Light Matters

Designing illumination systems with high-brightness LEDs

Next time you visit Paris, look up at the Eiffel Tower. A name inscribed on the side facing the Champ de Mars is one of the brilliant French scientists who pioneered optics, lenses… and advanced lighthouses. Augustin-Jean Fresnel.

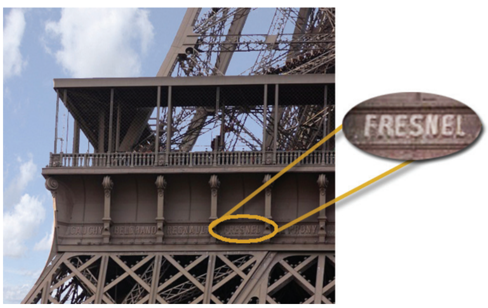

Figure 1 – The Eiffel Tower

Fresnel (1788–1827) made several key contributions to the field of wave optics, particularly on the wave theory of light and diffraction. But perhaps the most easily recognizable outcome of his work is the Fresnel lens, a device he invented around 1820 to enhance the effectiveness of lighthouses. Today, of course, Fresnel lenses are used in many applications, ranging from beacons, lanterns and warning lights to office copiers and overhead projectors.

Like many of the best revolutionary ideas, it is a simple one.

If you need to gather the light, say in a lighthouse, and direct it out as far and bright as possible, you have limited options. Reflectors can capture and redirect light otherwise lost on the sides and back of the light source, but are not efficient at gathering or collimating the light. A large glass lens is an improvement, but it has two serious drawbacks.

The first set of problems in using a large glass lens is thickness, weight and cost. Glass weighs approximately 200 lbs per cubic foot. Given that a three foot diameter conventional convex lens might contain over 6 cubic feet of material, that's about 1,200 pounds. Continuously wheeling a few of those around a small gas flame using a clockwork mechanism would present quite a challenge.

The second problem is optical loss. An appreciable amount of light will be lost (absorbed and internally scattered) as it makes its way through all of that glass.

Fresnel, like others before him, realized that the bending (refraction) of light in a lens occurred at the edges, where the glass meets air or other materials. The amount of bend is related to the differences in each material's index of refraction and the angle of the light ray passing through it. (More on Snell's law, refraction and internal reflection can be found in Light Matters LM-19 on the Avnet LightSpeed website.)

If only the surfaces and their angles are important, perhaps we don't need all of that glass material which fills the shape. Fresnel created a lens which reproduced the surface angles by taking sections of the convex edge and translating them to a flat plane, as in Figure 2 below.

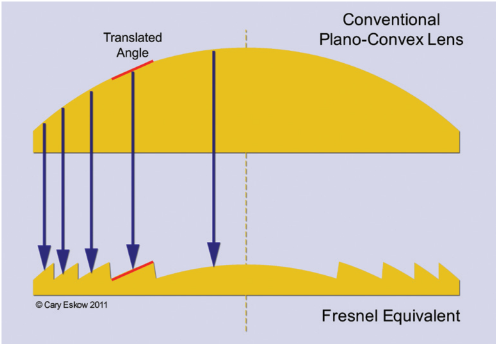

Figure 2 – Comparing a conventional lens to Fresnel near-equivalent

Why aren't all lenses made this way? Everything, perhaps most especially in optics, is a tradeoff. Fresnel lenses are very good at projecting, focusing and collimating light, but not ideal for transmitting images. Those near-vertical sides on the surface which separate each angled ridge will scatter a portion of the light. Thus images that pass through them are somewhat distorted. Fine for lighthouses though!

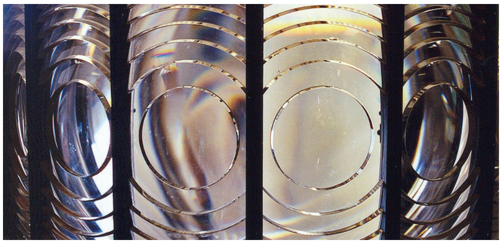

Figure 3 – Cape Willoughby lighthouse on Kangaroo Island, South Australia

If you'd like more information on lenses for LEDs, visit the Avnet LightSpeed (**www.em.avnet.com/LightSpeed**) or send a note to **LightSpeed@Avnet.com**. Questions, comments and postcards from Paris are always welcomed.

[1] The names of 72 French scientists and engineers are engraved on the Eiffel Tower

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is Global Director of the Solid State Lighting and Advanced LED business unit of Avnet Electronics Marketing. An ardent advocate of energy efficient LED-based illumination, he has worked closely with LED manufacturers, advanced analog IC and secondary optics vendors since his first patent using LEDs was issued two decades ago. Avnet works with customers through their national team of illumination-focused sales engineers who are experienced in thermal, drive stage and optics design. Prior to his LED lighting focus, Cary was Avnet's technical director and managed Avnet's North American FAE team.

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