Detailed Scientific Barrier Filter Discussion

INTRODUCTION

In this paper, we will discuss the differences in various barrier filters from a number of manufacturers. The purpose of this is to show graphically that *not all barrier filters are created equal*. Sometimes the "measured" differences are slight while the photographic differences are ***HUGE***!

In order to keep this discussion as brief as possible, it must be assumed that you either understand terms such as wavelength, the physics of light and fluorescence or you have referenced the other science pages on this site.

What does a barrier filter do?

Your blue excitation light source emits a great deal of monochromatic (single color) blue light. This excitation light causes the marine organisms to fluoresce (as discussed in much greater detail elsewhere on this site). You need to "block" this intense blue light to see the fluorescent colors emitted by the organism. This emitted light is often less than 10% the brightness of the excitation light. Your eyes (and camera) will be completely overwhelmed by the blue if you don't block it.

The technology of barrier filters has come a long way over the last few years. Below is an image of how it used to be done. Image courtesy: Larry Cohen.

As a side note, it's usually a bad idea to mix and match light sources, excitation filters and barrier filters from different sources. For some configurations, it may not matter while others will give horrible results.

At firedivegear.com (FDG), we custom "tune" all our filters and light sources for maximum output, spectral sensitivity and color saturation. Some will tell you it doesn't matter but the images tell the real story.

The light source / barrier combination you use will determine what colors you see and are captured with your camera.

APPROACH

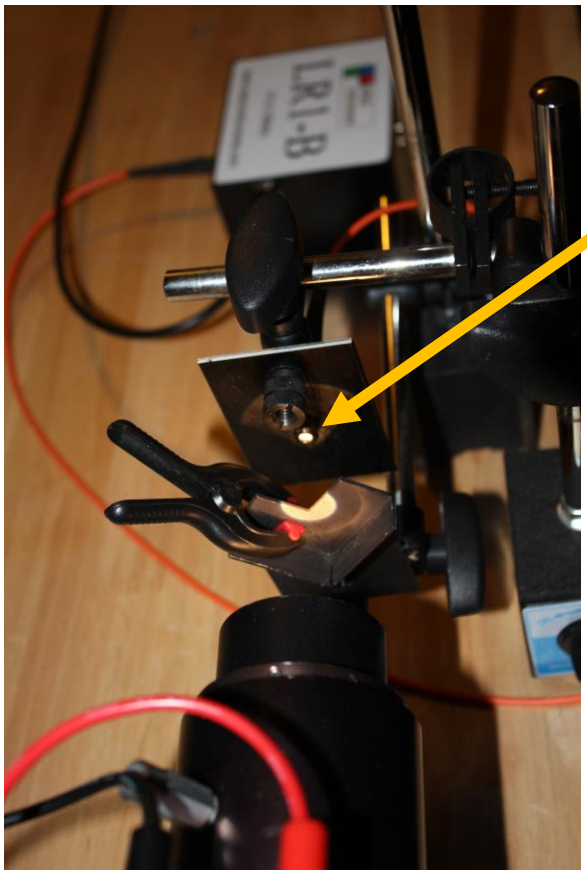
To some, this paper may seem daunting with the hypertechnoverbalizationisms, but there's a limit to how much we can simplify the discussion and still cover a very technical topic so bear with us.

To perform this series of analyses we used a computer controlled optical spectrometer. This is simply a device that measures the spectral output of a light source and displays the result as amplitude (brightness) versus wavelength (color). It does this by splitting the white light into its constituent colors using a transmission diffraction grating much like when light hits a prism. These individual colors are then detected with a CCD sensor (similar to that in a digital camera) and then sent off to the computer to be plotted.

The equipment used in this test is calibrated and traceable to the US National Institute of Standards and Technology (NIST).

The spectrometer was an ASEQ LR1-B connected via USB to a computer to capture the waveforms.

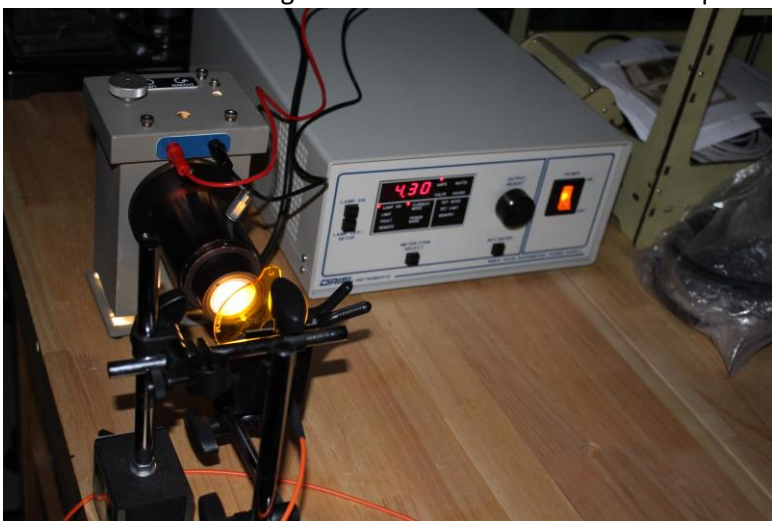
The white light source was a Newport-Oriel 6337 reference standard halogen 50-watt bulb driven by a Newport-Oriel 68831 Radiometric Power Supply Controller. The images below depict the test setup.



