Analysis of the Spectral Output Of Intense Pulsed Light Sources

One obvious benefit of intense pulsed light (IPL) systems is that the user is given access to a broad wavelength output available from the flash-lamp. Most systems produced today, by various manufacturers, use a xenon arc lamp as a light source. The normal, unfiltered output of a xenon lamp at typical application levels is between 370 and 1800 nm.

Selecting portions of the output spectra to better target specific chromophores in the skin can be accomplished through several methods, of which filtering the output of the xenon lamp is the most commonly used. There are two primary methods of filtering this output: dichroic mirror filtration and absorption filtration.

Dichroic mirror filtration has been used by Lumenis (ESC) since the inception of the Photoderm over ten years ago. The principle behind dicrhoic mirror filtration is the coating of an optical surface with a multilayer dielectric (absorbing) coating, which is designed to reflect light in a very efficient manner. In fact, dichroic mirrors can tolerate high power densities and can be designed to reflect over 99% of the incident light.

An excellent example of the use of this technology is in the articulated arms of high power, Q-switched lasers. The very short and very high peak power pulses of Q-switched lasers would ordinarily damage the reflective surfaces of silvered or aluminum mirrors. Therefore, the use of dichroic mirrors solves the problem. The mirrors in an articulated arm are mounted exactly at a 45 degree angle so that the incident laser beam hits the mirror at 45 degrees and reflects off of the mirror at 45 degrees. 45 degrees incidence plus 45 degrees reflection totals 90 degrees; the beam turns the corner or knuckle in the arm and continues to propagate down the middle of the arm. We can therefore see that dichroic mirrors are very angle sensitive.

The above example is relevant to intense pulsed light technology because it illustrates how angle-dependent dichroic mirrors are. If a single wavelength laser beam (Ruby at 694 nm or YAG at 1,064 or 532 nm) hits the dichroic mirror even slightly off angle, the reflection coefficient deviates from its nominal value, and some power is lost. For an IPL, the dichroic is designed to reflect all of the light back to its source in a certain wavelength range. If we take a look at the 560 nm cutoff filter on the Lumenis Quantum, you would assume that all of the light of shorter wavelengths than 560 nm would be reflected and not reach the skin. Actually, because the Quantum uses a dichroic mirror, which is angle-sensitive, a portion of the shorter wavelength light passes through to the skin. In other words, the coating on the end of the quartz waveguide is designed to reflect the light that hits the coating perpendicular to the plane of the waveguide (90 degrees) and reflect it directly back into the handpiece. With a laser beam (both monochromatic and very directional), this could be accomplished. However, with an IPL, you have a broad angular spectrum, so the multicolor light arrives at the coated surface at many different angles (See Figure 1) in tauge 180º vs. several minutes to a laser.

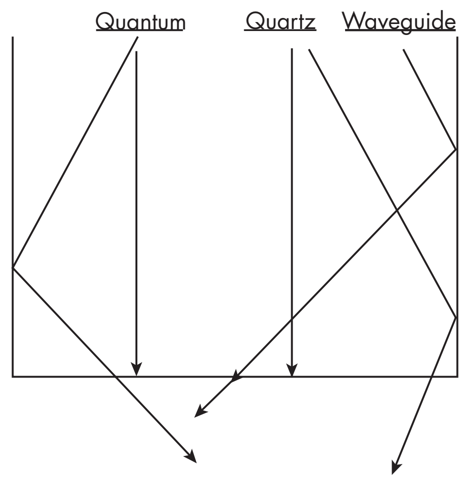

Figure 1. Quantum Quartz Waveguide

Light hitting perpendicular to the planar surface will be cut off properly. Other rays of light entering the surface after reflection off side surfaces will pass through the output surface at a different angle than that which the cut-off filter is designed for, and will have a blue coloring. You can observe the output of a Quantum and see the wavelength change as you rotate it in your hand.

While a significant portion of the light does arrive perpendicular to the surface coating, approximately 10 – 15% of the light passes through the filter and hits the skin. Therefore, the cut-off wavelength of a given dichroic filter does not, as many manufacturers claim, define a sharp boundary separating “light” from “darkness.” Rather, there is a “twilight” transitional region. The curve below illustrates how the actual dichroic “cut-off” filter works for an IPL device. (See Figure 2.)

What does all of this mean clinically? We used to attribute the “burning” side effects of the Lumenis

