Scientific Facts for You

All light sources make photons in specific ways. How each type of luminaire physically works determines how useful it is in any application. The physics controls the output. That spectral output in visible light impacts the presentation.

Does it look beautiful? Can you see the subtle changes in color and shadow? Or is the lighting hiding some of the real beauty?

Fast facts are brief articles designed to arm you with information. Here is a quick look at color and presentation. For a more complete understanding of photons, search the web site.

A Distorted World of Color

Welcome.

Welcome to the world of RGB. Your computer monitor uses light created by phosphors much like an LED (it might even be an LED screen) to simulate thousands of colors. But your eyes are much more talented. Your eyes can distinguish millions of subtle shades and difference in tone from pigments, dyes, paints, surfaces, natural objects, etc.

The computer is a simulation. It is why Walmart displays the televisions for sale at over saturation. Color is shuffled into a smaller palette with less variety and nuances. Your monitor might be with set at higher saturation than normal too. Even printers, especially for photographs, can be over colorful with primary colors dominating removing many of the real colors. So pay attention. You will have to look closely since your computer, pad or phone has you at a disadvantage.

Your eyes are real life. And real life is always more beautiful. Real life always has more colors.

But a monitor is all there is to discuss this concept. What do you see? What do you really see? Does it take your breath away?

Lighting a Painting

Artists mix different pigments and dyes within paints to get a wide variety of results. Good art shows that light through an RGB world just does not cut it. Ask Microsoft. The idea of putting the worlds masterpieces on monitors or even artwork in homes by monitor did not work. The deep beauty wasn't there.

Great art, and also great treasures, have beauty that is amazingly complex. Though our eyes use three enzymes to interpret photons into RGB signals, the way the mind works is far more exacting. We see billions of colors differently. We also see the most subtle differences. For example, we can sort red pigments. We can tell the difference between a dye or a glaze. We are wonderfully made.

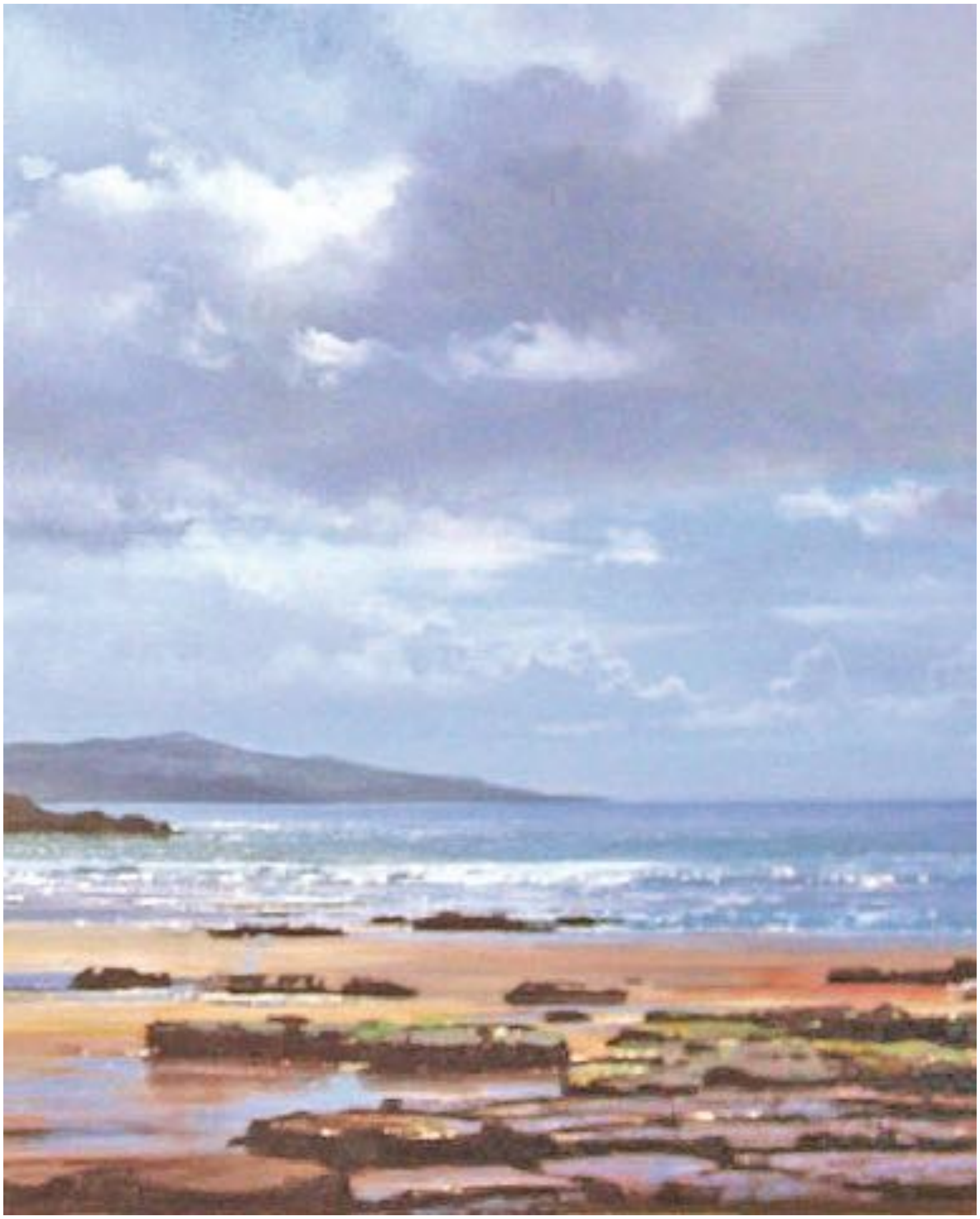
But you have to look close.

Your computer screen is masking much of what is real. What do you see in these examples? What reflected photons are different depending upon the light source?

