PHILIPS

White paper

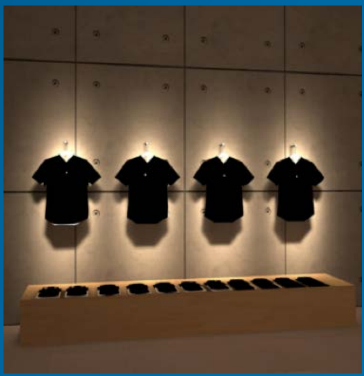
Quality of Light in Fashion

How to **attract and engage** your shoppers?

The effect of lighting beyond specifications

Nowadays, Quality of Light is often positioned as a key differentiator in retail fashion lighting. Correctly lighting a fashion area requires, among other things, comparison of specification sheets on Quality of Light criteria such as CRI and light output. This white paper addresses a potential omission in these specification sheets, namely luminaires with the same values for Quality of Light criteria, yet which give lighting that is radically different when perceived in terms of color and distribution.

Let's imagine a fashion retailer who is comparing specification sheets for spot lighting and has come across the Philips TrueFashion portfolio including Fashion Proof Optic lenses. He or she will probably first inspect the color temperature, followed by the lumen package, beam angle and efficiency, as well as color rendering index. However, the practical meaning of these metrics is not particularly clear for everyone. In many cases these specifications are similar, yet the effect of the light in terms of color and distribution may differ quite radically. This is illustrated by Figure 1.



12° lenses

12° reflectors

Figure 1, above: Comparison of two sets of optics, both with 12D beam angles. Top picture: Fashion Proof Optics which focuses the light in spot without halo, thus increasing intensity by up to 30% and contrast by up to 100%. Bottom picture: reflector optics which always have a core with halo (spill light).

Figure 2, right: comparison of three LED flavors with standard 930 spectrum. All products have the same specifications (CRI 90, 3000 K and 2700 lm) yet different color perceptions.

