White Paper – Why We Use A Dichroic Filter

We get requests nearly every day asking why we use dichroic filters on all our torches and strobe filters. This topic has deep science behind it and is detailed, albeit *briefly* here. If you don't want to slog through the physics simply go to the bottom of this document and look at the photographic evidence and you will see why buying torches from a source that does not use dichroics may be a mistake.

What is a dichroic filter?

Dichroic filters are a type of interference filter. They have multi-layer thin-film coatings deposited on a substrate using high vacuum deposition techniques. A high voltage electron "gun" is used to vaporize various metal oxides such as aluminum, titanium, gold, silver, silica, magnesium, zirconium, chromium and various others which settle on the substrate. Each film layer is approximately one one-thousandth of a millimeter thick. The film coating typically consists of between 20 and 50 separate layers. The substrate or base material is a special type of glass or sometimes polycarbonate that has low thermal expansion properties. Dichroic filters are expensive to produce and the equipment required to produce them is very expensive.

Dichroic film structures typically consist of one of the following design types: short wave pass, long wave pass, bandpass, or notch filter. They provide very accurate color by selectively passing or blocking light of a small range of colors while reflecting other colors. These design types comprise the basis of color determination and color separation. Performance is determined by the transmittance and/or reflectance of a band of wavelengths (colors).

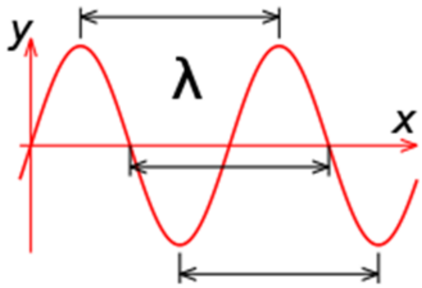
The films are deposited on large diameter substrates that are later fabricated into smaller sizes either by scoring and breakout or with a waterjet cutter.

What is does it do?

Dichroic filters use the principle of thin-film interference, and produce colors in the same way as oil films on water as you've surely experienced. When light strikes an oil film at an angle, some of the light is reflected from the top surface of the oil, and some is reflected from the bottom surface where it is in contact with the water. Because the light reflecting from the bottom travels a slightly longer path (albeit a microscopic distance), some light wavelengths are reinforced by this delay, while others tend to be reduced or canceled, producing the colors seen. This is the principle of interference. This interference is what makes a dichroic filter block or pass wavelengths of light (colors) that we either want or don't want.

We need to discuss some physics to understand how they work.

What is wavelength?

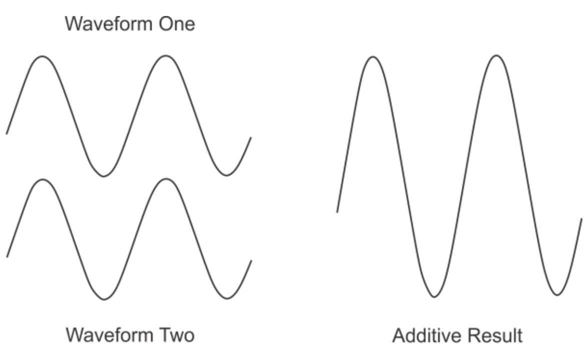


The term wavelength is simply the distance from one point on a wave to the same point on the next wave and is designated as the Greek letter lambda λ. This distance is usually measured in Nano meters (one billionth of a meter). The wavelength is inversely proportional to the frequency (F).

$F = 1/\lambda$ and thereby, $\lambda = 1/F$

What is interference?

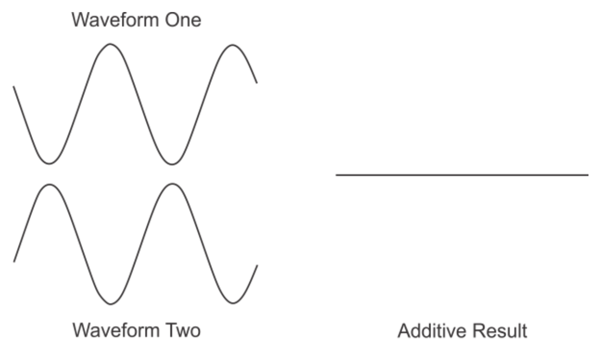
When two rays of the same wavelength occupy the same path and are in phase, their effects add, as in the figure below.