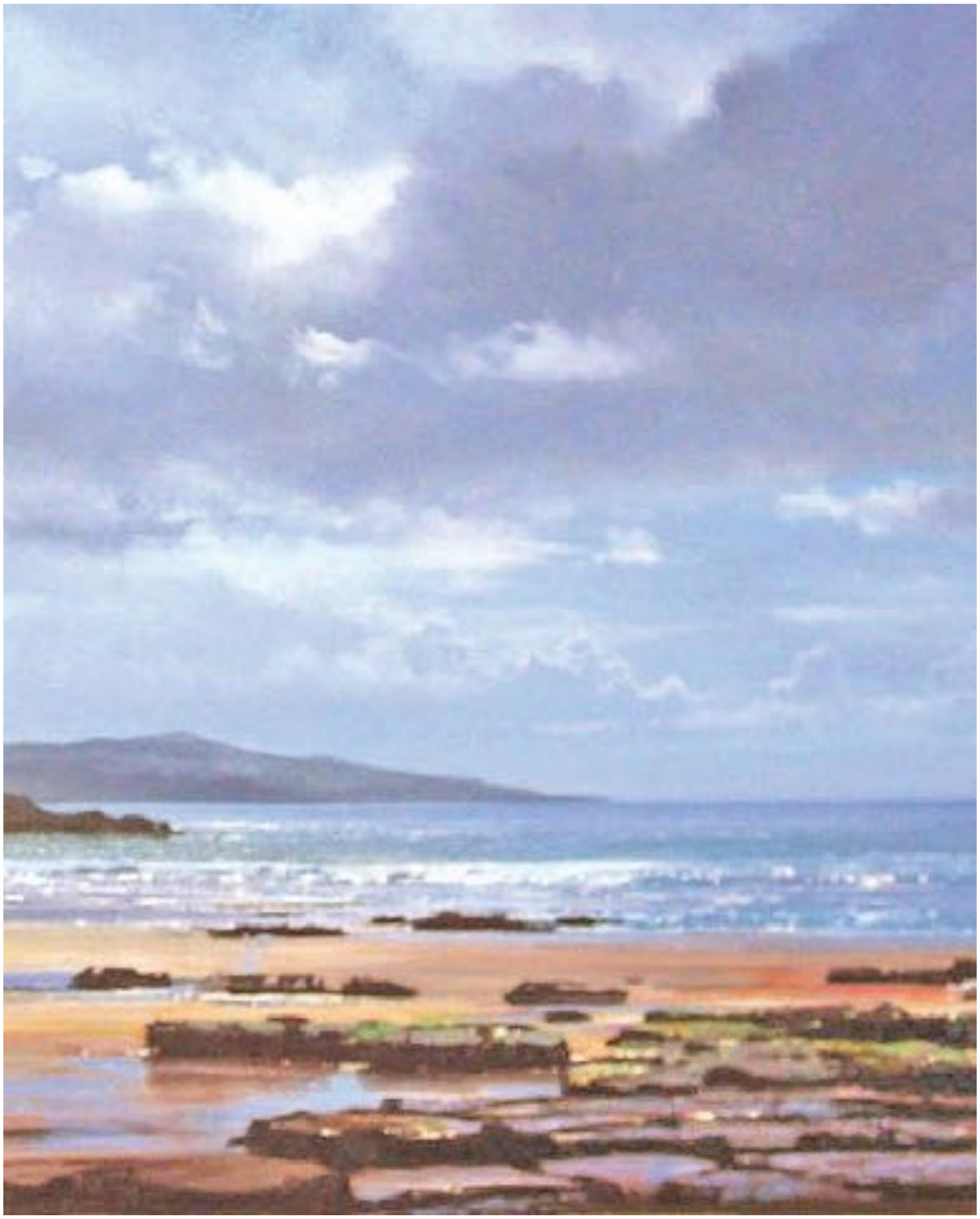
We are designed to see in sunlight. Sunlight has ALL the colors. It supplies our eyes ALL the visual data.

For an artist, sunlight is the light filtered through a white canvas or white cotton sheet. It is also defined as the perfect light that comes through a studio's North facing windows. It is never direct. It is the light so data rich that you can tell warm pigments from cool pigments even though the color is considered identical.

This beautiful seascape is lit with artist-specified sunlight.



Here is this beautiful seascape now lit with NoUVIR fiber optic lighting.

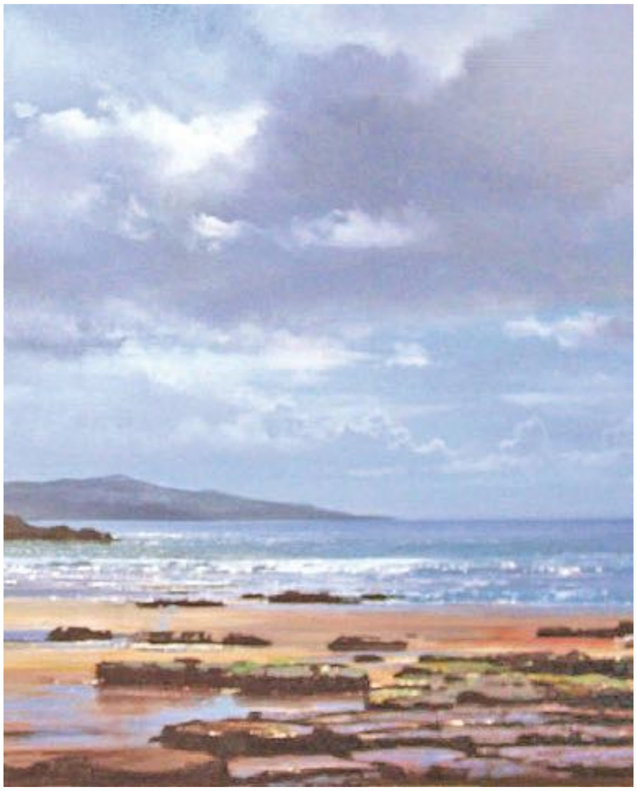


Scroll back and forth. Do you notice any differences? The cloud in the upper left is a little lighter from a reflection or sheen picked up in the photography. But check the sky. Look at the ocean. Compare the colors of the rocks and sand.

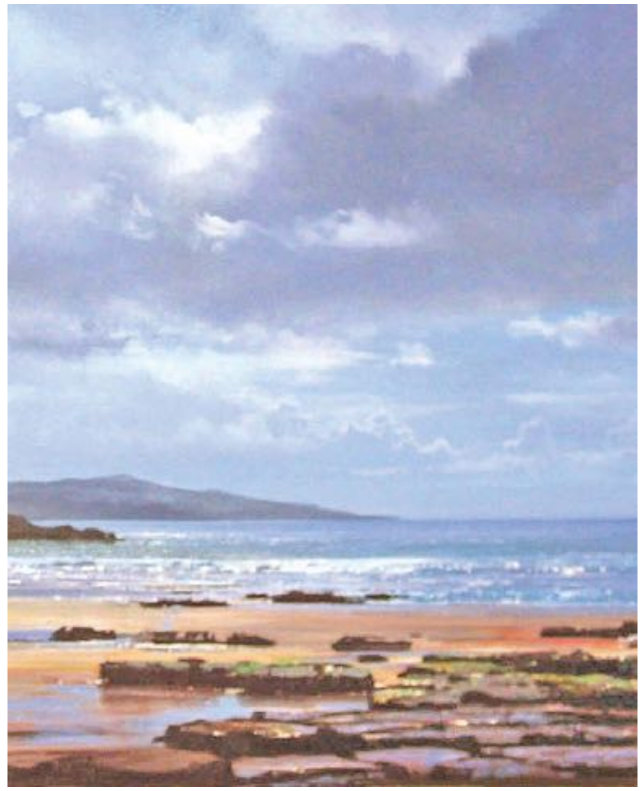
In real life, this painting will make you pause when you see it. It is breathtakingly beautiful. This artist is a master.

