Out of the Wood

BY **MIKE WOOD**

Lumen measurement, yet again . . .

I HAVE NO APOLOGIES for bringing this topic up again. It's really only the third time in 12 years, so I don't feel too guilty. I was walking around LDI this year and it struck me that we were reaching a plateau in technology with white LED, dichroic color, automated spot luminaires. Every company had at least one, many of them on their second generation, and they all had pretty much identical feature sets. Of course, I exaggerate slightly, but it seems to me that we are very rapidly reaching the same point with white LED based automated spotlights that we did 15 years ago with discharge lamp versions. That is, the product became commoditized. Every manufacturer's product could do the job, some better than others, of course, but basically everyone was at a similar technological level. At that point, other than price the only differentiator becomes brightness. That indeed seemed to be the case at LDI, every manufacturer was touting more lumens. (*Before you start writing to me, and saying that the units have different feature sets, yes, that's true. However, every light has the core features of gobos, color, iris, zoom, and focus, with maybe framing shutters thrown in. After that it becomes which special effect you like best, and those are arguably transitory.*)

> **" Leaving aside any questions of 'marketing' lumens, there are still many legitimate ways the measurements could be taken and give you different results. "**

However, what isn't the same between all those manufacturers is how they measured the lumens they are selling. Leaving aside any questions of "marketing" lumens, there are still many legitimate ways the measurements could be taken and give you different results. What's an informed potential purchaser to do?

And, it's not just at a trade show. Go to any lighting shootout and you'll nearly always see a row of luminaires, all pointed at a white wall or cyc. There'll also be someone with a light meter, measuring the output at that wall. They usually only measure one point, the center of the beam. There's no doubt that a single center beam measurement has some use, a camera will need to be adjusted for that light level as it falls on the performer's face, and it gives you a reference point for how bright the luminaire is. However, it's only a very small part of the story. That single measurement tells you nothing about the light spread of the luminaire, and how the light is distributed across that spread. There is a general misconception that everything must follow automatically from that single illuminance measurement. Well, it doesn't. Different luminaires can have the same center output but appear wildly different. Some are peaky, some are flat, and others may have a hole in the center. The size and shape of the beam is as important to how bright the luminaire appears as the footcandle or lux level in the center. You need to know the total output of the fixture as well as the illuminance profile; both are important to understanding the performance.

> **". . . lumens reported by an integrating sphere will always be higher, in some cases significantly higher, than that reported by other methods. "**

Let me recap with a figure from one of my earlier articles on this topic. Take a look at **Figure 1**. This figure illustrates three possible light beam profiles: "A" is a hypothetical perfectly flat beam, "B" is a peaky distribution often seen from ellipsoidal luminaires, and "C" has a small dip in the middle and straight(ish) sides that is a distribution sometimes seen in Fresnel and other wash units. Each of the three beam shapes has exactly the same center level reading, as indicated by the red dotted line. This means that a light meter would read the same for each fixture when placed in the center of the beams at points a, b, and c respectively.

However, that center illuminance (measured in footcandles or lux) doesn't tell us how much light in total is coming out of the unit. To do that, you have to add up the illuminance readings over the whole beam. We can make a good analogy with buckets and water. The second row of **Figure 1** is the same as the first but with the light profile curves turned upside down to make U shapes. The final row takes that U and rotates it to make a bucket. The flat beam, A, gives

