VOLUMETRIC LIGHTING AND RT5

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An age-old problem in electric lighting concerns the management of light in the so-called "glare zone". This generally refers to light exiting a luminaire at vertical angles between roughly 50 and 90 degrees above nadir (Figure 1). Glare hinders visibility and is a known source of discomfort. It is therefore a primary consideration in luminaire design. However, it is also well understood that light emitted into this zone can have very positive effects on the perception of an architectural space and the rendering of its contents and occupants. RT5™ luminaire balances these two concepts with specific regard to the modern office environment.

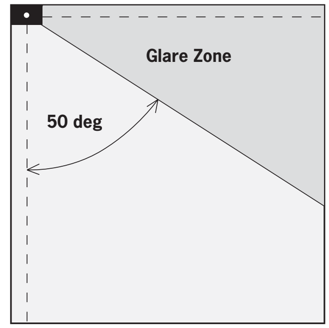

Figure 1

The "Glare Zone" Revisited

The visual system is most sensitive to glare when the light source is directly in the center of the line of sight, and this sensitivity diminishes as the light source is moved away from that line of sight toward the periphery. Assuming a horizontal gaze, this implies that luminaire brightness must be more strictly controlled in directions approaching horizontal.

A similar argument can be made relative to reflected images of lighting equipment in computer video displays, although recent advances in display technology have all but eliminated this once crucial consideration.

Today's computer displays utilize a much larger radius of curvature, and flat screens are becoming more and more prevalent with time. At typical orientations and viewing positions, this reduces the reflected field of view such that only very distant portions of the ceiling are visible. Anti-reflectance technologies are routinely incorporated, and screen brightness also has been significantly improved. But most importantly, software developers have overwhelmingly chosen to present information in positive contrast (dark characters on light background). While certain niche applications may still require special attention, the collective impact of these advancements has substantially mediated the problem at large.

Lamp shielding has long provided an effective means for achieving light control relative to glare. When comprised of highly reflective material, the shielding additionally can be used to intercept light that otherwise would be emitted near the horizontal, and to redirect that light downward through the principles of specular (mirror-like) reflection (Figure 2). The result is both effective and efficient.

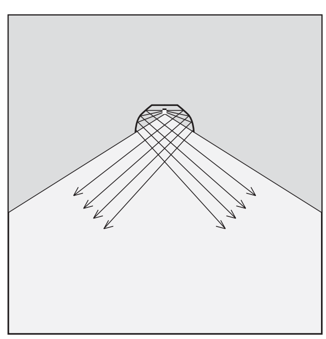

Figure 2

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One potential problem with this approach is that the luminance of the reflected image of the lamp typically is very near that of the lamp itself. Thus, great care must be taken to control the manner in which the reflector "flashes" the lamp image. The glare potential is high, and so is the tendency for this flash to attract attention as a result of its dynamic nature relative to occupant movement within the space.

Another characteristic of this control method is that it tends to produce relatively sharp cutoff. In fact, sharp cutoff often has been considered a key performance attribute for various lighting products. The sharper the cutoff, the stricter the light control in the glare zone.

Although highly effective in certain applications, sharp cutoff also can be problematic. In most cases, the photometric distribution tends to be so downwardly concentrated that it results in highly directional illumination. While the illumination may be extremely uniform over a relatively low horizontal task plane, the upper regions of the space are quite the opposite. The modeling of three-dimensional objects can be harsh, the uniformity of illumination at higher elevations is poor, and vertical surfaces tend to be rendered with abrupt scallops, resulting in something commonly referred to as the "cave effect" (Figure 3).

Figure 3

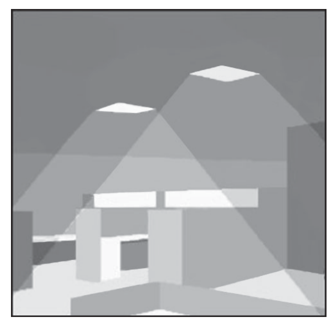

Figure 4a

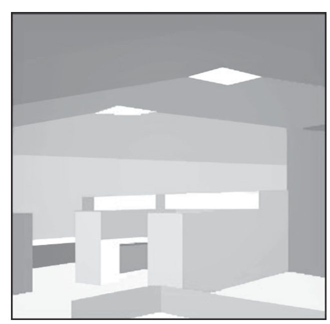

Figure 4b

Volumetric Lighting, What and Why

The term "volumetric lighting" simply refers to lighting that is less directional and more uniform throughout the entire volume of a space (Figures 4a and 4b). Volumetric lighting extends beyond the work plane to adequately illuminate the entirety of the interior, resulting in a better balance of luminance throughout the visual field. The space feels brighter, larger, more public, and more relaxing. Facial rendering is more natural, consistent, and complimentary. Shadows tend to be softer and less pronounced, and the appearance of the space is less defined by sharp, arbitrary transitions in surface brightness. Volumetric lighting does a better job of rendering architecture, its contents, and its occupants true to form.

The attributes of volumetric lighting are well understood and appreciated, as evidenced by the popularity of indirect and direct/indirect suspended lighting. In this case, the ceiling is essentially transformed into a light source.