Let’s see the images side-by-side for further comparison.

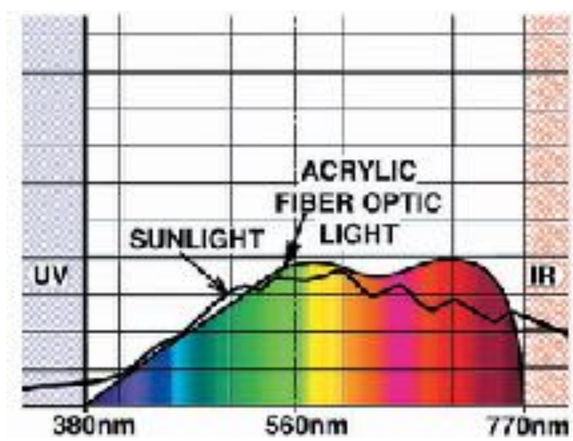
Indirect “Artist” Sunlight



NoUVIR Fiber Optic Lighting



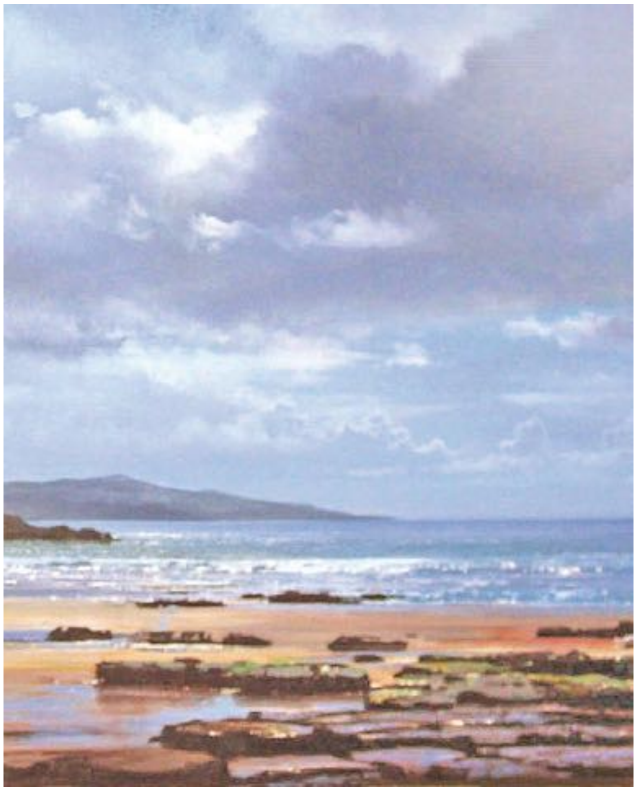
NoUVIR fiber optic lighting matches the visible spectral output of sunlight to within 96%. But unlike sunlight (even that defined by an artist), there is no UV and no IR. The light is far safer. How often have you seen the warning not to place artwork in direct or indirect sunlight. Sunlight fades and damages.



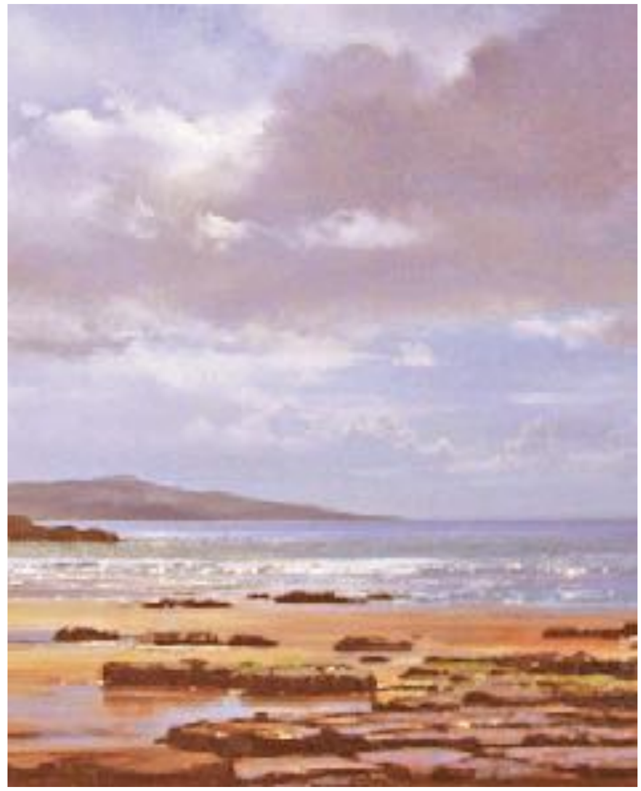
The spectral curves indicate the visual performance. Sunlight has a little peaked places in color where different molecules floating in our atmosphere filter at a little different rates. But sunlight is a continuous, data filled source. Compare sunlight imposed onto the NoUVIR curve. There is a little more red that helps counter the sharp cutoff in the red color; but the curves are very close. This is why the presentation is very close.

What about a halogen source? What is the light’s presentation? The painting turns slightly orange.

Indirect "Artist" Sunlight

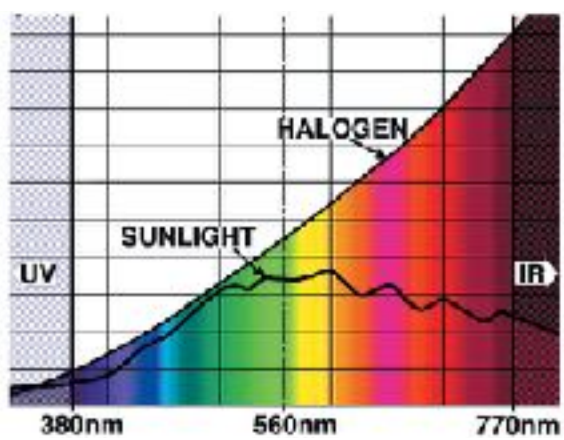


Halogen Lighting



This is a top-quality halogen lamp running at full voltage creating as much white light as possible. Yet the painting feels darker. Notice how an increase in red makes the red in the clouds stormier. The sea and sky is not that bright, cheerful blue. The rocks and sand are more colorfully dominant in the foreground and the mountain has moved also forward loosing distance. The focus takes away from the ocean. It is still a glorious work of art. But it is not as superior as it demonstrates under ideal lighting.

