Measuring light in the endoscopic system

A comparison of Measuring the Light Output of Medical Optical Devices using a Common Lux Meter and the EndoLume

Introduction

Intuitively, light measurement seems simple. But in reality, measuring light is one of the trickiest measurements there is. From spatial variation, to color (wavelength) content, to background "noise" (reflections, etc.), optical light measurement is a very complicated topic. And the human eye, with its built-in automatic gain compensation (our pupil), is one of the worst tools there is!

This paper will introduce and compare two common methods of measuring the quality of light output from medical devices such as Xenon light sources, fiber optic cables, and endoscope illumination bundles.

Types of Light Measurement

We'll start with some basics. Light measurement falls into two broad categories: Radiometric and Photometric. Radiometric measurements treat all wavelengths (colors) equally, while photometric measurements attempt to measure light with the same color sensitivity that the human eye has. Naturally, for imaging applications such as endoscopy, photometric measurements are preferred.

Each of these broad categories can be further broken down into two more specific categories of light measurement: Power and intensity. Power is the total "flow" of light from a source and is similar to gallons per minute of flow from a garden hose. Intensity is the light power output spread out over an area. This measurement is similar to the pressure in the flow from that same garden hose and can vary significantly depending on where in the "stream" you measure it. However no matter what the spray pattern of the hose looks like, it doesn't affect the total flow through the hose. The common units of visible (photometric) power are lumens and of visible intensity are lux (lumens per square meter).

Measuring Power versus Intensity (Lumens versus Lux)

Intensity meters, such as lux meters, are the most commonly encountered light measurement tools. This is primarily due to two factors. First, by definition intensity is a sampling measurement. Therefore, assuming that the light you're measuring does not vary sharply over the size of the probe, you can get a reasonably accurate intensity reading any place that you can physically fit the detector head. (This is usually true for environmental measurements, but not so for medical optical devices.) Second, the most common reason to measure light output is for imaging, whether by the human eye (e.g. – determining the quality of workplace lighting) or for photographic purposes. Both of these applications are sensitive to the intensity of the reflected light in a scene.

To measure light power with a lumen meter (also called a photometer), you must gather ALL of the light from the light source. In most situations we encounter, this is not possible. (Imagine trying to measure the total light power from the sun!) However with medical optical devices (e.g. – a light cable), this is not only possible, it is preferred. By measuring the total power input to a device and then the total power output, you can easily and repeatably determine the condition (efficiency) of that device.

Measuring Optical Medical Devices

We'll demonstrate how these different methods work with a couple of example case measurements…

Example Case 1: Measuring a Light Source

One of the most common causes of a dim image complaint by a surgeon is a fading Xenon bulb. When using a lux meter, measuring the intensity of a light source output depends very highly on the type of cable interface fitting used. For example, the light source in Figure 1 has a rotating turret interface which includes fittings for the most common manufacturer cable styles (Wolf, ACMI, Storz, and Olympus). The design of each fitting differs significantly from one another. This variation can cause significant differences in the measured output when using a lux meter. However the optical bridge of the EndoLume power meter was designed specifically to accommodate this situation.

The data chart in Figure 2 shows the results of measuring this turret equipped light source using a high quality lux meter and recording the light intensity in front of each of the 4 turret fittings. The variation from one turret fitting to the next varied more than +/- 60% around the average of the four readings. The output from the same light source and fittings was then measured using the EndoLume power meter. Figure 3 shows that the variation from one turret setting to the next using the EndoLume power meter was only +/- 4% around the average of the four readings. Testing with other brands of light sources indicates that much of the variation measured by the EndoLume is likely due to variation in design of the turret fittings. So while a lux meter won't even allow you to make consistent measurements of a single light source output, the EndoLume is accurate enough to experimentally determine the quality of your light source's turret design.

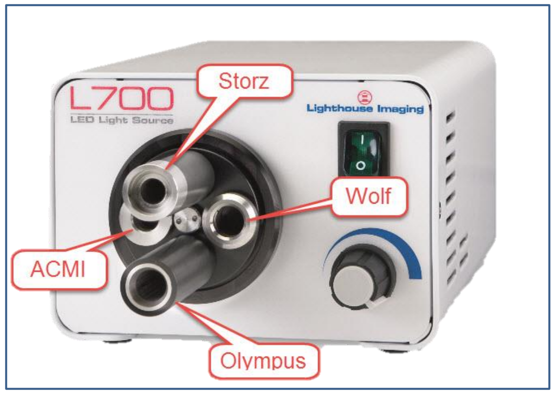

Figure 1

Lux Meter		
Fitting	Lux	Dev Avg
Wolf	215000	53%
ACMI	224000	60%
Storz	51000	-64%
Olympus	71000	-49%

Figure 2

EndoLume		
Fitting	Lumens	Dev Avg
Wolf	1450	4%
ACMI	1340	-4%
Storz	1340	-4%
Olympus	1440	3%

Figure 3

Example Case 2: Measuring a Light Cable

Unlike testing a light source, where you wish to measure the total power output of the device, with a light cable (or with an endoscope), what you are really interested in is the ratio of light output to light input. This is known as the transmission efficiency of the device.

$$\text{Transmission Efficiency (\%)} = \frac{\text{Light Output}}{\text{Light Input}} * 100$$

The reason you must first measure the input power is because the measured output power of the device being tested depends not only on the quality of the device itself, but also the quality of the light input source. A very strong input source will create a stronger light output than a weaker source. This of course makes perfect intuitive sense, however it is also where measuring intensity using a lux meter may lead to false interpretation.

In Figure 4 we see the results of measuring the output of a universal cable and comparing it to the input to the cable using the various turret fittings with a lux meter. Here we see that the "efficiency" measurement comparing the output to the input varies wildly. In fact, for several of the measurements, the light intensity is actually as much as two times ***higher*** at the output of the cable than at the output of the light source. This suggests that the light is made ***stronger*** by going through the cable! A physical impossibility!

Lux Meter Input	120000
Fitting	"Efficiency"
Wolf	56%
ACMI	54%
Storz	235%
Olympus	169%

Figure 4

In Figure 5 we see the same measurements made using the EndoLume. With the EndoLume, the efficiency measured is virtually constant, varying by less than +/- 2%, no matter which brand of fitting is used with the universal cable.

EndoLume Input	437
Fitting	"Efficiency"
Wolf	30%
ACMI	33%
Storz	33%
Olympus	30%

Figure 5

What is also not reflected in these data sets is the sensitivity of the lux meter to alignment. Both the light source and the light cable lux meter data presented here are taken by maximizing the lux reading while "adjusting" the alignment of the lux sensor to the input source. With the EndoLume, there are no adjustments or variations. You simply choose the correct fitting and connect the parts together.

So while in theory you can use a lux meter to measure light source output or cable efficiency, the process is difficult at best and may lead to false interpretation. Any variation in the technique used, from the brand of fitting chosen to the way the detector is held, can make significant changes in the resulting data.

With a specialty medical power meter such as the EndoLume, you simply follow the clear and concise instructions and get quick, simple, and repeatable data with which you can make informed decisions regarding the condition of your light sources, light cables, and endoscope illumination bundles.

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