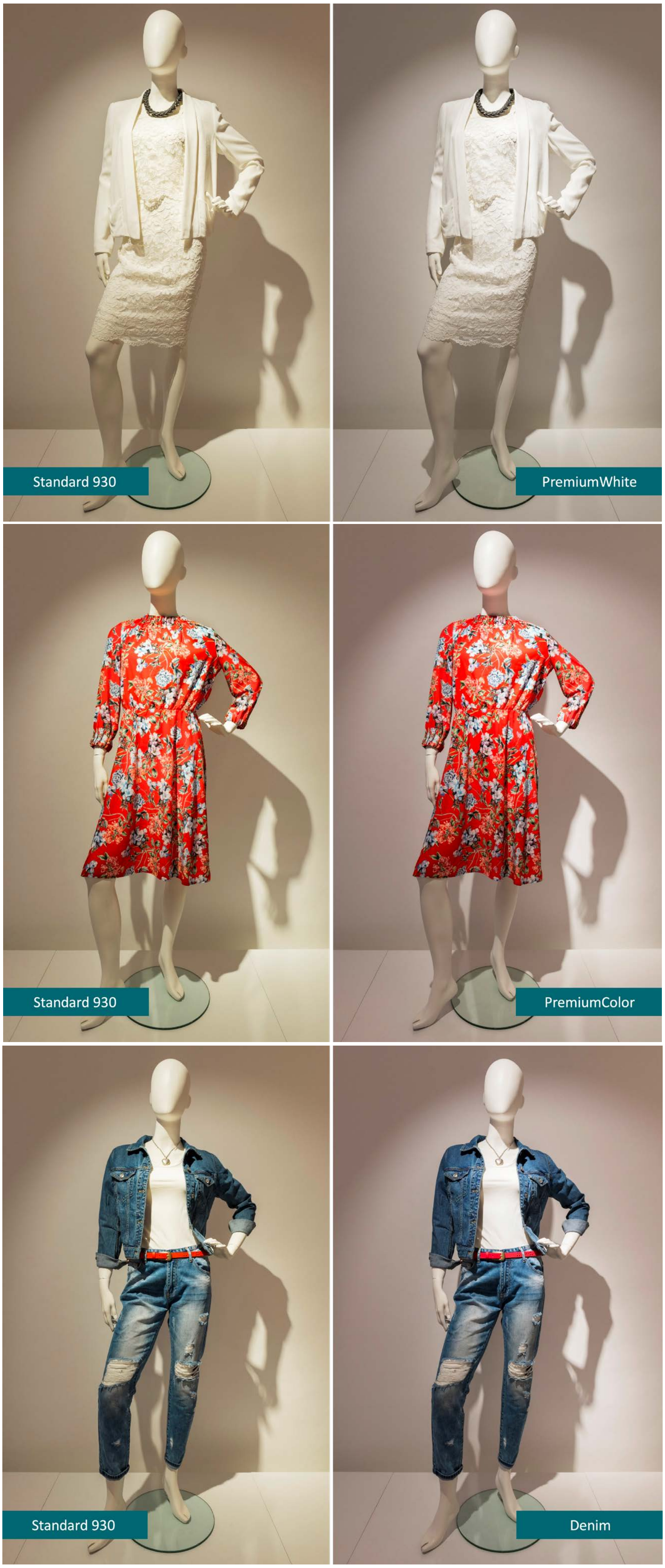


Figure 2 compares three LED flavors: 930 vs. PremiumWhite, 930 vs. PremiumColor and 930 vs. Denim. Obviously, the LED flavors differ in the effect they have on the fashion items and the surround; PremiumWhite and PremiumColor transform the yellowish dress and dull red dress under 930 into a bright, white dress and a vibrant red dress, whereas the Denim flavor creates a much truer and bluer denim look. Their specs however, i.e. color temperature and CRI, are the same.

The same goes for Figure 1, which shows two fashion walls lit with projectors, whereby the architecture uses Philips Fashion Proof Optics lens (see 12˚ lenses) and below is reflector based. (12˚ reflectors) (See also separate part beam shaping LED architectures).

The beam angle and light output of both architectures are the same, yet here again the appearance is quite different, both in terms of brightness and spot size.

In both examples similar specs results in distinctive light effects, so how can we express this in terms of Quality of Light? Yes, seeing is believing, but we also need to be able to convey the meaning of the added value of our products. How do the Philips fashion portfolio options distinguish themselves from each other and ensure superb quality?

Let's dive a little deeper into the relevant color and beam quality aspects in fashion!

Seeing and describing light

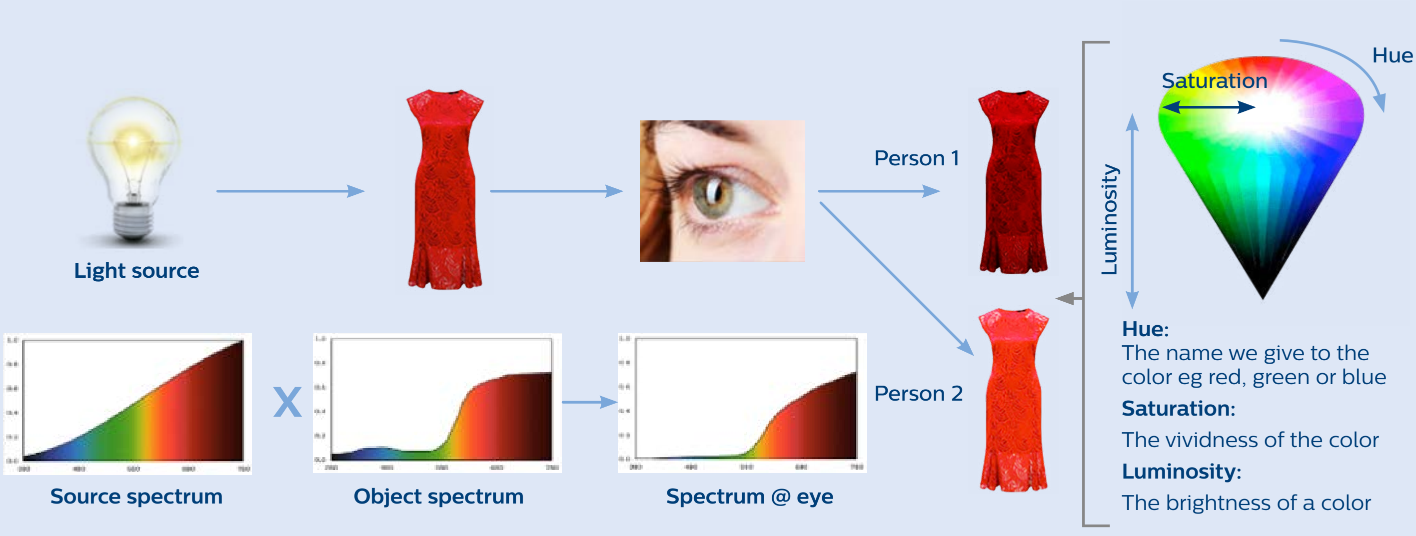


Figure 3: The way in which we perceive the world around us is determined by several factors. Light coming from a light source (e.g. an incandescent light bulb) is reflected by objects (e.g. a red dress) and perceived by an observer. How we perceive the dress depends on the composition of the light source (called the source spectrum or spectral power distribution; SPD), the reflective properties of the dress, and lastly the properties of the human visual system. How we describe this object, e.g. a red dress, is determined by the hue (in this case red), saturation (e.g. highly saturated, or more pastel-like) and the brightness (luminosity) of the reflected light.