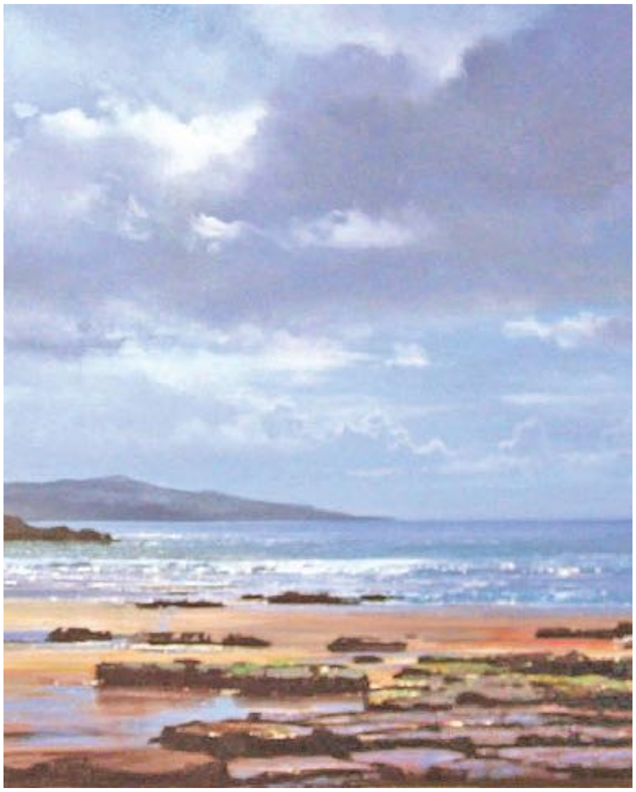
This artist does not use a titanium white with its warmth. Instead this artist uses the silver, brilliant whites of zinc and other pigments that imitate lead white. Note how the halogen lamp has shifted the white. It is still white. But it is not the same silver brilliance as it has lost the vividness.



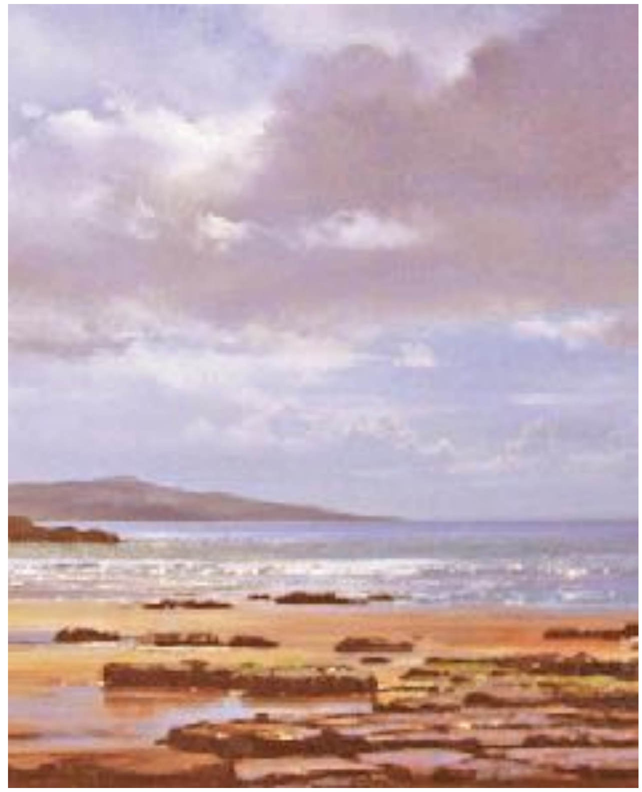
Again the spectral curve predicts the shift to red of the presentation under a halogen lamp. The halogen lamp has more yellow with a dominant orange and red output. The bias is obvious in looking at the sunlight curve superimposed on the spectral output of the lamp. The reds as content are 3x or more. This is why the artwork slightly changes its appearance.

Now shift back to comparing NoUVIR fiber optic lighting verses halogen lighting.

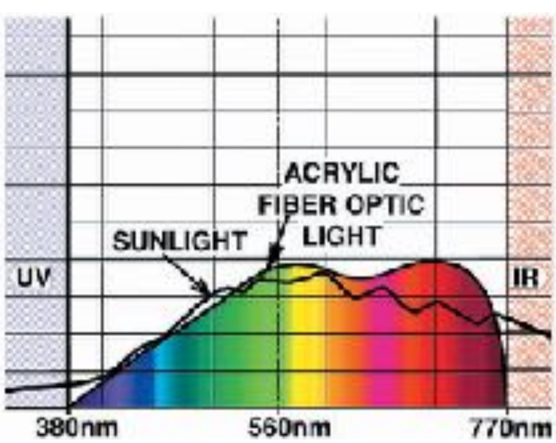
NoUVIR Fiber Optic Lighting

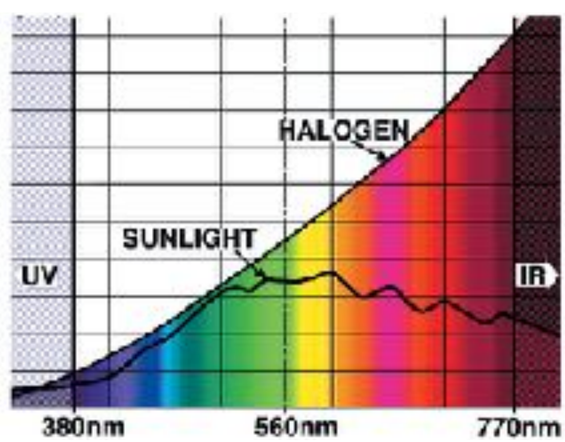


Halogen Lighting



This example is under RGB conditions. Your monitor, pad or phone is influencing the colors. But you can still see a difference. Many of the real colors of the painting you cannot see. But even so, which presentation would you prefer in your home? And visual inspection shows the NoUVIR lit image matches the original.