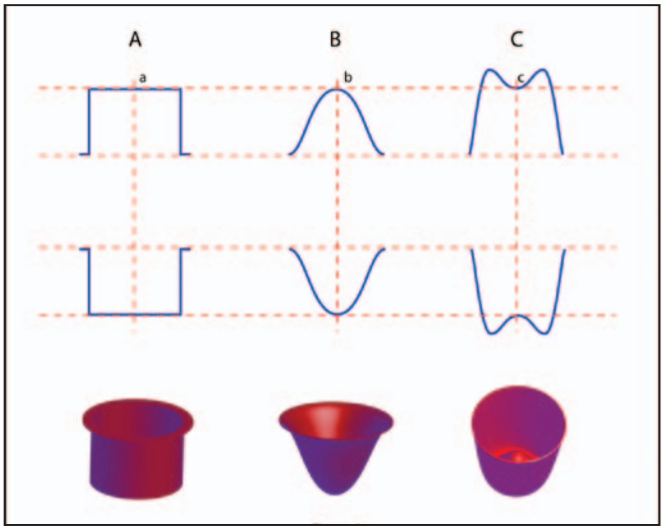

Figure 1

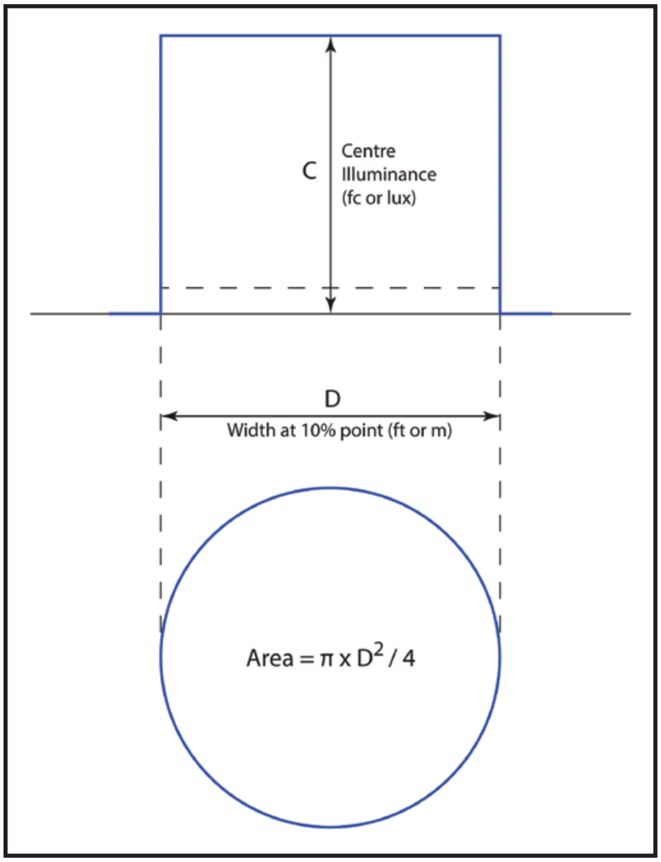

Figure 2 – Perfect light beam

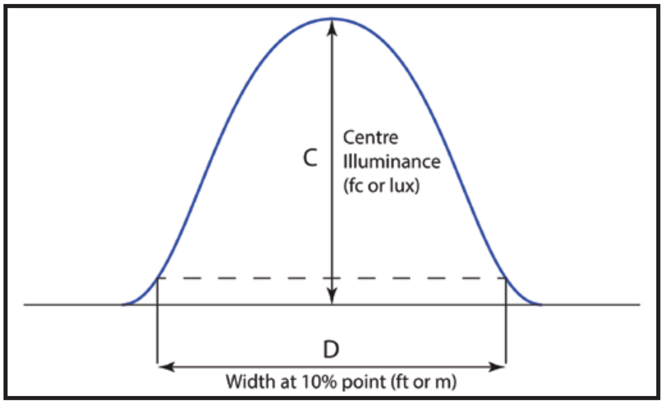

Figure 3 – Real light beam

you a cylindrical, straight sided bucket while the other two give more complex shapes. If we were to fill these imaginary buckets with water, the amount of water each one holds is analogous to the total lumen output of that fixture. It's clear that bucket A would hold more water than bucket B, for example. Remember, lumens are a measure of the total amount of light, not its intensity, so a very wide, shallow bucket might hold the same amount of water as a narrow, deep one. Similarly, a very wide dim luminaire might actually output just as many lumens as a narrow bright one—it's just that those lumens are spread out over a wider area. (*ESTA Standard* E1.9 Reporting Photometric Performance Data for Luminaires Used in Entertainment Lighting *could help you here. If data for the luminaire is reported using this standard, then there will be an iso-illuminance diagram which will show you the beam shape.*)

If our light distribution were to actually look like A (and no real light does) then calculating total lumens is simple. We just need to work out the total area of the beam and multiply by the illuminance. **Figure 2** shows what this looks like.

