 713 nm
5. **Argon:** 760, and 809 nm

Note: Constant energy levels shown below 400 nm and above 720 nm may be a result of measuring equipment noise.

Other factors that affect light output and the SDG of a lamp

1. **Quantum efficiency of each phosphor:** Mercury (Hg) has its primary emission at 253.7 nm (about 84.5% of the emitted energy) and a secondary emission at 185 nm (about 7% of the emitted energy), the balance are those earlier mentioned that are in the visible region to begin with (about 8.5% of the emitted energy). The 253.7 and 185 nm photons are typically absorbed and excite the phosphor molecule to emit its signature emission. But not all of the photons emitted by the mercury result in a phosphor generated emission. The Quantum Efficiency is defined as quantity of photons that achieve phosphor excitation resulting in a photon emission divided by the total number of 185 nm and 253.7 nm photons emitted. This value varies greatly from phosphor to phosphor.

2. **Planckian Efficiency of the phosphor:** We have defined this as the loss of quantum photon energy resulting from the conversion of the Hg emitted photons to the lower energy, longer wavelength photons emitted by the phosphor. Per the Planck Relation Equation, we have $E=hc/\lambda$. E is energy, h Planck's constant, c the speed of light, and λ the photon wavelength. A quick and easy example: If a

253.7 nm Hg emitted photon is absorbed and a resulting 557.4 nm photon (exactly twice the wavelength of the 253.7 nm photon) is emitted by the phosphor, then the resulting photon has only ½ the energy as the excitation photon. In this simple example the resulting 557.4 nm the Planckian Efficiency is only 50%. As it would be this 557.4 nm photon is just about in the middle of both the visible light region and the useable plant light region. So it is not a far stretch to see that the Planckian Efficiency is going to average around 50%. It will be lower for the reds as they have longer wavelengths and higher for the blues as they have shorter wavelengths.

3. **Excitation region and absorption sensitivity of the phosphor:** This is the wavelength range of photons that the phosphor can absorb and the sensitivity of that absorption. This is a direct contributor to the Quantum efficiency, but is also a contributor to phosphor reabsorption.

4. **Phosphor reabsorption of photons:** The longer the wavelengths that a phosphor emits the more likely it may have an excitation region that extends into the visible light range and may absorb photons that were already emitted by another phosphor. This can make designing a lamp to emit a specific spectral distribution difficult. It will also contribute to additional Planckian efficiency losses.

Summary Conclusions: When considering a lamp's output and a plant's absorbance regions it's important to realize that SDGs can be presented in different formats where side by side comparisons of lamp types and technologies may lead to incorrect conclusions. As a general rule when reviewing any of the SDG formats, one should not place as much credit on the narrow spiky peak wavelengths that likely do not have as much net intensity as the broader wide spectrum regions.

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