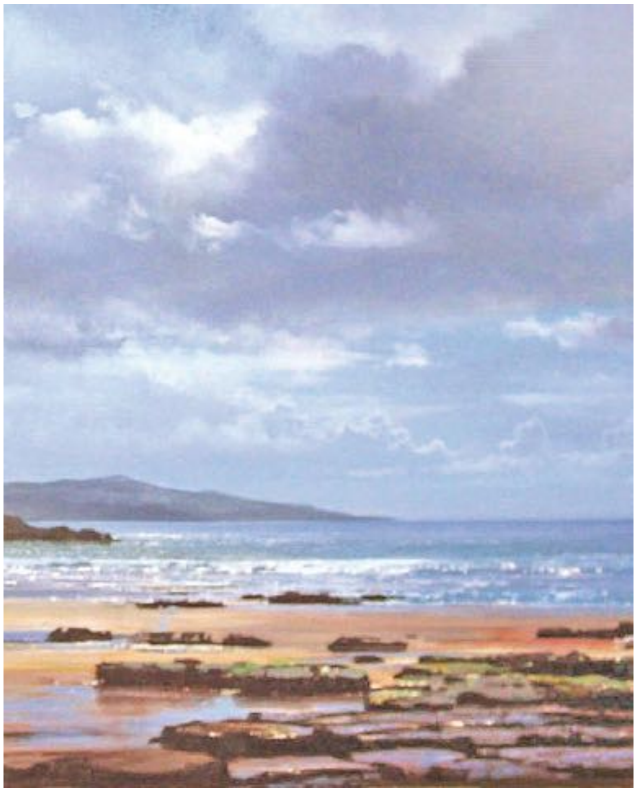




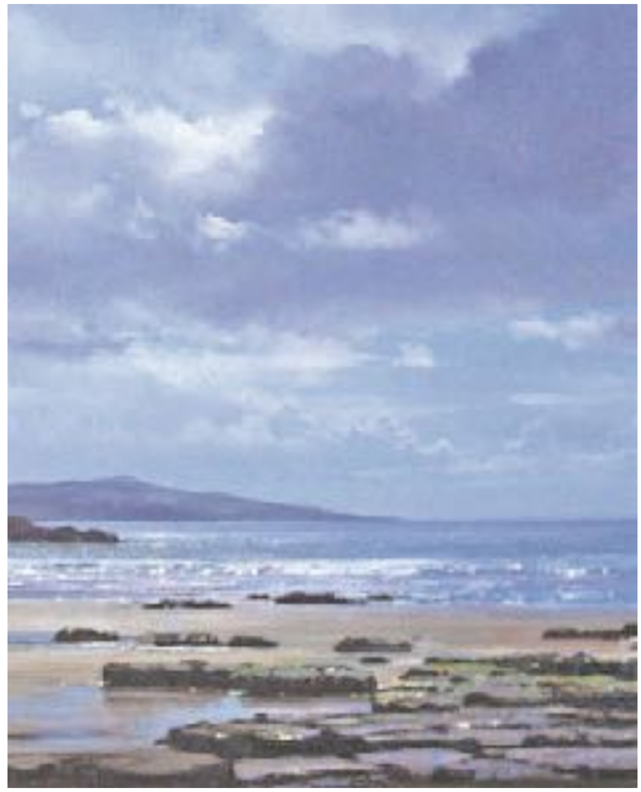
This painting is valuable. The removal of the UV and the IR help preserve the artwork. But the removal of the IR also helps with seeing the work. The human eye responds to some of the infrared spectrum. The iris of the eye contracts to protect the retina. Simply put, your eyes do not work as well or have as great a depth of perception under lighting with high IR content.

What about LEDs for lighting? First a few things need to be qualified about the LED source. This source is a high-quality (expensive) LED with a good mix of phosphors made by a well-known manufacturer (no cutting of quality control) with the best output for “white” light which includes the critical bastard amber filter. Other LEDs with less quality will produce worse results in presentation.

Indirect “Artist” Sunlight

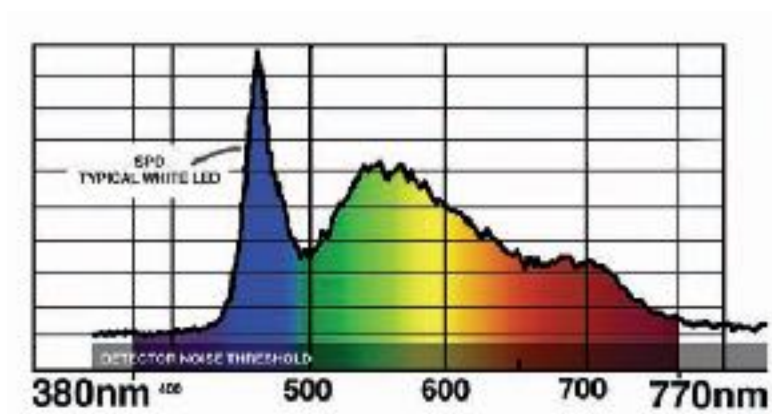


White LED Lighting



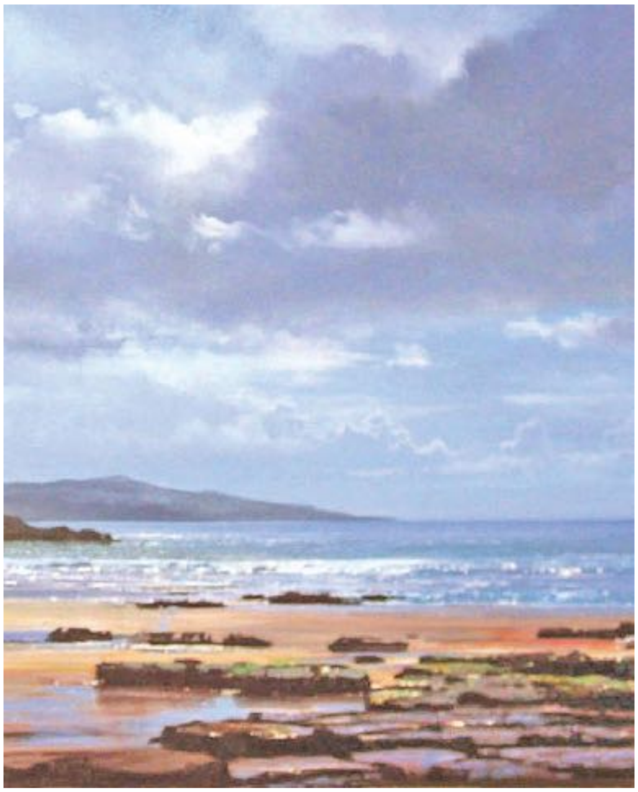
Again, this is still an exquisite piece of art. But the presentation is not what it should be. Colors get washed out to a certain specific blue and the green-yellows shift the browns of the rocks and sand. dulling the beach Is it any wonder that art galleries that sell art still use halogen lighting. Is it also any wonder why there is a consumer resistance to bring LEDs into the home. The current trend in homes are to use Edison lamps that are LEDs to get an orange-yellow color that is more inviting. But that bias does not remove the blue spike.

The LED lighting is too blue. The depth in the painting disappears. It is still beautiful. Unless you could compare, you would have no idea what you are missing. But you are missing beauty.