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Suspended lighting is good, but it becomes less effective as the suspension length is reduced, and many applications do not afford the luxury of high ceilings. Additionally, suspended lighting tends to make a definitive architectural statement that is not appropriate for all applications.

The need exists for a highly efficient recessed luminaire capable of providing quality volumetric lighting. However, volumetric lighting is dependent upon high angle illumination, and this becomes a challenge in terms of glare management. As mentioned previously, specular optics directly image the extreme brightness of the lamp. The solution lies in recognizing that luminous intensity is the product of luminance and area. For a given intensity value, the brightness of the luminaire can be reduced if the area from which that brightness emanates can be increased in size. This is another way of saying that the solution is to create a luminaire whose brightness is relatively uniformly distributed over the entire luminaire aperture, and this implies that diffusing optics, rather than specular, must be employed.

RT5 Optics

The challenge with diffusing optical systems is that they tend to be inefficient. Light often is reflected multiple times before exiting the luminaire, and this drives luminaire efficiency down.

Materials exhibiting extremely high reflectance (98%+) are available, but incorporating them would constitute a material dependency that may or may not be appropriate for lighting equipment. Performance over time is a concern, and a relatively small amount of dust or other contaminants can have a powerfully detrimental impact on such systems.

RT5 represents a breakthrough in luminaire optical design because it is an effective light diffusing system that also happens to be very efficient. It achieves its performance and control by carefully combining elements of light diffusion, shielding, and Fresnel reflection.

The primary purpose of the refractor is to efficiently and uniformly diffuse the extreme brightness of the T5 lamp over its entire surface while illuminating the adjacent reflector. The size of the refractor allows for greatly reduced maximum luminance, which strongly decreases the glare potential in direct view.

The refractor achieves its abnormally high efficiency by employing a two-stage strategy. An upper diffusing layer gently softens the lamp image, while the prism geometry of the lower refractor acts to distribute brightness evenly in the across-lamp dimension (Figure 5). The reflector uses highly reflective diffuse paint to ease the luminous transition from the refractor to the ceiling by distributing brightness across the entire luminaire aperture.

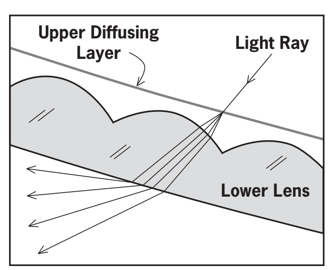

Figure 5

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This further reduces the potential for glare while providing the soft, high-angle brightness that is critical to volumetric lighting. This approach additionally results in a luminaire whose appearance is static with respect to occupant movement, thereby reducing its ability to distract or command attention.

Although relatively low in brightness, the refractor still may be too bright for direct view at angles very near horizontal in the across-lamp dimension. Remember that in this dimension, the prisms are designed to distribute light broadly. This is what gives rise to the use of shielding in that plane, albeit minimal.

In the along-lamp dimension, the refractor uses the principle of Fresnel reflection to control high-angle brightness. When light enters or leaves a refractive material in air, some of the light is transmitted while some is reflected (Figure 6). The proportion that is either reflected or transmitted is dependent upon the incidence angle. At angles perpendicular to the refractive surface, most of the light is transmitted; at grazing angles, most of the light is reflected.

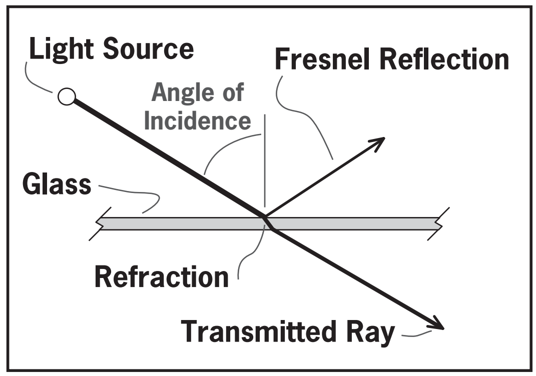

Figure 6

Figure 7 plots Fresnel reflection for acrylic as a function of incidence angle. Through proper choice of refractor geometry, this phenomenon can be used to control high-angle brightness in the along-lamp dimension. The result is a refractor that naturally and smoothly becomes less luminous with increasing vertical angle.

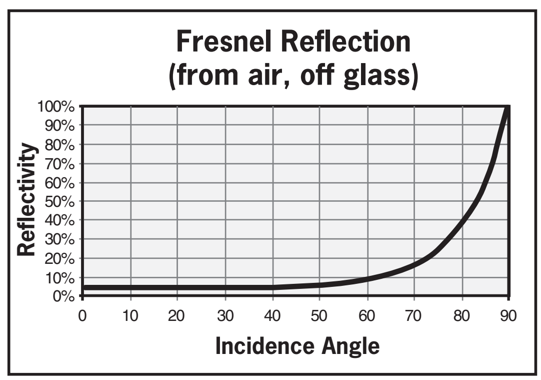

Figure 7

While deceptively simple in appearance, RT5 represents a significant advancement in lighting. It saves energy while providing high quality volumetric lighting in a recessed configuration.

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