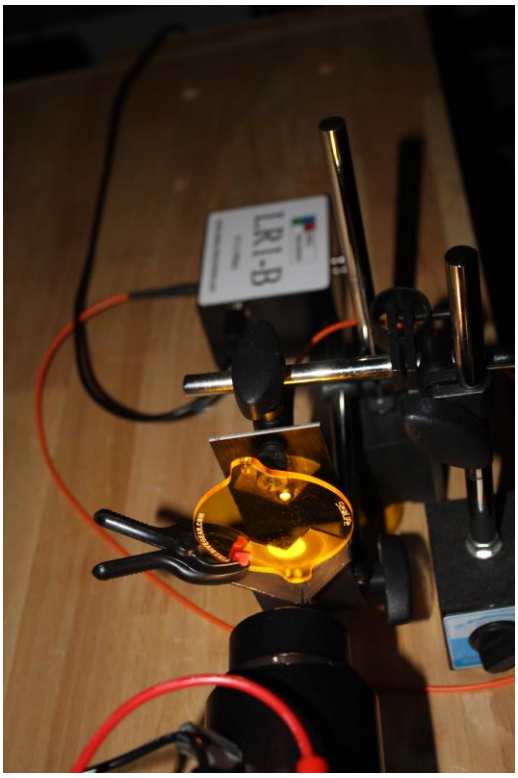
The image at left shows the white light base line measurement. The light illuminates a cosine corrector connected to the spectrometer via a fiber optic (orange) cable.

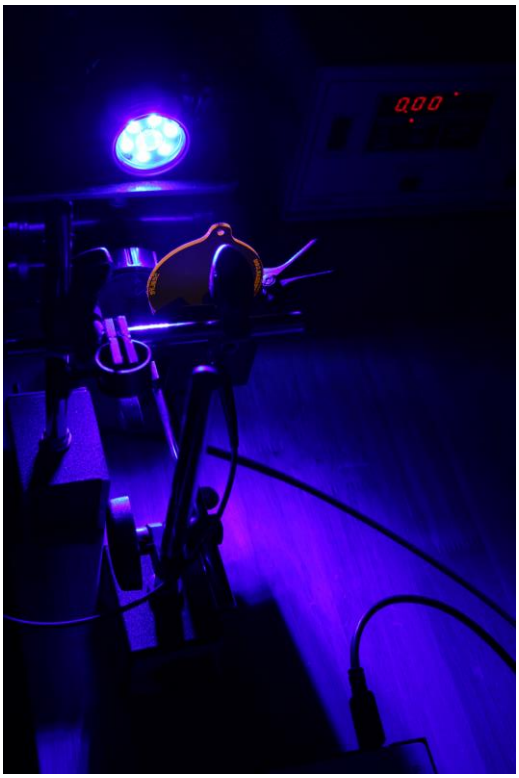
Cosine Corrector

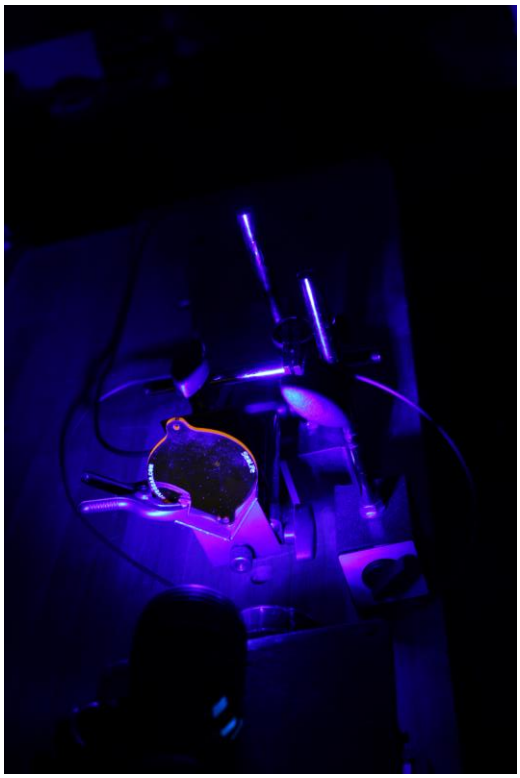
Below is the same configuration with a test barrier filter in place.



Barrier filter - white light measurement from a different angle.







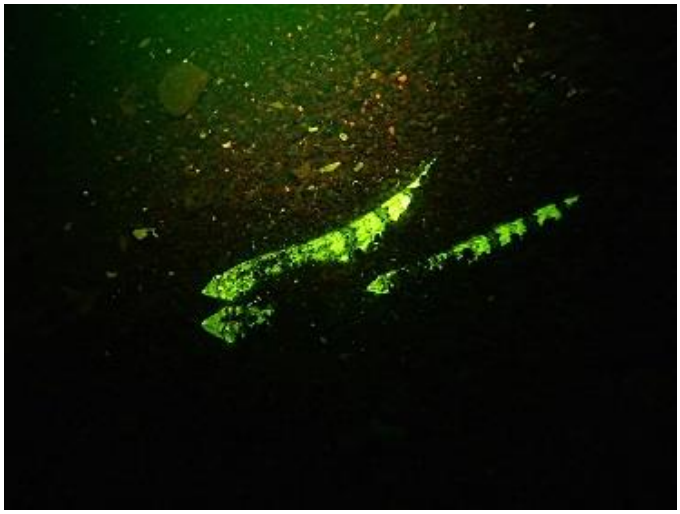
Blue light exposure as shown above.