With a round cylinder like this the math is simple: the area of the circle is π times the diameter squared, divided by four: $A = \pi \times D^2 / 4$. The total lumens is the center illuminance times this area or C x A.

If we substitute in some real values we can check this out. Let's say the luminaire has a diameter of 6' at a throw of 10', and the center illuminance is 200 fc.

Total lumens = $\pi \times 6^2 \times 200 / 4 = 5655$ **lm**

The units are important; lumens themselves are the same in both US and Metric Units, but the quantities you measure to derive them have to be consistent to get the right result. If you measure the radius and distances in feet then you must measure the illuminance in footcandles. Measure in meters and you must use lux. Either way you will get the same answer in lumens.

Total lumens are unaffected by throw distance. If the original data is good, it should give the same answer, or close to it, for any throw.

Now we have the absolute maximum value possible for the total lumens of this light: 5,655 lm. In reality, the output beam won't be completely flat, so this figure will be reduced. But by how much? **Figure 3** shows a possible situation.

We can still get values for C and D, but the total volume in our sloping sided bucket will be less than that of the perfectly straight sided, cylindrical, one. We also have to decide how far out we go. Where does the beam end? It's common in our industry to report field lumens, which are the lumens within the points where the light has dropped to 10% of its center value. However, some companies report cut-off lumens, which is light to the 3% point, while still others report total lumens where they capture every photon of light they can and report it as part of the output. How do you know which is which?

We can work out some theoretical reductions in the output if we assume the distribution is a true cosine curve. For example, a cosine curve from a profile spot where the edge brightness is one third of the center brightness (a center to edge ratio of 3:1) would have a total field lumen output of 65% of that of the flat beam. Just to complicate things further, most fixtures are not true cosine curves. Wash lights, in particular, can be peakier, which reduces the output even more from the flat field, perhaps by a further 20%.

Clearly just taking a center beam measurement isn't the best way to go. It gives us a rough idea, but we could still be significantly in error. What we need are methods for accurately measuring the total output of a luminaire. There are sophisticated systems available using digital cameras from companies like Radiant Imaging. There are also systems using an integrating sphere to capture the light. Finally, the architectural world likes to use a device called a photogoniometer where the light is rotated so that the distance to the measuring device remains constant (as opposed to a flat wall system where the edges are further away from the light source than the center). All these systems are in use in our industry; some manufacturers use the camera method, while others use integrating spheres. These methods are all accurate in their own way, but actually measure different things. It's important to understand why and how they might differ.