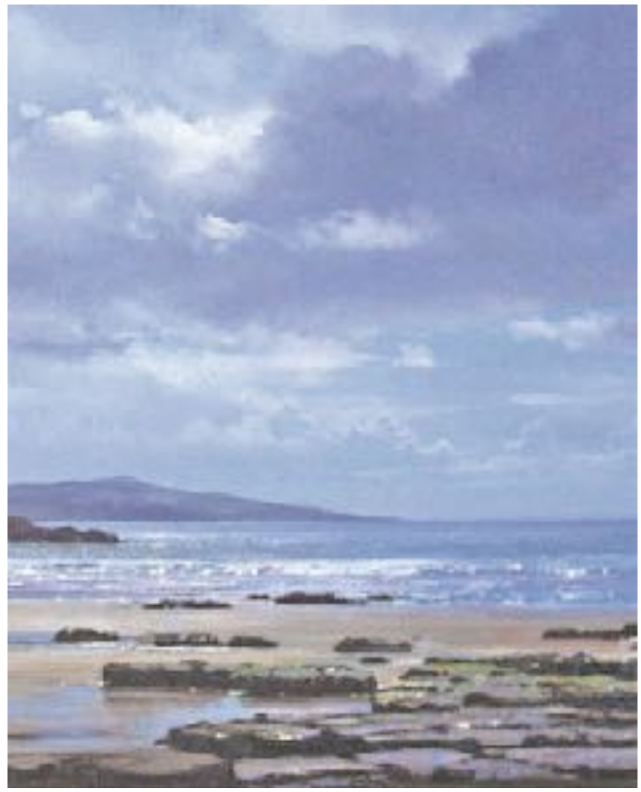


The spectral output again can predict the presentation. The LED has a dominant blue spike of color. And an under representation of red. What is surprising is that people do not notice the graying of the artwork. When asked people will state that the art looks nice. They like the painting. They do not miss the vividness being gone. But the artwork is not as appealing.

NoUVIR Fiber Optic Lighting



White LED Lighting

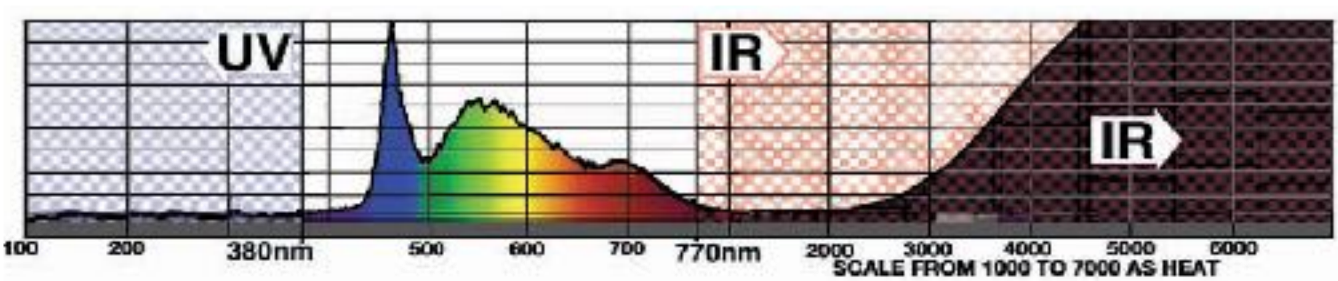


Again judge which lighting makes the artwork seem more lovely and valuable. People will stand twice as long in front of a painting lit by NoUVIR in a museum setting. Seeing more color and more beauty is more enjoyable.

Because it is interesting, look at what has happened to the white. Again, this artist uses a brilliant, almost silvery white. The LEDs authoritative blue has shifted the white into a blue tone. This work really does not have a true white. If the artist used titanium white with its warm tone, the white in the surf and clouds would have shifted to a gray. The color displacement would be less obvious. The work would not look quite so blue.

A designer put it this way. “LEDs have no soul.” The presentation can make a painting or some other beautiful treasure seem to loose its soul.

Here is a more complete look showing MORE of the real output of an LED lamp. See how the IR climbs. Again, this is a good quality LED with excellent heat control.



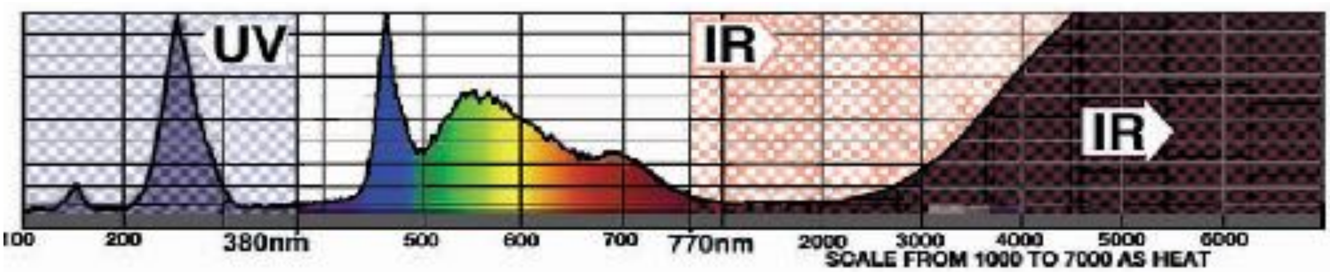
In the curve much of the IR is still not in the graph. Some LEDs start the IR climb at 1200 nm instead of 3000 nm. But all LEDs have heat.

Doubt there is IR in an LED. Have you been told over and over again that LEDs are IR free? Put one in a box and light it up. It can be as simple as an experiment with a shoe box. The temperature in the lamp will become obvious.

Also look at an LEDs construction. The heatsinks are there for a reason. One popular manufacturer buries a miniature fan inside the lamp to cool the circuitry.

Also check out the instructions for the LED lamp. Marketing has not sanitized all instructions for use. An LED lamp's instructions use to say operation had to be in free air and the lamp oriented aimed up (not down) to control heat.

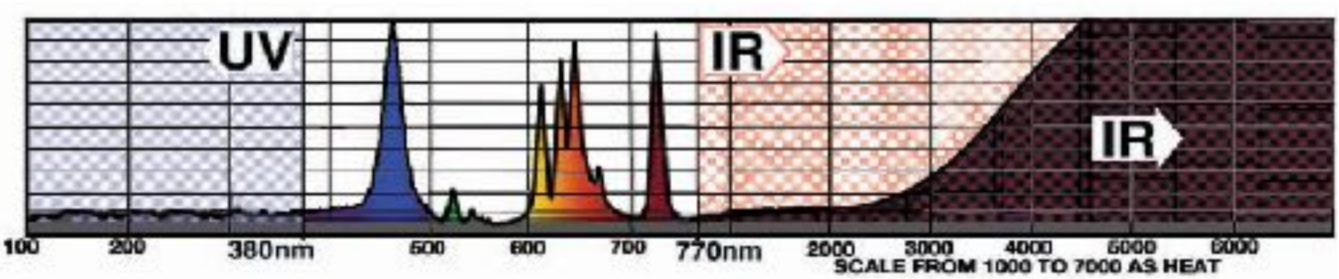
LEDs **without** good lenses that filter ultraviolet have UV spikes. Different manufacturers will have these UV peaks at slightly different places depending upon the materials they are using. But the UV exist. The visible blue spike and these UV spikes below 380 nm are part of the physics of how the lamp works. The intensity of the blue light is also one of the reasons why the lighting industry has been having serious discussions about retinal damage caused by "blue light."