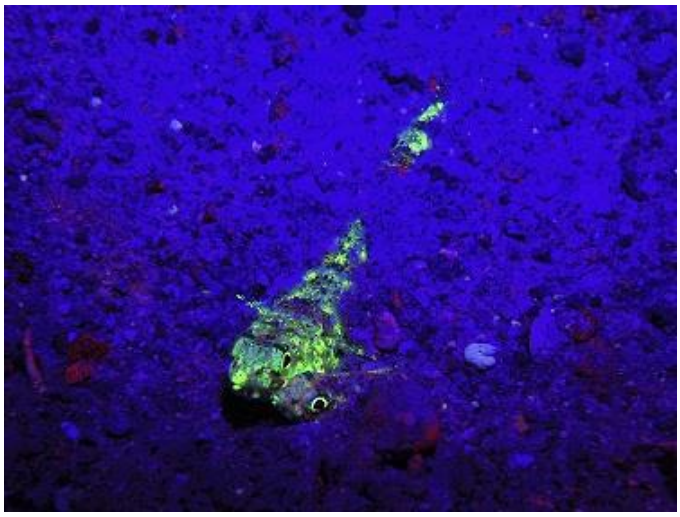
The first task was to look at the spectral "bandpass" of the filter to white light. The bandpass is the band of wavelengths (colors) that pass through the filter and at what amplitude each of those colors pass. Doing so with white light will tell us what we can expect the *filter* to "capture" in the spectrum of the emitted fluorescent light.

Next, we used the same spectrometer setup only this time using a reference blue light emitting torch at 450 nm (peak) to determine how much blue "leaked" or passes through the filter.

We will digress for a moment to discuss filters that pass some portion of the blue spectrum. Some things will fluoresce blue and if they do, you need a filter that will pass it in order to capture it photographically. Other times the blue that you capture may be considered "contamination". It is passing a small percentage of the *reflected* blue light coming off of sand, rocks, dead coral etc. There is great debate about this. Some people believe that 100% of the blue should be blocked. Others believe that a tiny percentage of blue can enhance the aesthetics of the image. At firedivegear.com, we are in the latter group. Filters that block 100% of the blue invariably have a strong green tint to the images and capture 0% of anything fluorescing in the blue. They lack contrast and color saturation. Our filters are designed to present roughly 3% of the reflected blue light to pass through the filter to your eyes and to the camera.

Below is an example of this. The left image of the lizard fish is taken with a filter that blocks 100% of the blue and the image on the right is the same target with a filter that passes 3% of the blue. You decide which is a more pleasing image.





DISCUSSION (White Light Source)

We have two sets of graphs. The first set is the spectrum analyzer results using the calibrated white light source.

Each of the graphs below show a baseline trace in **red**. This red trace is the output of the 6337-reference standard halogen bulb. These bulbs are designed to reproduce the solar spectrum of the sun. The data were plotted from 350 nm to 950 nm. The human eye can detect *approximately* 400nm – 750nm. Note that the peak wavelength of the reference source is in the 590nm - 620nm range (the green/yellow part of the solar spectrum) which is exactly what the sun produces at its peak wavelength. All of the white light traces have the baseline image for reference.

The **blue** trace labeled S1 is the standard firedivegear.com (FDG) barrier filter to compare against the white reference trace and the traces of barriers from other manufacturers. There are four sets of these white light traces. This was done because to put all 19 traces on one graph would have made it unreadable. But the baseline and FDG filter trace are on every chart. The "S#" designation simply means "Sample x". To avoid copyright infringement or other hassles, the actual manufacturer names are not included but are available upon written request. The arrow simply shows where the 450nm point is. 450nm is where the maximum excitation occurs.

Figures 1-4 show some of the more common barriers on today's market. Again – the red is the white light trace and the dark blue trace (S1) is the FDG filter's response to it. It begins to "*turn on*" at about 460nm giving just a "touch" of blue to pass. Note the other filter traces turn on 15 to 20 nm later. This may not seem like much difference but in fact it translates to the entire elimination of the blue as seen in the images above of the lizard fish.