Fashion is all about **colors!**

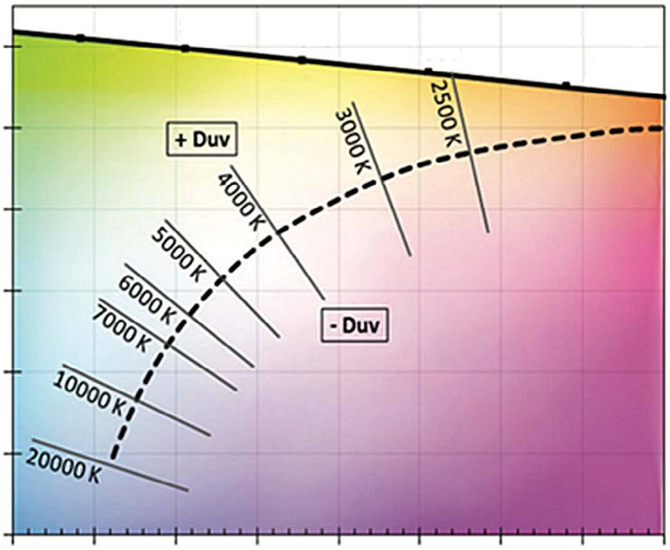


Figure 4: Color space with blackbody line.

White appearance

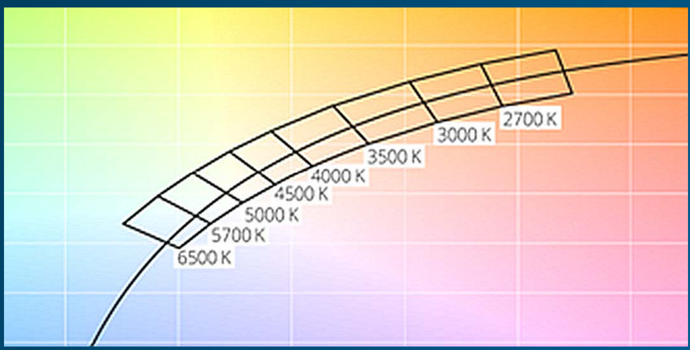
The color temperature (CT), in its most basic form, tells us something about whether a light source is experienced as warm (reddish white) or cold (blueish white). The origins hereof can be found in incandescent lighting, where a metal filament is being heated to a temperature, and then emits light with a certain color. A filament temperature of 2000 Kelvin will be quite reddish, whereas a temperature of 10,000 Kelvin will be quite blueish. If we were to heat this filament from 2000K all the way to 10,000K and plot all the corresponding emitted colors in a color diagram, we would get a line, called the blackbody line (BBL), as shown in figure 4 (dashed line). Here it is important to realize that all points on this BBL are considered to be white light.

An interesting phenomenon occurs when we are in an environment with a particular CT. Within a minute our visual system adapts to this CT, making us perceive the light as a neutral white [1]. This means we mainly perceive a CT when we change our environment, for example, entering a fashion store where the CT is 3000K from the street where the CT is 6500K. Upon entering the store, the light in the store seems very warm and cozy compared to the light outside.

However, our visual system quickly adapts and then we perceive the light in the store as a neutral white again. Upon exiting the store, and going to a higher CT, the process again takes effect and the light outside will appear to be very cold.

However, with the onset of new lighting technologies, such as LED, we are able to generate light that does not lie on this BBL. Research [2] shows that if we dip below this BBL just a bit, the light is experienced as more white. Now, a pessimist might say that for the last 200 years or so we have been doing things wrong, producing light that is not as white as it could be. However, an optimist might recognize the opportunity to create light sources with a higher Quality of Light that produce an optimal white!