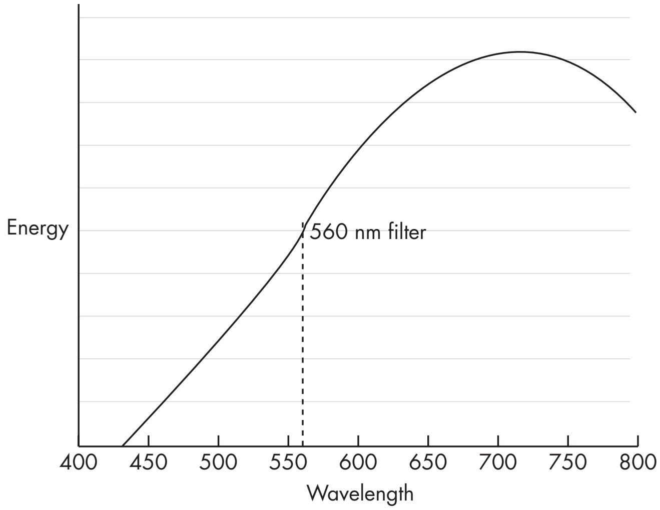

Figure 2. Wavelength Cut-off with Dichroic Filter

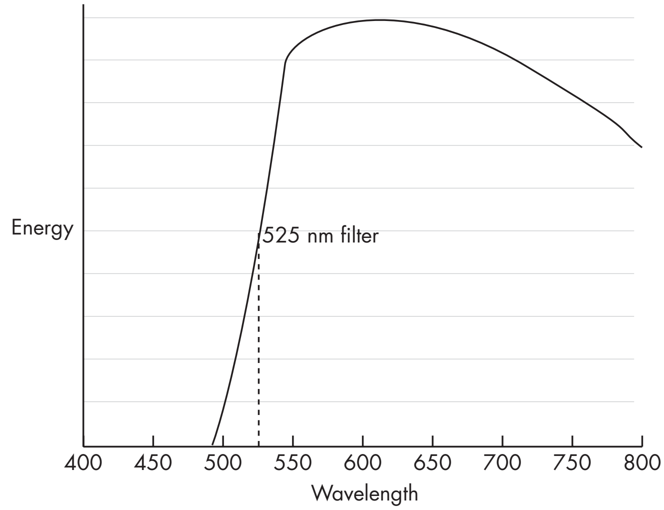

Figure 3. Palomar Wavelength Cut-off with Absorption Filter

Vasculight or Quantum to the "spiked output pulse" of the systems. Clearly, this output pulse profile does contribute to the problem, but the larger issue may be the method of filtering the output. Because they use the dichroic mirror method discussed above, they get too much "blue" light when they don't expect it. This extra blue light increases the potential for skin damage.

Dichroic mirrors are also employed by the Cooltouch Prima and the Sciton IPL accessory. Both use a "slide-in or snap-on" approach to filters for their new systems. They must be designed as dichroic mirrors for one very important reason: if a product uses absorption filters, these filters need to be actively cooled. This should be obvious because if the filter is designed to absorb light, the light energy will be converted to heat, and if the absorption filter is not cooled, it will crack in a very short time.
Prolite avoided this problem by using an absorbing organic dye to cut out certain wavelengths. However, as we know, these "gel" filters lasted less than 100 pulses before they had to be changed. The Prima and Sciton use optically coated dichroic filter glass, which also heats up and cracks if it absorbs light.

On all Lux handpieces, Palomar uses an absorption type of filter which is water-cooled (as is the lamp), to protect the system and greatly extend the handpiece lifespan. This water cooling is encompassed in the two hoses that are connected to the EsteLux and MediLux Systems. The Active Contact Cooling of the new StarLux System provides both coding of the filter and the contact surface. Therefore, any system that uses snap-on or slide-in filters may appear to have a simple idea that only requires one hand piece and just a few filters, but they will not have a sharp cut-off of the wavelength and will thus experience problems such as the Lumenis systems. See Figure 3 for Palomar's absorption "cut-off" filter technology, which illustrates the sharp cut-off and considerable selectivity of Lux handpieces.

Palomar employs both absorption and dichroic filtration in its Pulsed Light Systems. The dichroic mirror technique is used in particular in the LuxG and LuxV handpieces, where the middle portion of the spectrum is cut out to create "dual-band" hand pieces. Thus, in the LuxG the majority of the wavelength range between 650 nm to 870 nm is reflected back up into the handpiece, which in turn provides extra protection to the skin. (See Figure 4.)

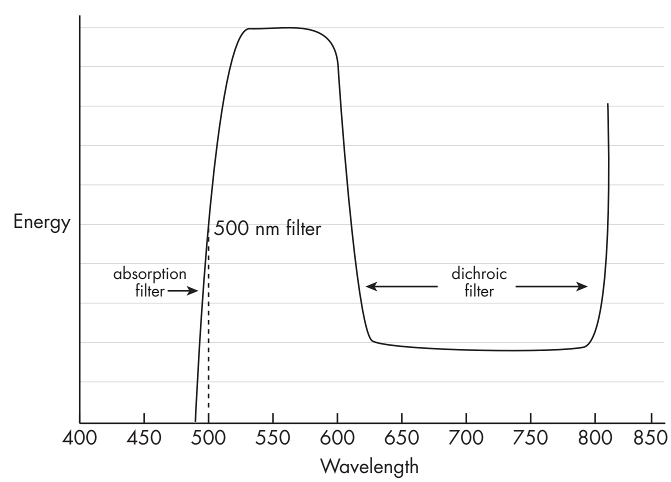

Figure 4. Palomar Wavelength Cut-off with Dual Filtration of Absorption and Dichroic Filters

It is very likely that other systems use the same dichroic technology for selecting wavelength ranges, but again all things are not equal. Properly manufactured dichroic coating can be expensive and if inexpensive, less effective coated optics are substituted, this means that the claimed wavelength ranges are really just an approximation.

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