An older LED lamp will produce more and more visible blue light. The light will get dimmer over time with the color degrading. Some lamps loose half their visible output in just a two years of use.

LED lamps come in color temperatures that range from 2800K to 5600K. Most lamps that are more yellow use more phosphors and are less energy efficient. The blue light peak of energy still exists. It is still what is shown in the graph. But the green-yellow part of the curve is shifted by more and more phosphors. Again, the chart shows the best, most color balanced LED lamp available. Cheaper lamps will have worse spectral curves.

One of the more promising ways to "improve" LED performance is to make the lamp more tri-stumuls like the LED below much like a tri-stimulus fluorescent lamp. The goal is to make the lamp RGB.

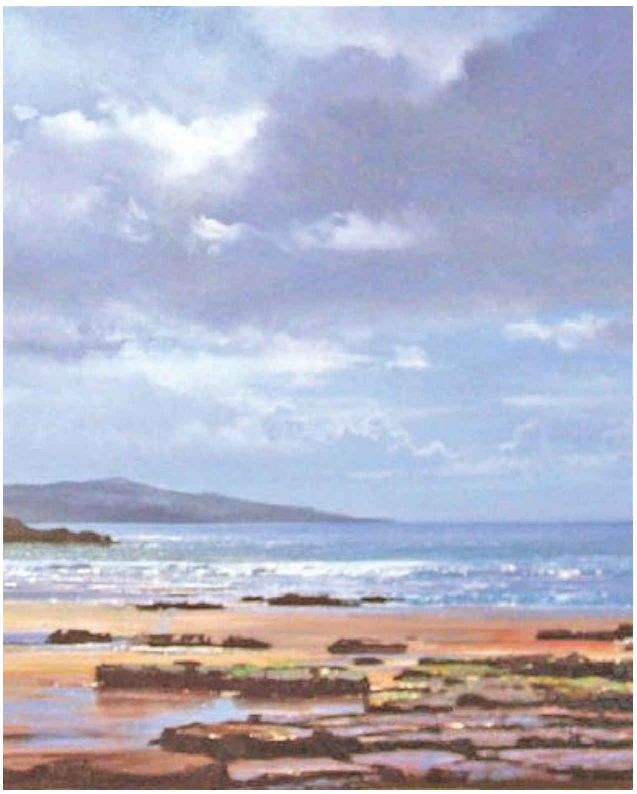


The output of this LED lamp is a mix of blue light plus green plus orange plus red. Some LED lamps are purple plus blue plus green plus red. The gaps are colors that the lamp does not produce. In the seascape, these colors mute and turn gray.

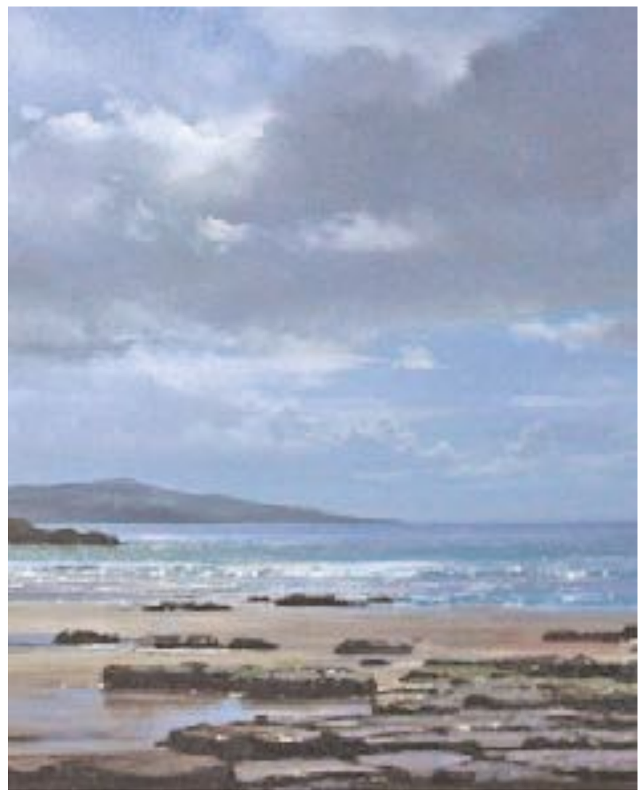
As you can guess, this type of LED is very good at conserving energy. But its presentation is poor. The same goal and techniques of using very specific phosphors to get better energy savings is also occurring in fluorescent lamps. A fluorescent lamp uses UV instead of blue visible light. Then uses metallic salts as rare earths and metals like mercury to produce the other colors. Cutting back the mercury and other heavy metals has dropped the color quality of fluorescents over the years.

Fluorescents are more energy efficient. But the industry is being driven to lamp output with taller spikes and larger gaps of missing colors. Compare the seascape lit with NoUVIR fiber optic lighitng to a modern “white” fluorescent lamp. The painting is duller. The colors more mute with the blues darker as the lights output washes away color differences.

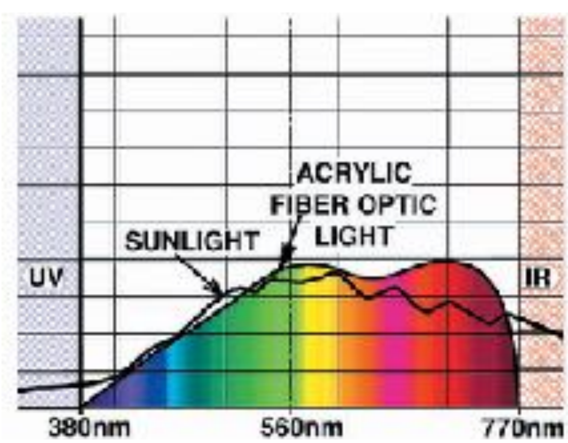
NoUVIR Fiber Optic Lighting

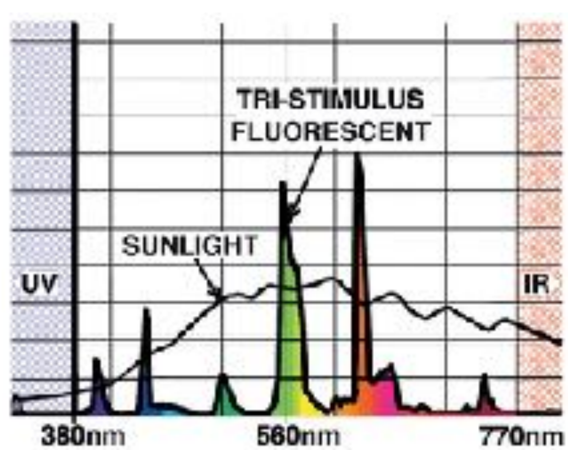


Fluorescent Lighting



Again the spectral output predicts the presentation problems.