This is exactly the reason why most of our LED flavors are a bit below the BBL: for whiteness optimization! Knowing exactly how far to go below the BBL is where Quality of Light comes in. Going back to figure 4, colors that are not on the BBL but along the lines perpendicular to the BBL are correlating with that particular color temperature (meaning they have the same value); hence the term correlated color temperature. The distance from the BBL is captured by Duv (pronounced delta-u-v): the larger the Duv, the larger the deviation from the BBL and the greater the difference in color - yet at the same color temperature!



LED binning

LEDs tend to be similar but rarely identical due to variations in LED manufacturing process. Hence, led binning is introduced to standardize the match between LEDS with respect to their color, lumens and voltage, making the production process more efficient and the end product more attractive for the attractive for the consumer. The ANSI standard defines bins around the BBL for each CT in a color diagram to limit the spread in chromaticity coordinates to match CCT and Duv. We subdivide the bins into smaller bins to gain more similarity between their LEDS and a higher quality, though at the expense of production costs.

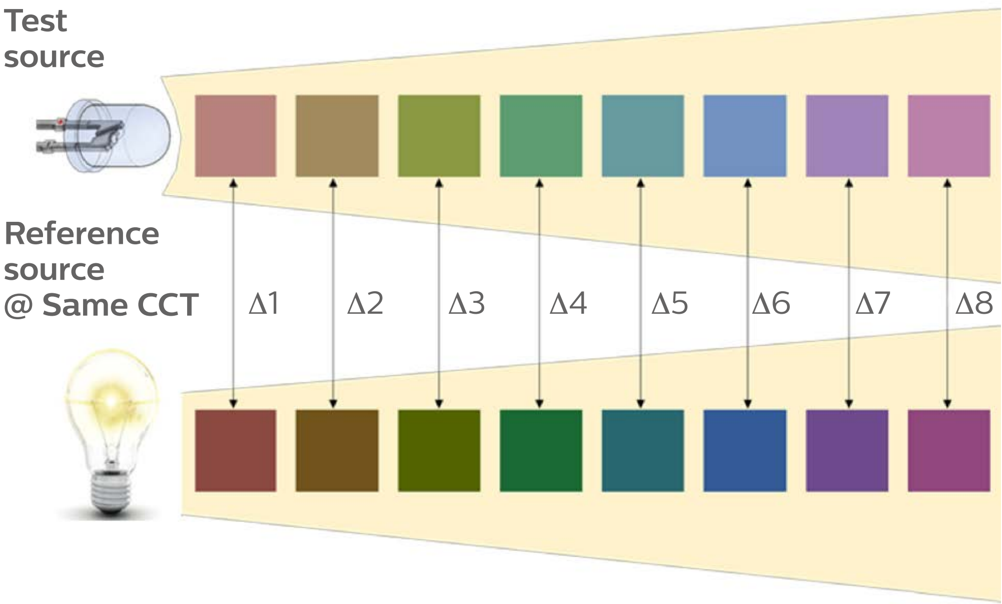


Figure 5: Color Rendering Index base.