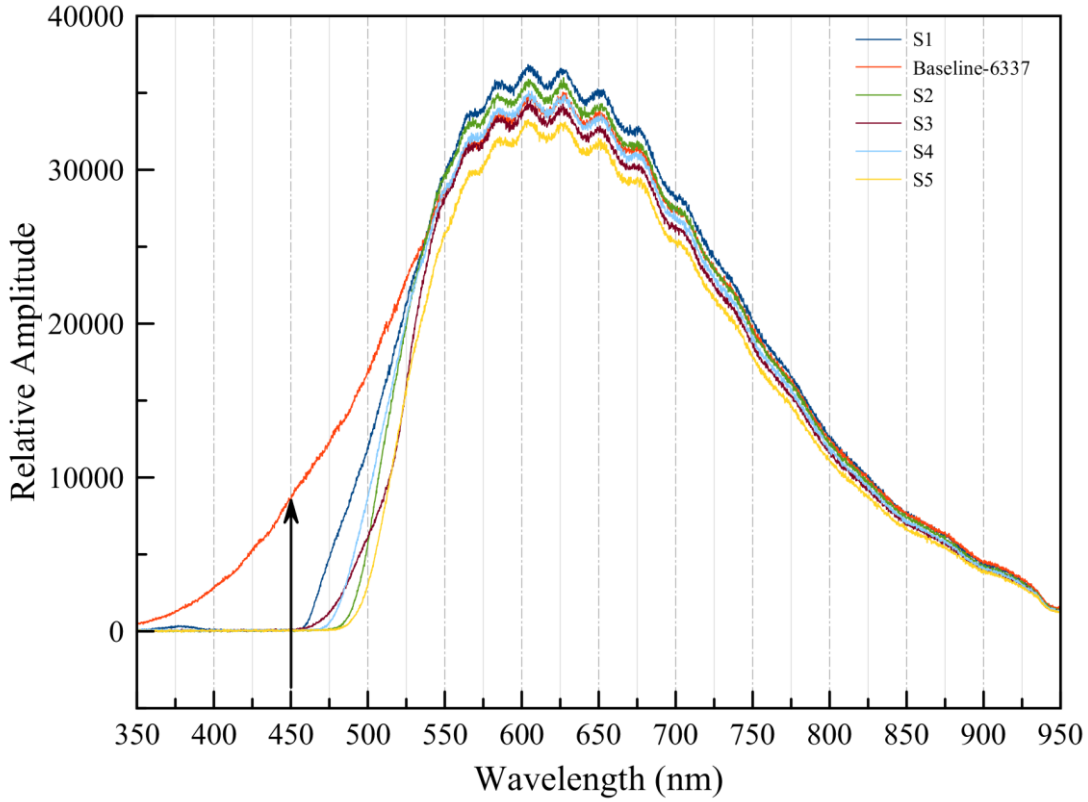


Figure 1

When looking at Figure 2 - S6, (green trace) is very close to the FDG performance in wavelength but the amplitude is lower by about 10%. This means 10% less brightness requiring slower camera shutter speeds and wider aperture. S8, (light blue trace) is also fairly close but it starts to roll off at about 550nm (cutting out green) and the total amplitude is dramatically lower. S7 (burgundy trace) almost completely kills the green hues as well as blue. S9, (yellow trace) allows a bit more green to pass but the overall amplitude is dramatically reduced.

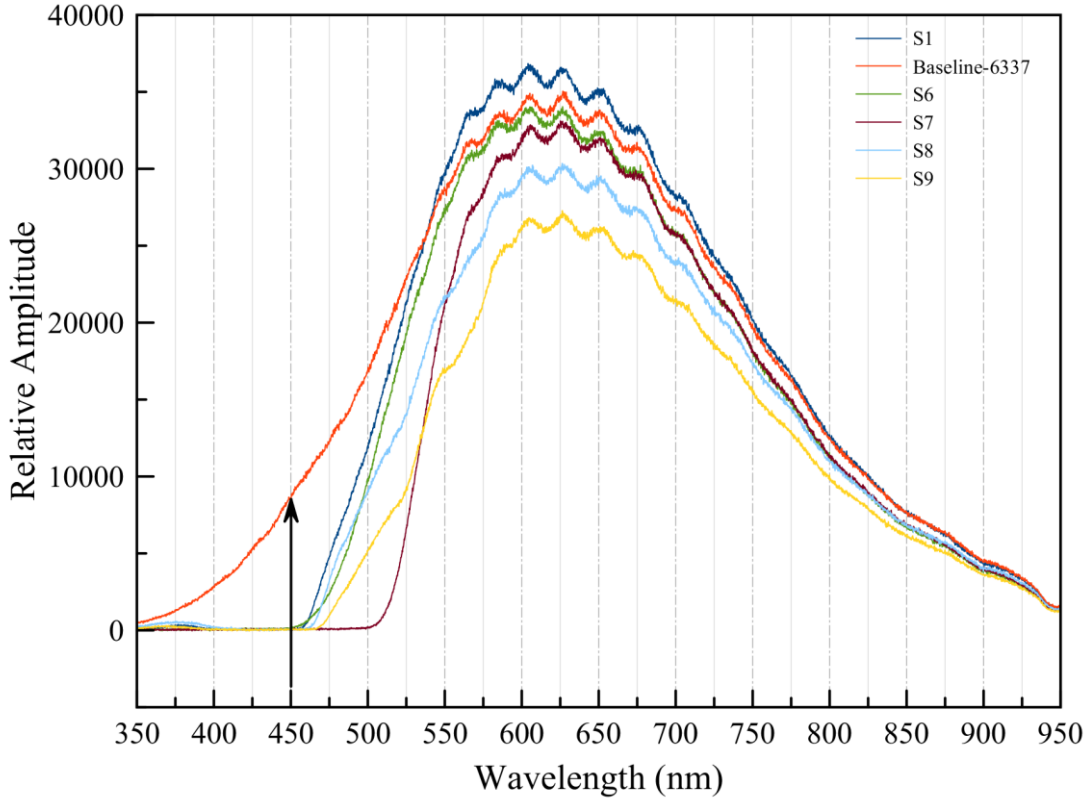


Figure 2

Now to Figure 3. Things are getting a little crazy with a couple of these filters. S12, (light blue trace) is going to be VERY blue and all the other colors will be attenuated severely. S13, (yellow trace) will be very green. S10, (green trace) will be less green but very little to no blue. S11, (burgundy trace) will have zero blue and about 5% green leaving very little to capture fluorescence since most creatures start to fluoresce somewhere in the green. S14, (black trace) is effectively worthless. No blue or green and the transmission amplitude is unacceptably low.