What Is Color?

Art students are taught all colors can be mixed from three primary colors. They are red, yellow and blue. Add white and black and you have a working palette.

It is true. You can get a lot of colors. And this basic palette will teach a great deal about how eyes see color.

But top artists use six primary colors, two blacks, two whites and usually add violet, a fluorescent or brilliant orange and sometimes a vibrant lime green. They know color is more complex. Humans see the subtle differences between these cool and warm pigments of the same color sets of red, yellow and blue. For a reference see the excellent book: *Blue and Yellow Don't Make Green* by Michael Wilcox.

Computer students, and even some experts, are taught that all colors can be created from red, green and blue. A good RGB monitor can produce thousands of variations of color. But monitors have never been able to really share the awe of a painted masterpiece or the glory of standing on a mountain trail overlooking a valley.

Remember when art museums were going to be all monitors? Remember when homes were going to have virtual art rotating in framed screens? It did not work. A real painting by an unknown artist is more beautiful than the RGB of a masterpiece on a computer monitor.

Printers learn that any color can be created by cyan, yellow, magenta and black using the paper for white. Color is CYMK. Printing is a four-color process with four plates. When it is not. Fine printing jobs are often done with five, six or even eight plates to add colors to the CYMK to broaden the scope of colors. Just look at a Pantone® book that compares CYMK colors to inks that can be purchased. There is a difference. Some colors just cannot be made from CYMK.

We see color. But what is it really? It is reflected data. So seeing is a system. It is not just the color of the object. It is also the light and if that light can produce the colors to be reflected.

Today the lighting industry is in constant debate over color. But ask any artist. Color is beauty. And ugly lights rob things of their beauty.

What Is Color Rendition?

Color Rendition is how accurately a light source renders or presents each color using Northern sunlight as the standard. The lighting industry grades lamps using a Color Rendition Index or CRI. A grade of 100 is 100% or the best possible score. Grades can be as low as 40 which means 40% of the colors are accurate and 60% inaccurate. We have all stood in a parking lot at night under orange sodium vapor lamps and seen terrible color rendition.

Fluorescent and then LEDs have changed a greatly impacted lighting products. Originally the Color Rendition Index was a fairly accurate predictor of what people saw. The test was 80 color panels shuffled and sorted by test subjects. It was genuine, human beings judging color. The results were whatever the test subjects sorted as an average.

The first tests were randomly selected test subjects. Different ages, Glasses and no glasses. Everyone that was human was a potential test subject.

Reading tests were also added to see if different light sources helped people read faster or inhibited reading. The answers gave birth to a whole science. But for discussion here, the most important fact gleaned was that glare impairs vision. The more hidden a bright light source, the better people saw.

The CRI tests favor halogen lamp manufacturers. The color samples were not that close in color. Think of a large box of crayons or pastels. For example, a person would sort a lemon yellow from a pale orange. Or detect that a color sample was black compared to navy blue.

Halogen Lighting CRI 100

Cool White Fluorescent CRI 74

NoUVIR Fiber Optics CRI 100

A Color Rendition Index of 100 meant that 100% of the color tiles were sorted accurately. A CRI of 80 meant 20% were in error. A CRI of 72 (many phosphor, energy efficient lamp results like fluorescents and LEDs) had an error rate of 28% or almost 1/3rd the colors misidentified.

Look at the cups. A halogen light source is yellow, but has a CRI of 100. All the color tiles were sorted correctly with a score of 100% as every one of the colors was biased the exact same way. This fluorescent has a CRI of 74. About 1 out of every 4 colors were misidentified. The cool-white lamp is missing colors. NoUVIR fiber optic lighting has a CRI of 100. But see the big difference in presentation. The colors are superiorly represented.

This shows the problem with CRI. Both the halogen and the fiber optic lighting score the same grade. In this case, a poor fluorescent was picked, because it is very energy efficient. Often the tradeoff for getting deep savings in energy is getting ugly light that provides poor color rendition.

So there is a need for a better standard.

Few in the lighting industry test pigments. Can you tell the difference between a titanium white and a zinc white? The titanium white has a warmth to the white. The zinc white has a silver coolness.

Can you tell the difference between a Mars black and an ivory black? Painters know Mars is a brown black whereas modern ivory is a blue black. Pigments molecular structures reflect different colors. The human mind may have poor color memory. But the human eye can tell the difference. These subtle differences are often the difference between a masterpiece and a pretty craft faire painting.

By the way, “Yes.”

You can tell the difference between titanium white and zinc white, and between Chinese white (evaporated zinc oxide) and even lead white under NoUVIR fiber optic lighting.

“Yes.”

You can tell the difference between the warm Mars black and the velvety-tone ivory black under NoUVIR fiber optic lighting.

This is NoUVIR’s CRI test.

You can also see the slight blue bias in lamp black and the dead neutralness of black printer's ink. You can tell the difference between phthalocynine, prussian, cobalt, ultramarine and manganese blue. NoUVIR uses some difficult tests to check color. in a light source.

But back to the lighting industry.

Test subjects are expensive. So college students became the normal subject. Young eyes work better. They sort color easier. They handle poor light quality. For decades the lighting company would pay the university that would pay the professor to run the tests that might pay the graduate student doing the work that may, just maybe, would give the students some benefit other than experience.

The test dropped to 40 samples. Then in some case, the test became 20 samples. Then computers came along. Color sampling was a great way to get rid of humans.

Today CRI is calculated as a computer program. Pick your program. They all provide different results. The debate over CRI has now become a critical battleground in the industry.

Everyone wants a CRI as close to 100 as possible.

Even the government wants better grades as CRI is critical to the acceptance of energy saving lamps. But the fact is today's CRI is a questionable number. Lighting companies shop around to find the best results. The same LED lamp can score a CRI of 68. Or it can have a CRI of 92. It all depends upon who tested it. Chances are if this particular LED was tested by young humans, the actual results would be a CRI around 72.

What does this mean? Use spectral output curves to judge a lamp's presentation. The curves are far harder to monkey with as data.

Summing Up the Science of Color

Now you know more than most graduate students about color and color rendition. But if you want, you can skip worrying about your choices in lighting robbing your collection of its beauty. NoUVIR has already done the work. You know the color is perfect.