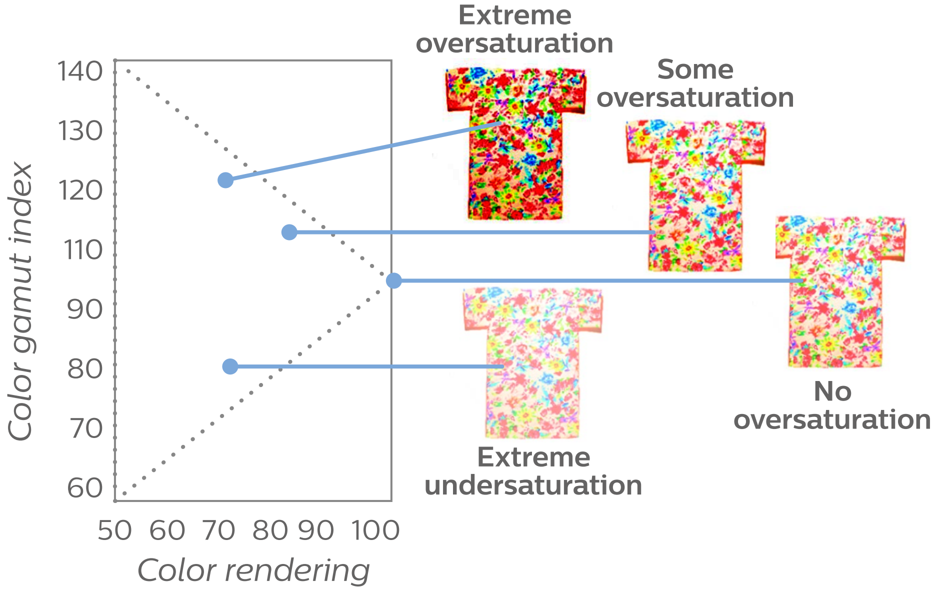
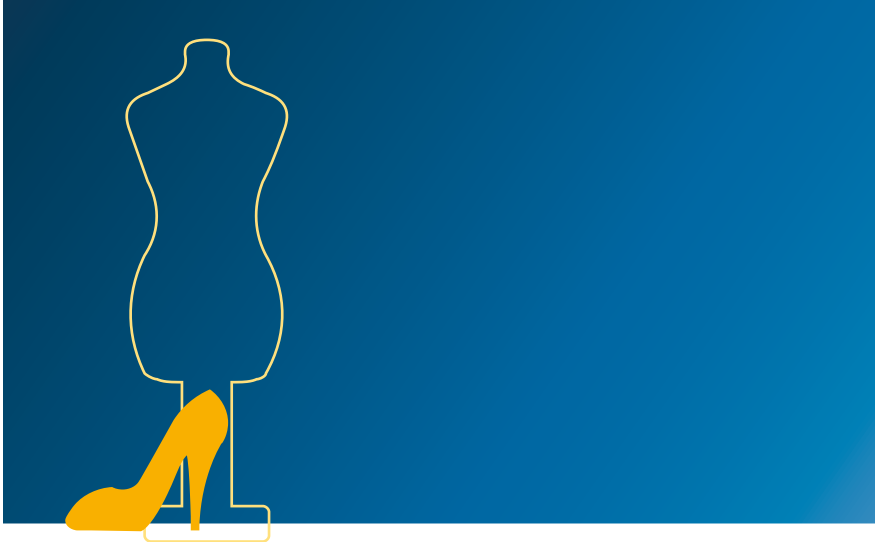


Figure 6: Color Rendering Index vs. Color Gamut Index.



Color appearance

We now understand why a particular light is perceived to be whiter than another with the same color temperature. In fashion, whiteness is only part of the story: fashion is all about colors! CCT and Duv alone are far from sufficient to describe color appearance. Actually as visualized in figure 3 we need to have a look at the spectrum of a source. For example, if we replace the incandescent bulb in the figure with a LED source without any red in the spectrum, the red dress cannot reflect red and we cannot perceive red! This offers huge flexibility, especially using LED technology, where we can fine-tune spectra. However, this requires yet another metric to express the extent to which colors are rendered properly by a specific light source: the **color rendering index (CRI)**. Most people in the lighting business will have an idea what CRI means, but it is important to realize how it is calculated in order to understand what CRI actually is (and what it is not).

The CRI is exactly what we just outlined with the dress example: a quantification of the color difference between a test and a reference light source based on how they render eight specific colors as visualized in figure 5. Additional samples were later added to quantify more saturated red (R9) and skin tones (R13), but these additional colors are not part of the CRI definition (the CRI number on product data sheets do not say anything about R9-R13). A common misunderstanding about CRI is that it says something about consumer preference: with LED technology we are able to create one light that is preferred over another, even though the CRI is significantly lower. What the CRI does tell us is how well a light source shows colors, compared to a reference light source with the same color temperature. This reference light source is incandescent or halogen in most fashion applications (and it's a whole other question to what extent one wants this in fashion stores). The closer the values are to 100 the more closely the light will resemble the reference source.

Hence, a light source with a CRI of 90 only indicates a difference in color rendering relative to the reference source, and is not informative as to the direction of the difference, i.e., whether object colors will appear, on average, more or less saturated.

To tackle this problem, the **color gamut index** (CGI) was introduced, which indicates the direction of the average color change [3]. Similarly to CRI, a color gamut index of 100 indicates no difference with the reference source, whereas values greater than 100 indicate more saturated colors, and values smaller than 100 indicate that colors will appear, on average, less saturated (see figure 6). It is a misunderstanding that the higher the CRI/CGI combination (or even worse, the higher the CRI), the 'better' or the more preferred a given light source is. Choices made in this CRI/CGI balance are often application dependent, although there is a range to play in when maintaining a proper degree of naturalness, which is key in fashion. For example, a slight oversaturation of colors results in a more preferred color appearance, yet can only be accompanied at lower CRI values and has a small efficiency penalty. In fact, with LED lighting technology, it is possible to create a low CRI light source (e.g. CRI equals 70 or 80) that looks fantastic in fashion applications.