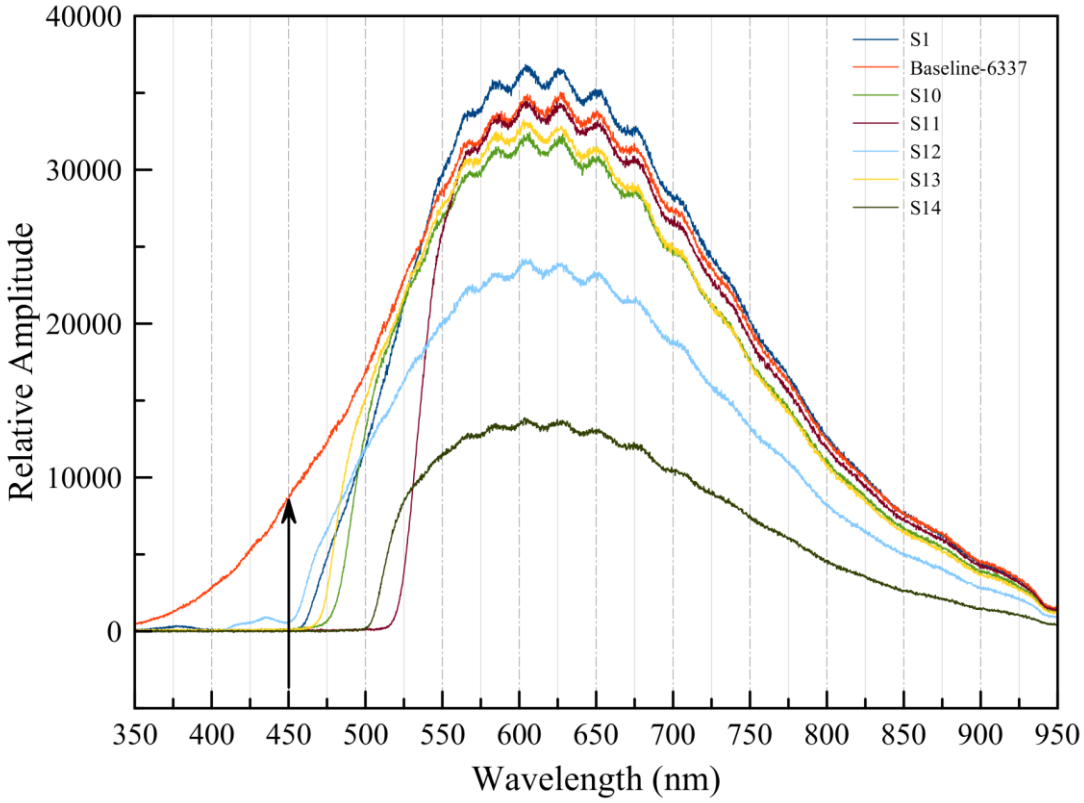


Figure 3

In Figure 4, things are really falling off the rails so to speak for S15, (green trace) and S18, (yellow trace). These will have some bit of blue, no green what-so-ever and only a bit of yellow with lots of orange and red. That assumes of course that the