technical bulletin: **BOUNDING RAY OPTICAL PRINCIPLE™**

In architectural lighting design, essentially two schools of thought exist. Lighting equipment should either disappear into or explicitly complement the surrounding architecture.

Architectural downlighting traditionally falls into the first category, while indirect lighting is a good example of the second category.

As a rule, architectural-grade downlighting should place emphasis on the architecture and draw little attention to the actual lighting hardware. This presents an interesting engineering challenge because the human visual system is physiologically attracted to brightness and motion and brightness is a necessary element of illumination.

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HUMAN VISUAL FIELD

Foveal and Peripheral Regions

To understand the impact of brightness and motion, let's take a look at the visual field of the eye. The human visual field is separated into two distinct regions: Foveal and peripheral (Fig. 1).

The foveal region, which is the center of the field of view, is about the size of a thumbnail at arm's length. This region corresponds to a small retinal location that is very densely populated with photoreceptors. Although surprisingly small, the foveal region provides the sharpest views of an object.

The much larger peripheral region (60° above and 70° below the foveal region) corresponds to retinal locations that are significantly less densely populated with photoreceptors, therefore it does not provide the high visual acuity of the foveal region. The peripheral region is, however, extremely sensitive to motion. To a significant degree, the purpose of the peripheral region is to help determine where the attention of the foveal region should be directed. This innate capability is part of our natural survival instinct that helped keep our early ancestors from ending up as lunch for a hungry predator.

With peripheral vision the brain differentiates little between inputs to the eye caused by physical or perceived movement. For example, the sudden brightness caused by flash (reflected lamp image) on a downlighting reflector is as real an indicator of movement as would be a physical object actually moving into your peripheral vision. Peripheral vision sensitivity decreases with distance from the fovea. Therefore, the closer the perceived movement is to foveal vision the higher the probability it will be detected.

Downlighting Design

Considering these physiological characteristics of the eye and the goal of good architectural downlighting to draw little attention to itself, the ideal design would minimize the perception of movement due to sudden brightness from flash. In other words, architectural downlighting should not be noticeably bright to the eye. Because of the curved nature of downlight optics, reflector flash can be highly dynamic and relative to the movement of people within a space. Even very small changes in location, such as taking a step, can result in changes in the size and position of downlight reflector flash. When these changes occur quickly or dramatically they stimulate peripheral vision with a high probability of attracting attention.

The most favorable way to control flash and its probability of peripheral sensitivity is to allow the eye to see the downlight lamp before any flash is visible on its reflector. Then, once the lamp is visible, allow the flash to begin high on the reflector (adjacent to the lamp) and grow towards the aperture opening. This "top-down flash" performance characteristic, although subtle, reduces the dynamic nature of flash by introducing the reflected lamp image to the viewer at a controlled rate. The "lamp before lamp image" technique restricts visible brightness to within the luminaire's shield angle and thus flash is always furthest from the foveal line of sight. The end result is that the downlight has the least probability of attracting attention to itself, therefore it is more apt to "disappear" into the architecture.

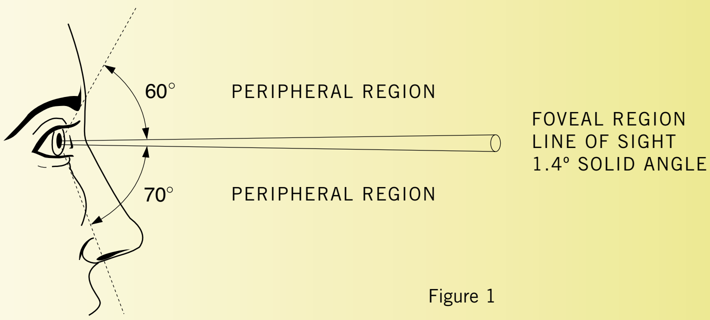

Figure 1

Today, many, if not most, downlighting reflector contours are based upon conventional "point source" optical design methodologies, which assume that all light exiting a lamp radiates from a single point. Based on this assumption, reflector contours are designed to, in theory, capture a large percentage of the light being generated by the source and redirect it out of the downlights and into a given space. When designing optics for incandescent luminaires, the point source assumption is not unreasonable due to the relatively small size of the incandescent filament.

CHALLENGE FOR OPTICAL DESIGNERS

Early Compact Fluorescent Lamps

The introduction of compact fluorescent lamps in the 1980s presented a new challenge to optical designers. This was primarily due to the fact that compact fluorescent lamps emit light more or less uniformly over their entire outer surface area. Without a single point responsible for radiating the majority of light, point source optical design methodologies are not effective. Early compact fluorescent downlights were excessively bright and visually "noisy" in appearance due to dramatic changes in flash relative to the position of the viewer. While the practical benefits of compact fluorescent technology were substantial, downlighting manufacturers struggled to apply the technology without sacrificing aesthetic attributes normally associated with architectural grade downlight products. The benchmark all aspired to was the six-inch incandescent downlight.

Recognizing the shortcomings of point source optical design methodologies, Gotham Lighting set out to develop a new approach.

Bounding Ray Optical Principle™

The insight afforded by the application of Bounding Ray allows Gotham to precisely control the nature of flash. By using Bounding Ray, wallwash downlights can be designed to illuminate walls more uniformly and eliminate room side back flash. Downlights exhibit more uniform aperture illumination. Furthermore, Bounding Ray is applicable to any source that emits light over a large surface. By developing the optical contour based on the extremities rather than the center of a light source the optical performance and flash characteristics are similar regardless of source type. In other words, compact fluorescent, HID and incandescent downlights can all exhibit similar optical characteristics when designed from the Bounding Ray perspective. Also, due to the mathematical nature of the Bounding Ray Optical Principle, design parameters can be integrated into engineering software thereby ensuring consistency of design.

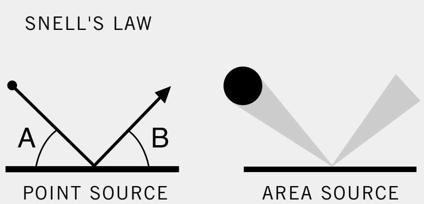

Figure 2

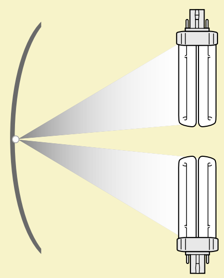

Figure 3

According to Snell's law of reflection, light that is incident upon a specular reflective surface will be reflected at an equal angle. When light is incident throughout a zone, as with compact fluorescent lamps, it is reflected into a zone of equal dimension (Fig. 2).

When light strikes a small section of a downlight reflector, it is reflected within a zone defined by the "boundary" or outline of the lamp itself. Because light travels in a straight line the reflected beam is determined by the specific geometry of the light source. Looking at the design of downlight optical systems in this way provided the insight that Gotham needed to solve the challenges presented by the compact fluorescent light source. By paying particular attention to the rays that define the boundaries of the reflected zone, Gotham optical engineers were able to create reflector contours exhibiting greater optical control than ever before. We call this design breakthrough our Bounding Ray Optical Principle (Fig. 3).

Bounding Ray was first utilized in the development of the Gotham Vertisys® vertical compact fluorescent downlight. Vertisys redefined the lighting industry standard for compact fluorescent downlighting. Since then, Bounding Ray has been incorporated into the Gotham AF (horizontal compact fluorescent), AH (HID) and A (incandescent) downlight fixture families. Now, Gotham downlights provide the same pristine, low brightness apertures regardless of source type, exhibit excellent optical control, uniform light distribution and a high degree of aesthetic appeal. Gotham Bounding Ray is the standard for architectural quality downlighting.

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