Two Waves In Phase

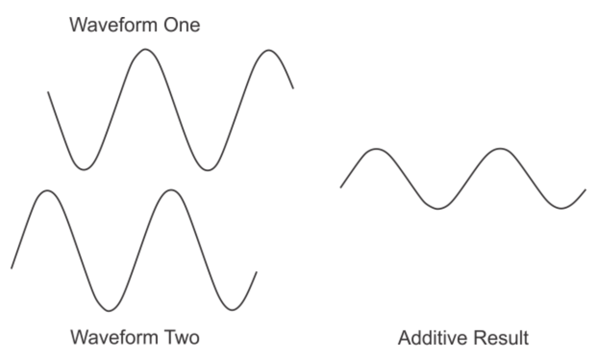
In other words, the light will be brighter.

On the other hand, if they are one-half wavelength <u>out</u> of phase (180 degrees) and of the same magnitude, they cancel each other and we have the phenomenon of interference as shown below and there will be no light.



Two Waves 180° Out Of Phase

Both of these effects occur in nature in the colors seen in soap bubbles and in other thin films, such as the oil slick on water mentioned earlier. For yet another less "black and white", or "all or nothing" example, see the below figure where the two waveforms are 90 degrees out of phase.



Two Waves 90° Out Of Phase

In the above case the resultant waveform is one half of either of the two original waveforms. The phase difference can be any number of different combinations and the two waveforms are not necessarily the same amplitude or even the same wavelength thus allowing for an infinite number of complex combinations of intensities and colors to be generated.

In a dichroic filter, the interference is created by alternating layers of optical coatings with different refractive indices built up upon the substrate. The interfaces between the layers of different refractive index produce phased reflections, selectively reinforcing certain wavelengths of light and interfering with other wavelengths. By controlling the thickness and number of the layers, the frequency (wavelength) of the passband of the filter can be tuned and made as wide or narrow as desired. Because unwanted wavelengths are reflected rather than absorbed, dichroic filters do not absorb this unwanted energy during operation and so do not become nearly as hot as the equivalent conventional filter (which attempts to absorb all energy except for that in the passband).

Advantages of dichroic filters

Much better filtering characteristics than conventional filters

Ability to fabricate a filter to pass any passband frequency and block a selected amount of the stopband frequencies (saturation).

Common Terms Relative to Dichroic Filters

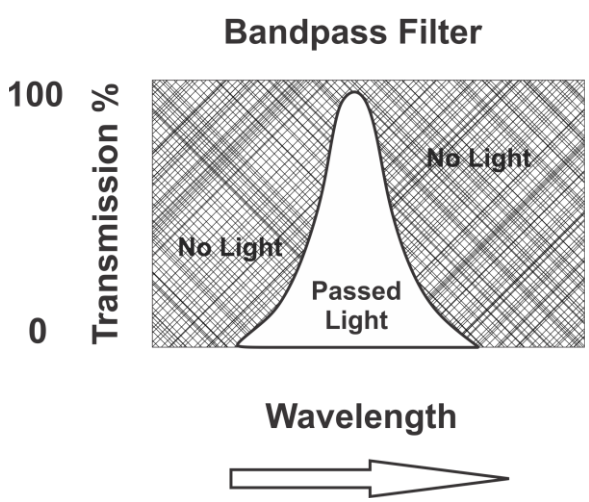
Substrate

The medium that a thin film is coated on. Typically, this would be glass but metal, plastics, and other materials are also often used. In the case of FireDiveGear dichroics, we use glass.