target is fluorescing in orange and red. Otherwise there will be almost nothing to capture. S16, (burgundy trace) and S17, (light blue trace) are much like S3 in Figure 1. These filters are not too bad if you want no blue.

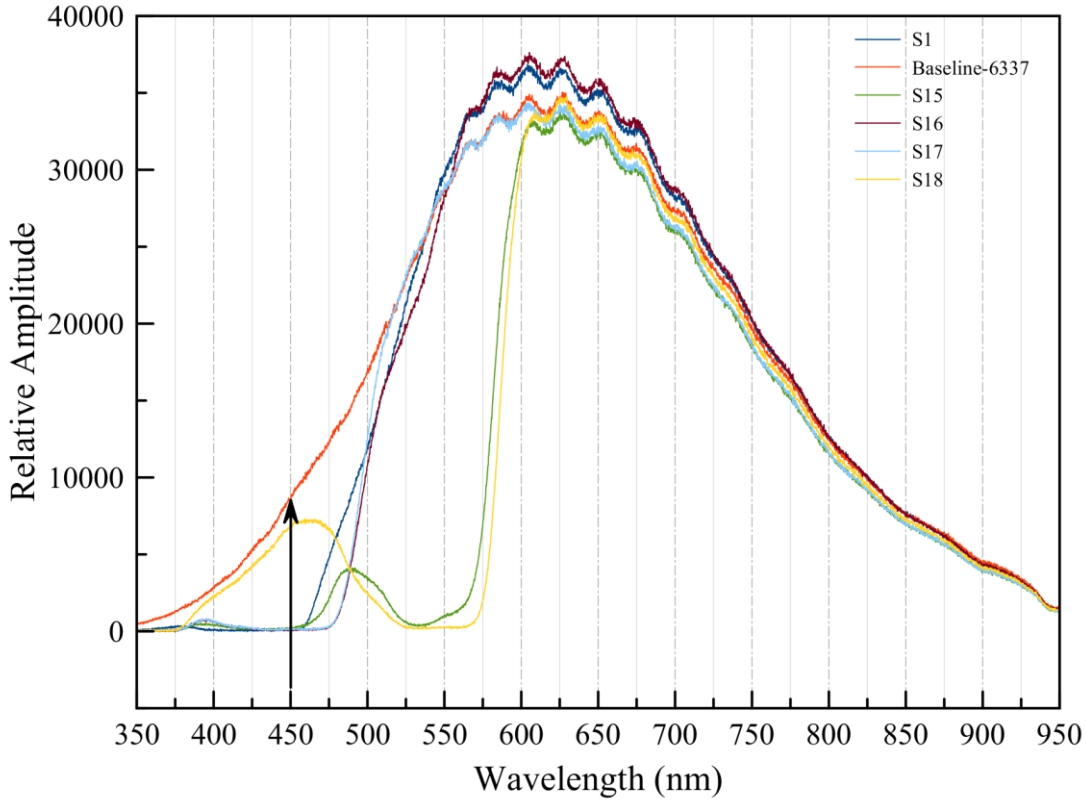
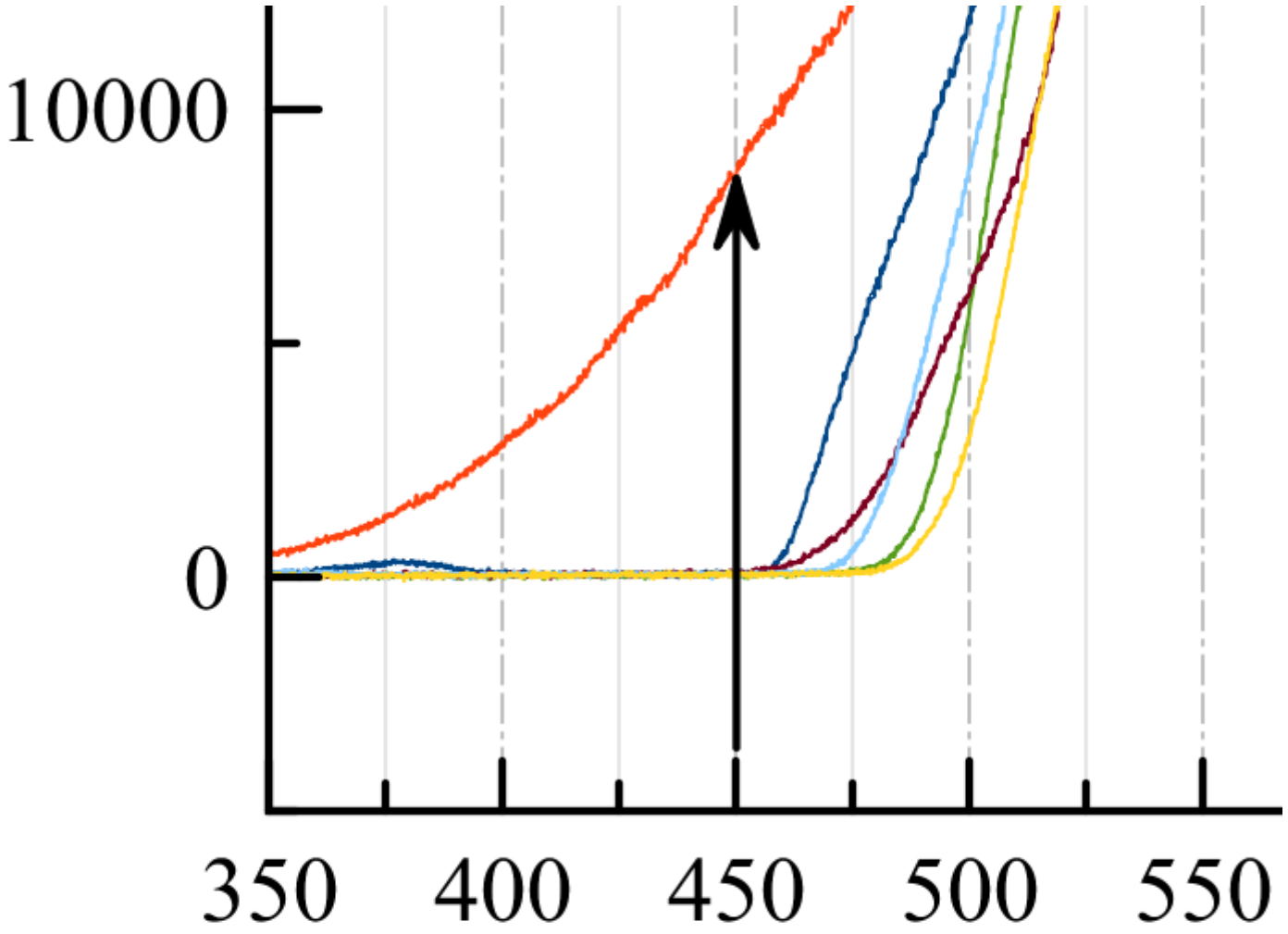