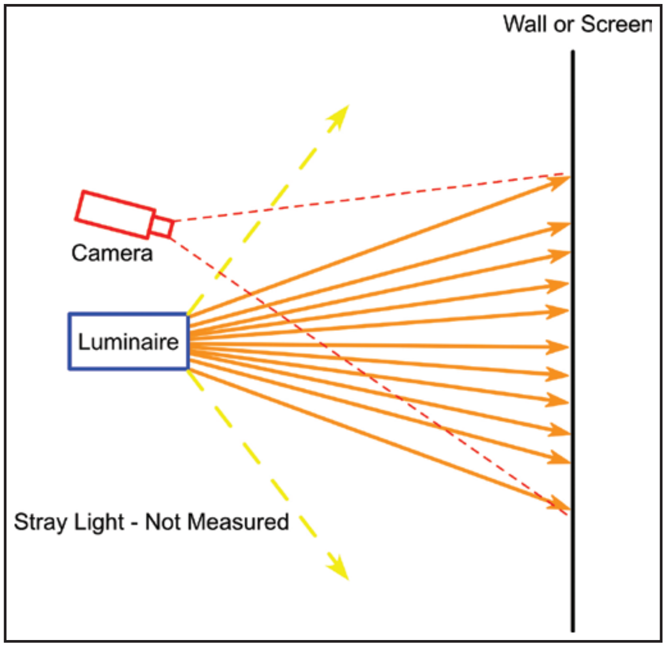

Figure 4 – Camera system

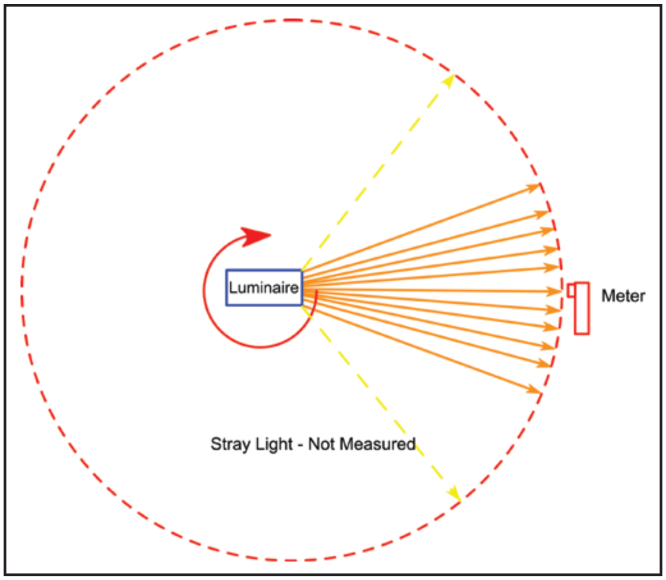

Figure 5 – Photogoniometer

The camera and photogoniometer methods (or other methods where the light is directed onto a wall or screen and many readings taken in a grid over the entire field) rely on taking hundreds, even thousands, of illuminance measurements over the whole field and then summing them to get the total. These methods are a very good indication of what the user will actually see as they mimic the real world very well. They are however, fairly expensive systems to purchase and complex to set up and keep calibrated. They need a dedicated dark space and are therefore tricky to use as part of a production line.

Much less complex are integrating spheres. An integrating sphere is a large hollow sphere, coated internally with a white, perfectly diffusing surface. The luminaire can either be placed completely inside the sphere, or, if it won't fit, the output lens is inserted into the sphere though an aperture. In either case, the light from the luminaire bounces around the inside of the sphere, and, as the name suggests, gets integrated into a completely even illumination over the inner surface. A second small hole can then be used to take an

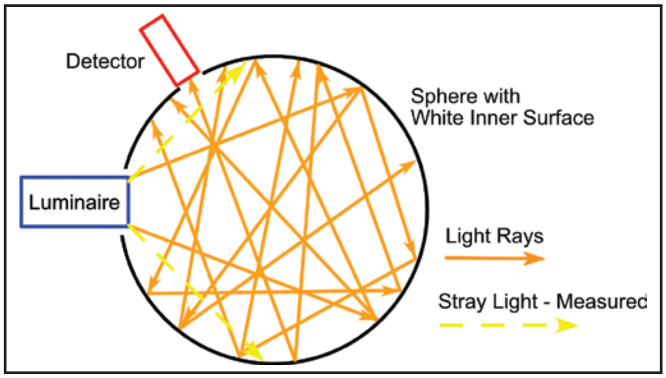

Figure 6 – Integrating sphere

illuminance measurement. Because we know that the illumination within the sphere is the same everywhere, we can use that single measurement with the surface area of the sphere to calculate the total lumens of the light source. The problem with this method is that it truly measures ***all*** the light emitted, even that light that is really spill light outside the usable beam. It doesn't measure just the field lumens value where the light is useful.

Because of this, the lumens reported by an integrating sphere will always be higher, in some cases significantly higher, than that reported by other methods. Don't be misled by this. Just because a sphere captures the light doesn't mean it's useful light. The sphere cannot distinguish between light in the beam and wasteful spill light.

Now we have some more information, let's go back and take a look at what our shoot out might actually look like. **Figure 7** shows what we might see on the wall. Three lights, all hard focused, all in open white.

This image was created on a computer, so it was possible to adjust levels so that all three beams here have exactly the same total lumens. The image on the left is a peaky beam, that in the middle is a flat beam, while the one on the right has a bright edge and a darker center. Which one do you pick? To my eye, the one that looks "brightest" is the beam on the right. The bright edge gives it high contrast with the surrounding area. To the meter measuring center illuminance, then the left beam with the hot spot will win. However, if you are doing gobo projection, then you might want the one in the center. The difference becomes even more obvious if you add in some ambient lighting.