Types of Filters

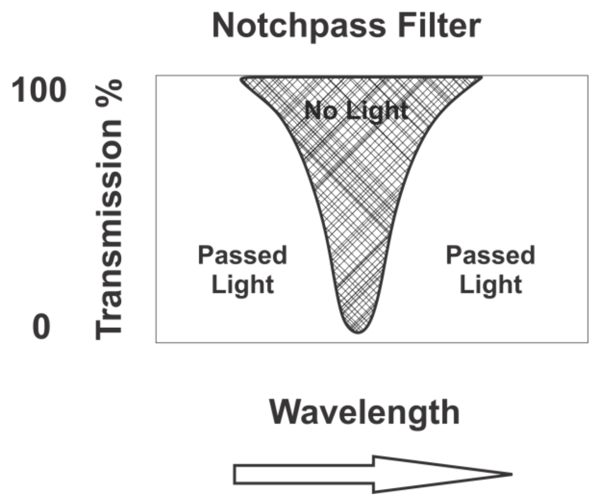
Filters are defined by how they pass light. The four primary types are Bandpass, Notch Pass, Low Pass and High Pass. The terms low and high referring to the respective frequencies being passed.

Bandpass Filter



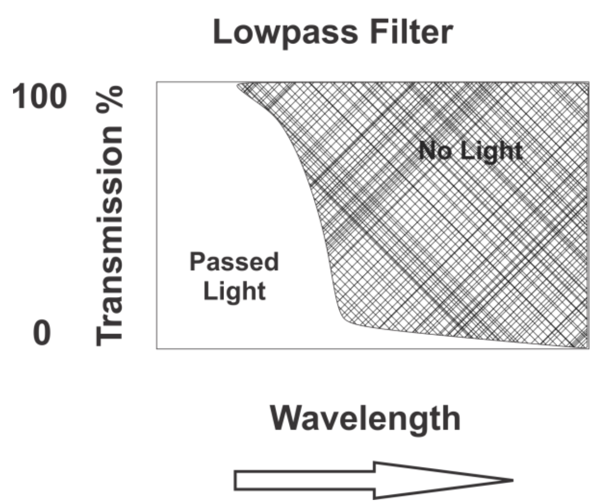
Bandpass filters transmit light in a small band of wavelengths and reject light below and above the selected band. This transmitted area is referred to as the passband. This is the type of dichroic filter we use at FireDiveGear.

Notch Pass Filter



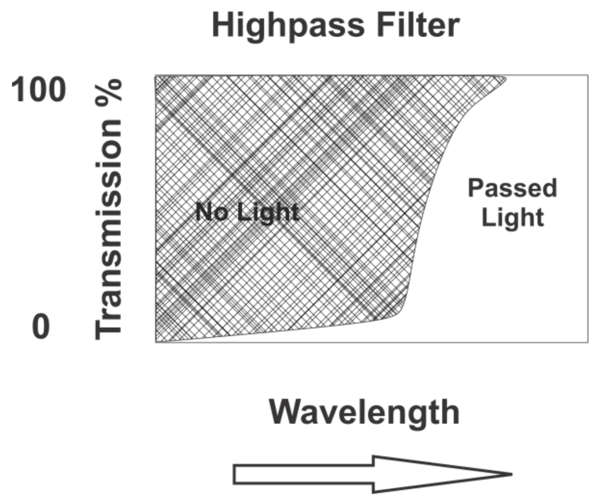
A notch filter is basically the opposite of a bandpass filter. This example refers to the degree that the filter "notches out" (eliminates) various frequencies of light.

Low Pass Filter



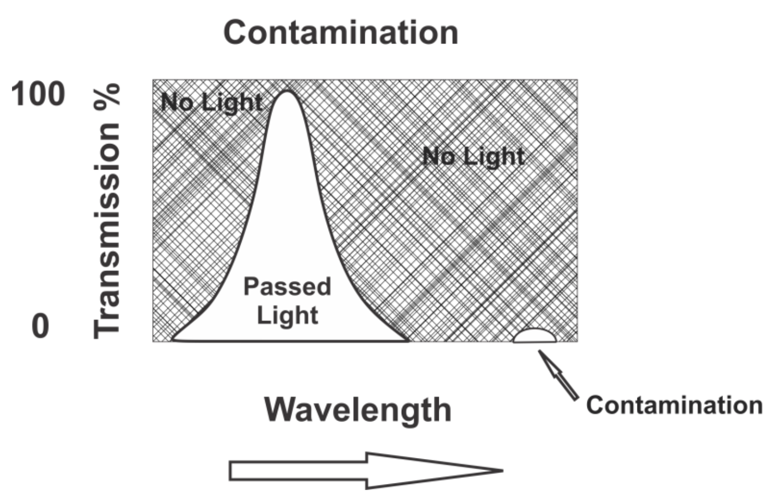
A low pass filter is simply one that passes low frequencies (longer wavelengths)

High Pass Filter



A high pass filter is simply one that passes high frequencies or shorter wavelengths.