Figure 4

Below is a cropped “blow-up” of the transition area of Figure 1 to get a better idea of how dramatic the differences are. As we said” 10-15nm can make all the difference in the world for contrast and color saturation. Go back and look at the two lizard fish images above. The left lizard image was shot with S5, (yellow Trace) and the right lizar image was shot with S1, (dark blue trace) - the FDG filter. There is less than 20nm of bandpass difference between these two filters but a world of difference in image quality.



DISCUSSION (Blue Light Source)

This is our second set of figures. As above, we have four individual figures to keep them from being cluttered with 19 individual traces on one figure. Red represents the output of the standard blue light torch and the **blue** trace is S1, the FDG barrier filter. Note also that we reduced the x-axis range of bandwidth from 350-950nm down to 350-500nm. The reason was to provide more resolution where we have all the "action". Since the light doesn't emit beyond about 470nm, there is no point in measuring further out because there is nothing there.

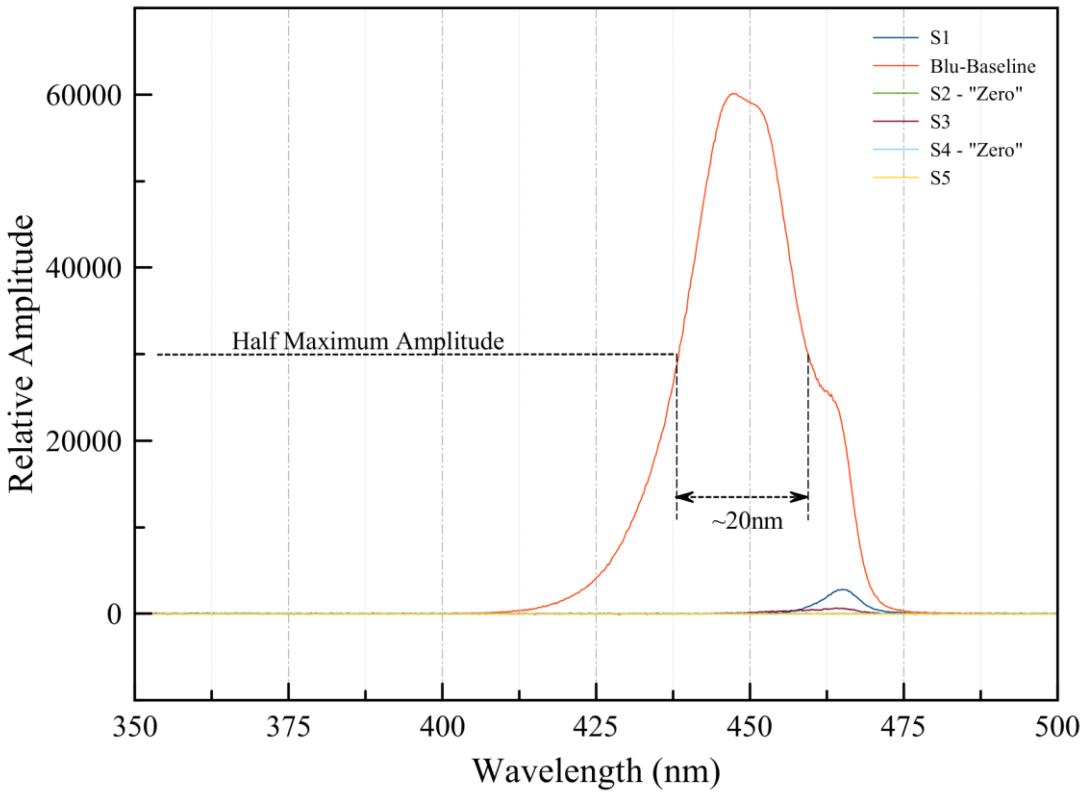


Figure 5

We can see the torch output baseline (red trace). This output shows a bandwidth at the base of about 50nm. However, it is common practice to claim the effective bandwidth of a blue light source at the "full width, half maximum" (FWHM) point. The question is: "What is the width of the waveform at its half maximum amplitude point?" In Figure 5 the relative amplitude on the y-axis maximum is about 60,000 units making the half max about 30,000. Therefore, the FWHM is about 20nm, centered around 450nm. This is a very narrow output which once again drives the point home that only a few nano-meters difference can have a huge effect. FDG torches, and strobe filters are designed to provide this very narrow, high power output at the point of maximum excitation wavelength to provide the greatest fluorescence emission.

Now for the filter analysis. We see that everything is basically flat lined in this blue region except the S1 FDG filter which shows about 3% in amplitude giving us this bit of blue.

Studying Figure 6 we see that S6, (green trace) is going to give us quite a bit darker blue and S8, (light blue trace) will give us some blue also but a bit less than the FDG filter.