The exact details go beyond the scope of this brief overview, but it is good to remember that high CRI is not a goal in itself. The best advice to give is to simply take a line-up of LED flavors (including 930) and observe the effect on clothes/fashion collections.

Experience the **intensity**

Light output and contrast

It is key for fashion applications to generate the right amount of light and to create accents in the shop that steer attention. The amount of light or brightness is specified by the light output. For light output we always communicate the **total light power**, which is expressed in lumen and indicates the amount of light that a luminaire emits in all directions. Lumen is a so-called photometric unit, which means it takes into account the sensitivity of the eye to different parts of the spectrum. In practice this means that the number of lumens differs between low and high CCTs when powered by the same electrical power, e.g., 2 Watt.

Communicating the total light power makes most sense for luminaires with a wide light distribution, yet it is known from research that for spots with a narrower light distribution the total light output is a poor predictor of brightness. This makes sense: distributing the same amount of light over a small area makes it brighter than over a larger area, yet the amount of lumen does not change.

Figure 7 shows two projected beams with the same CBI and similar perceived brightness.

To be considered an accent, light illuminating an area must be at least three times as bright as the ambient. This introduces the **accent factor** (also referred to as **contrast ratio**), basically indicating the brightness of what you are illuminating versus the brightness of its immediate surroundings. It is not very well defined, and it is good to note that under field conditions, luminous contrast is also influenced by other factors such as the surroundings and the adaptation of the eye. An accent factor of two refers to an accent which is twice as bright as its immediate surroundings and is roughly the threshold for noticeable contrast. For a truly theatrical effect, an accent factor of fifteen is necessary. Effects such as these are relatively easy to create by combining multiple projectors or by proper design of the architecture of the luminaire (see separate section *Beam shaping LED architectures*) see figure 9.

Hence, for narrow light distributions (also see next section) we communicate the beam intensity, which means the amount of light in a certain direction, which is expressed in Candela. The central intensity of the beam (CBI, Center Beam Intensity), most often the maximum intensity of the beam, correlates very well with perceived brightness.

Beam 1 **Beam 2**

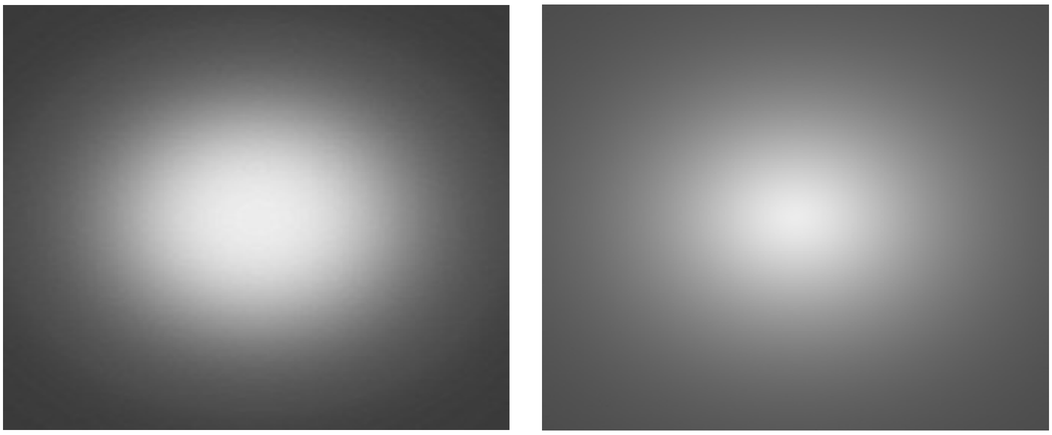


Figure 7: Two projected beams with same center beam intensity (CBI) and full width half maximum (FWHM)

Focus on your **collection**

In fashion applications a CBI is always specified in combination with the beam angle, e.g., a CBI of 65kCd for a beam of 6 degrees, introducing a second aspect of the beam: the beam angle. To convey the beam angle, the **Full Width Half Maximum (FWHM)** is most often used and can properly be explained from the beam intensity plot in figure 8 as the beam angle at which the maximum intensity is halved. Strangely, it does not describe the perceived spot size properly. The beam intensity plot of figure 8 relates to the two projected beams from figure 7, which as we now know have the same maximum intensity and FWHM (of 20 degrees), yet not the same perceived light distribution and spot size.