Contamination



Contamination is some amount of light spuriously transmitted from within a rejection band. It is also sometimes called a "leak" since it leaks light when it should be blocking it. This leak may or may not affect the perceived color of the filter. This can be an advantage or a disadvantage depending on the spectral resonance you are trying to achieve in your filter design.

<u>Thermal expansion coefficient</u>

This is a measure of how the length and volume of a type of substrate changes in response to an increase or decrease in temperature.

Additive and Subtractive Color Mixing

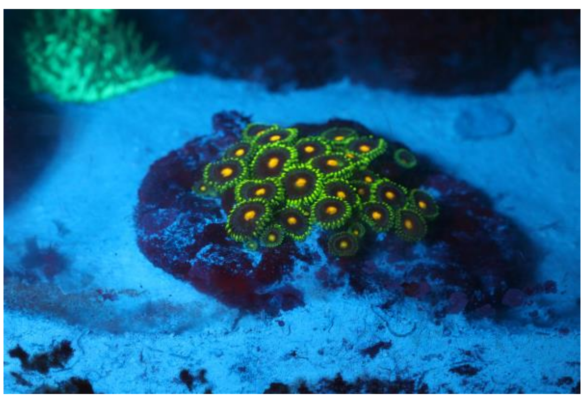
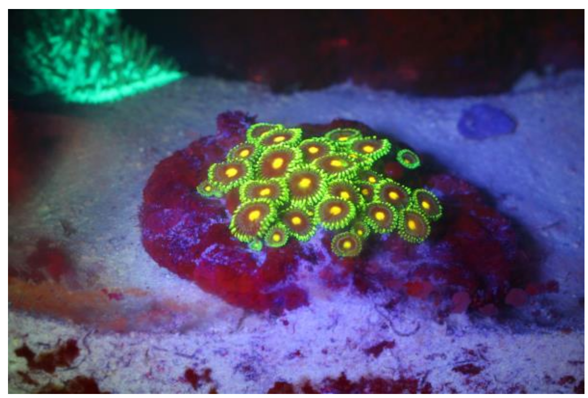
Mixing paint, where the more colors you mix the blacker (darker) the color becomes, is familiar to most people and is called subtractive mixing.

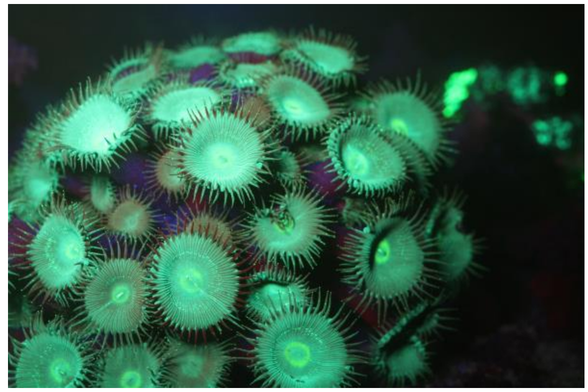
Placing a number of different color filters in one lighting fixture also results in subtractive color mixing of the light beam. As more filters are added the color progressively becomes darker, edging its way toward black as any filter placed in a beam of white light produces a particular color by subtracting all the unwanted colors from the white light so achieving a light beam of a particular color.

Subtractive color filtering is exactly why we use a dichroic filter on FireDiveGear torches. The LED's in the torch have a bandpass that needs to be filtered to "sharpen" or narrow that bandpass. This increases the brightness where we need it and maximizes the excitation efficiency of the light source thereby increasing the emission light of the target organism. This all results in greater color saturation when viewing, photographing and videoing the target.

Example Images

Now that we've slogged through the physics, what does a dichroic filter do for imaging? Below is a series of images taken with the same torch without (left image) and with (right image) a dichroic filter. *ALL* equipment, camera settings and setups are identical. A dichroic filter was simply placed in front of the blue LED torch for the images on the right.

You be the judge as to which of the images – left (without dichroic) or right (with dichroic) are more aesthetically pleasing.