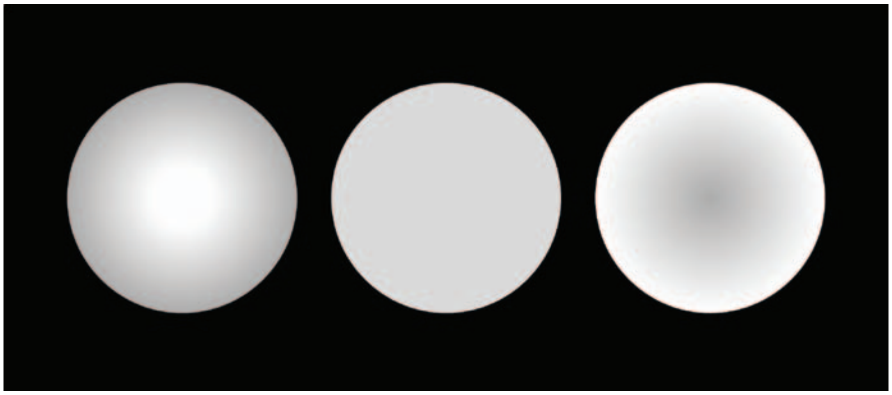

Figure 7 – Equal lumens

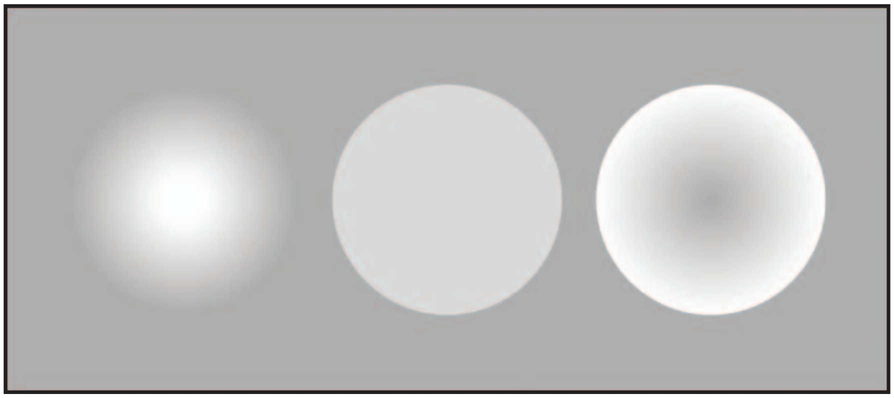

Figure 8 – Equal Lumens with Ambient Lighting

Now the beam with the hole in the center really stands out, while the one with the hot spot gets dimmer and the flat beam looks a lot better than it did before.

The message to take away here is that a shoot-out on a white wall is pretty much useless. Your eye is fooled too easily, and it tells you nothing about how the light will perform in a real situation. Look at total lumens, look at center illuminance, but most importantly look at how the light performs in a real situation on a real stage. Numbers are good on a datasheet but don't come close to telling you the whole story. Chasing lumens alone doesn't necessarily make for a good light.

The truth, as it often is in life, is *caveat emptor*. The buyer should beware and make sure that they understand what is actually being measured when a manufacturer reports total lumens. First, are they the lumens of the luminaire not the light source? (Yes, some manufacturers still report light source lumens, not luminaire lumens). Secondly, are they useful lumens? Do they represent what I can use on my stage or on my set, or does the figure include useless spill light? Ideally the figure should be field lumens, as that is the figure that best represents the useful light.

Now, at last, you should be in the best position to really judge the output of a luminaire; you know the total field lumens, you know the light distribution, and you know the center illuminance. With those three pieces of information you can make an informed decision. ■

Mike Wood runs Mike Wood Consulting LLC, which provides consulting support to companies within the entertainment industry on product design, technology strategy, R&D, standards, and Intellectual Property. A 40-year veteran of the entertainment technology industry, Mike is a past President of ESTA and Co-Chair of the Technical Standards Council. Mike can be reached at mike@mikewoodconsulting.com.