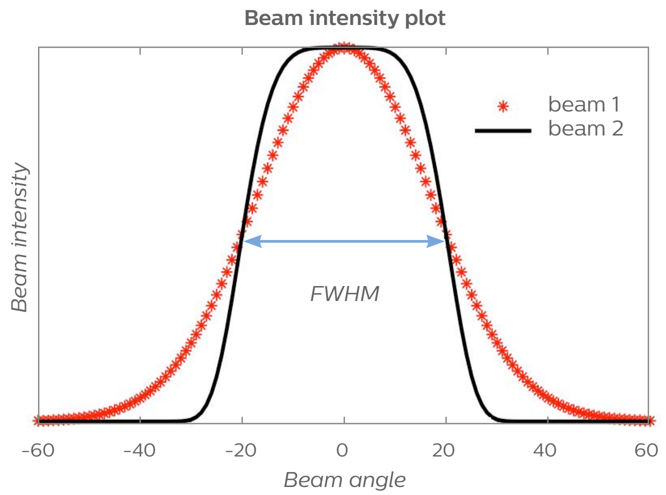
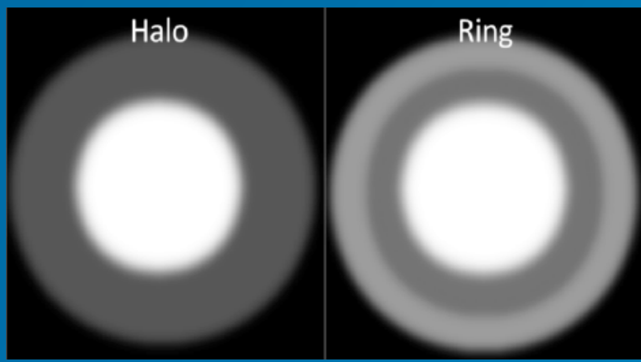


Figure 8: Beam intensity plot.

One of the problems with the FWHM is that it does not take into account the intensity change from center to the edge. Looking at the beam intensity plot again, the intensity of beam 2 decreases more rapidly, which indicates a more profound spot with less spill light (see separate part outer beam). Research indicates that from a perception point of view, the intensity decrease (or more precisely: the angle where the decrease of the intensity is maximum) often is a better predictor for spot size than FWHM. However, this angle, called the visual beam angle [4], is also not a perfect predictor for spot size since it is strongly affected by outer beam artefacts (see separate section Outer beam). Specifications of beam angle and beam shape are not reliable in predicting perceptions, and therefore

preferences. To determine people's preferences for beam shapes a large experiment was performed [5]. 41 participants evaluated different types of beams of their preference distributed over three categories ranging from extra narrow beam (<8°), to narrow beam (10°-13°) and medium beam (24°-28°).

The main findings were that beams with a smooth beam decay without halo (see section outer beam) were clearly preferred over beams with a halo effect. Also beams with a higher intensity in the center of the beam scored significantly better and were validated as more attractive. The characteristics that typically belong to a well-developed (Fashion Proof Optic) lens solution -no halo, higher beam intensity, smooth beam decay- score significantly better than reflector solutions.



Outer beam

The center of the beam is usually fully specified as well as the transition to the outside of the beam. What is missing is a classification of the outside of the beam. Most often this is referred to as spill light, which is a given side effect. Due to optics used to shape the beam disruptive changes in the outer of the beam are visible instead of a smooth decay. Visible changes in the outer beam are called halo or ring and are depicted in the figure above. The term halo is used for the effect that the bright core of the spots is surrounded by a (large) area of lower intensity, which usually ends in a sharp cut-off caused by the edge of the luminaire and the term ring is used for the effect that there is an increase in intensity in the outer beam that either fades out or suddenly end.

Create differentiating **experiences**

In a retail environment, creating the right atmosphere that matches the brand identity and purpose of the store is crucial. Especially since lighting is one of the defining factors of product appearance, ambiance and style of the store, it is vital to ensure a proper match between lighting and store identity when distinguishing from competition and to be clearly recognizable for shoppers. The good news is that we have already made choices in the fashion portfolio based on customer input and extensive user testing.

One such example is our Philips LED flavor portfolio. 930 is our standard flavor, which is an efficient solution but which has slightly under-saturated colors, similar to other industry-standard 930 products. PremiumWhite combines soft and natural white rendering with energy efficiency. CrispWhite optimally enhances bright, sparkling whites while maintaining strong and saturated colors. The new PremiumColor flavor heightens the contrast between colors and whites to provide a more saturated, vibrant color experience. Lastly, our Denim flavor enhances the unique denim look while maintaining a fresh and vibrant ambiance which matches very well with the look and feel of denim stores.