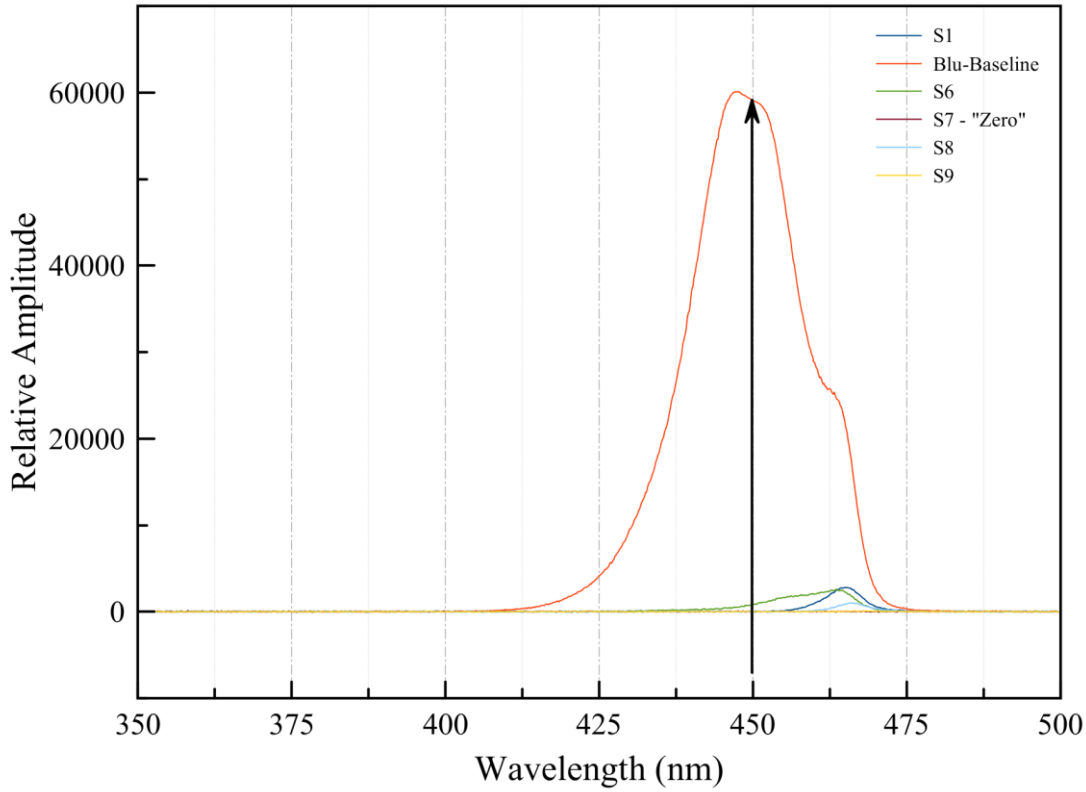


Figure 6

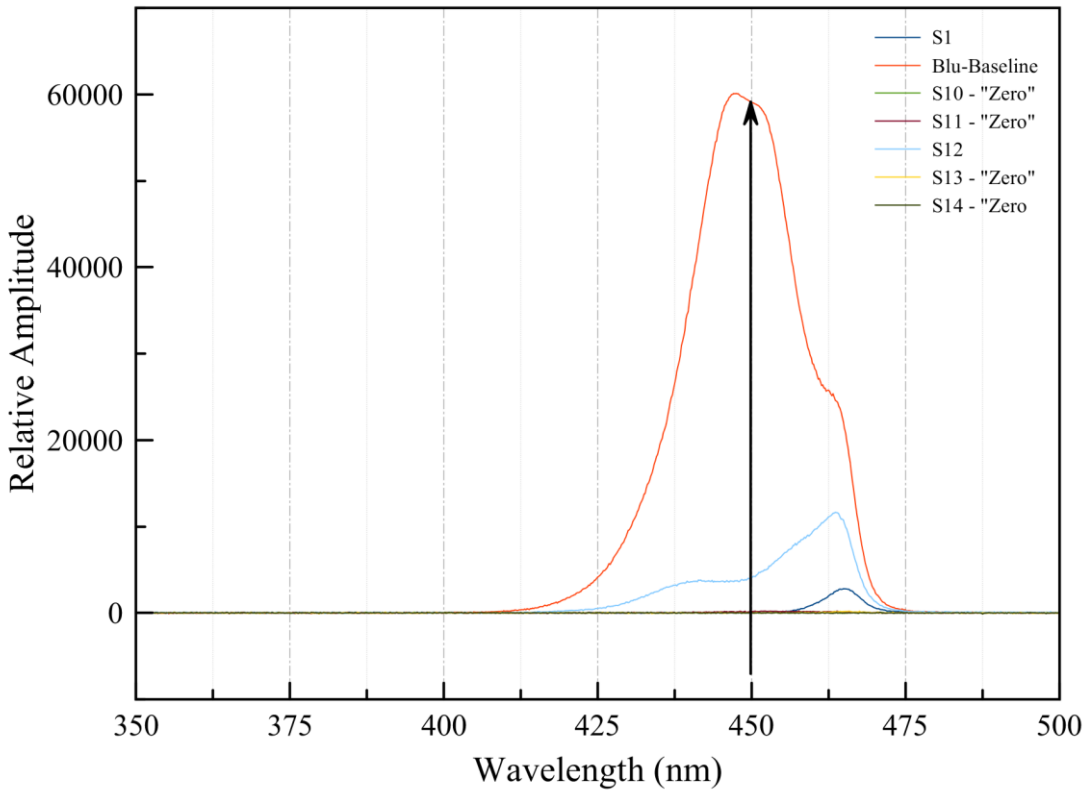


Figure 7

In figure 7, S10, 11,13, and 14 are all flat lined with no blue and S12, (light blue trace) will overwhelm you with blue.

Figure 8 is much as Figure 7 with S18, (yellow trace) basically allowing the majority of the blue content to pass which would completely overwhelm the fluorescence emission. All others being effectively zero blue content.

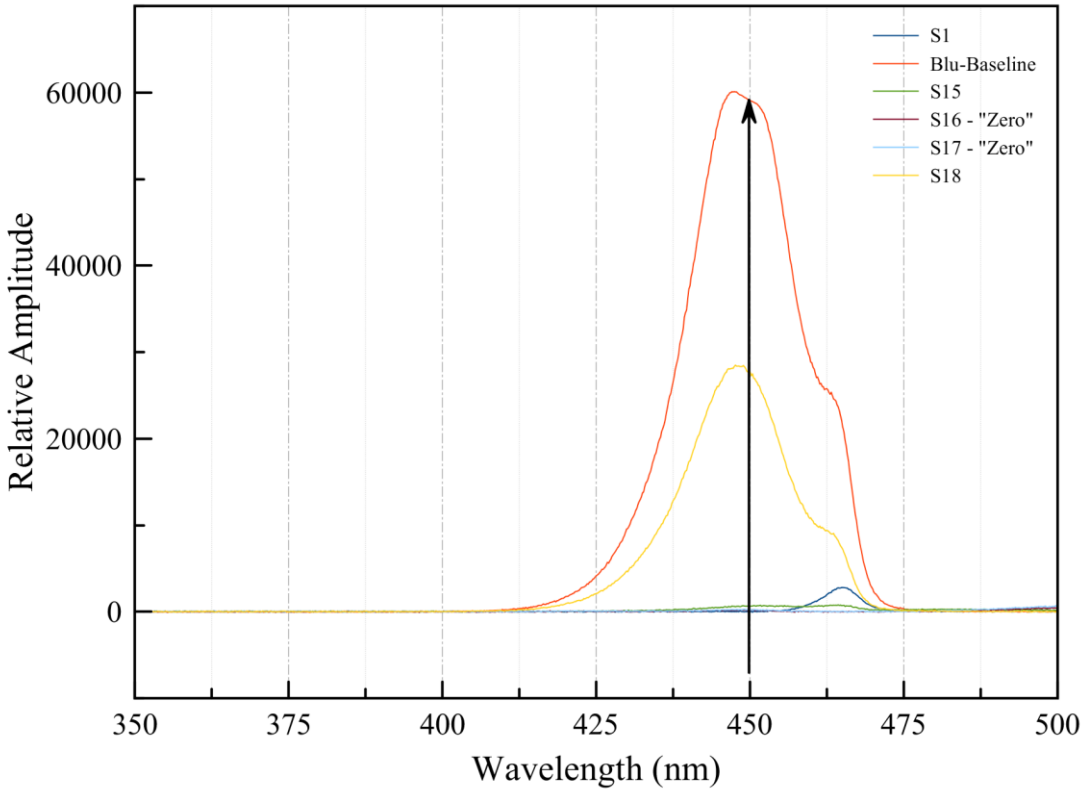


Figure 8

SUMMARY

The point of this entire paper is to drive the point home that "*not all barrier filters are created equal*". I hope that we have achieved that goal.

Some of the filters tested are going to give very poor photographic results, other are quite good.

The moral of the story:

Know what you are buying and know who you're buying it from. Understand the performance specifications because it will make the difference between an award-winning image and a snap shot.

Lynn Miner
Physicist
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