Similarly for the beam aspects, the Philips TrueFashion portfolio utilizes different architectures for different applications. Here the beam is classified into three groups according to their (FWHM) beam angle. The first category is the narrow beam, used to create contrast in the store and highlight specific items. To enable a beam with high CBI while minimizing spill light it uses the Fashion Proof Optic lens architecture. The second category is the medium beam, used to create a spotlight effect with some background light added to it. Center Beam intensity combined with low spill light is still key to enable a clearly visible spot effect. This is realized with a lens architecture where the design of the lens can be tuned to balance the light in the center and in the wider region to achieve the best change-over.
The third category is wide beam, which is mainly used to create a large uniformly lit area that gradually fades out. Spill light is less of an issue and it is more important to have enough light in the total beam. Hence, in this category reflectors are chosen.

Beam shaping LED architectures

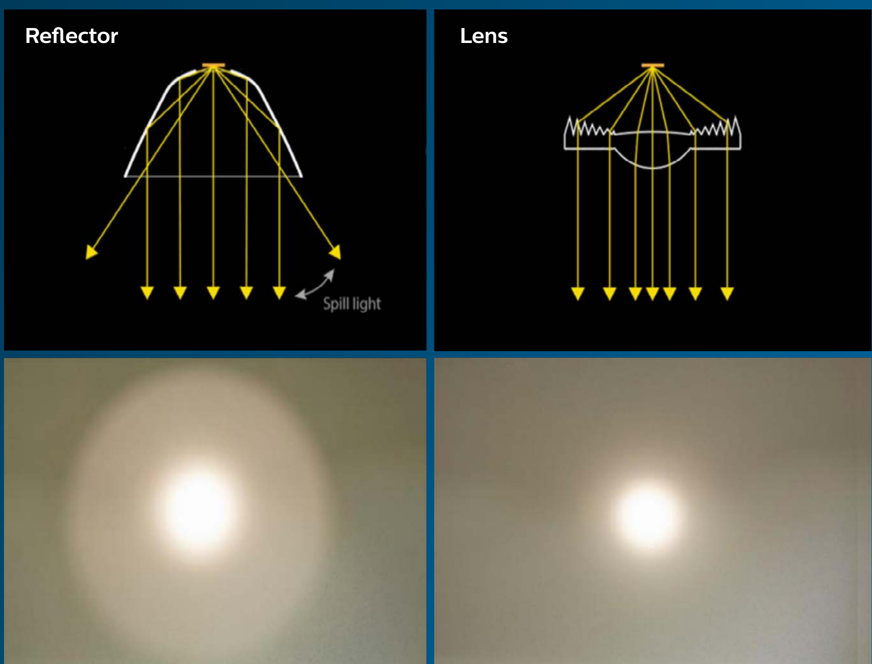


Figure 9

To shape the beam the most common architecture is a reflector since it has a high optical efficiency (almost all the generated light is utilized), a color homogeneous color beam (proper mixing capabilities of the facets in the reflector) and the low cost of the components. Lenses however have the benefit to control of all the light emitted out of the luminaire and thus controlling CBI, beam angles while minimizing spill light. Hence, in terms of Quality of Light, e.g., if looked at where the light is projected to and how it contributes to the lighting effect, with less light a brighter spot can be created. The fashion Proof Optics portfolio uses so-called Philips Fashion Proof Optic lenses, optics with a microlens array surface. This optics is optimized to deliver the LED flavors with a very high center beam intensity without spill light, while reducing glare. This results in up to 30% higher CBI and up to 100% higher contrast. Figure 1 visualizes the reflector, - and lens-based spots with the same beam angle.

Seeing is **believing**

It should be apparent by now that well-established criteria like correlated color temperature, color rendering index and Full Width Half Maximum do not paint the whole picture. Since it is impossible to fully judge the Quality of Light aspects on paper, the best advice we can give you is to do a simple test in your store with lens optics for a more engaging store experience with higher contrast and intensity. Our LED flavors will give your collection more natural and vibrant colors and textures. We all know: seeing is believing. Convince yourself of the impact of our lighting in the Lighting Application Center, via our Virtual Reality tool or we can even bring the experience to your doorstep. For more information, have a look at www.lighting.philips.com/main/systems/system-areas/fashion and contact us.

Acknowledgements

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Sources

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