Freeform Optics for Uniform Wall Illumination

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Freeform optical components have the potential to re-distribute light extremely precisely since their surface can be optimized for nearly all incident rays. This property has been exploited to create uniform illumination of non-symmetric shapes. Here we demonstrate that freeform optical components can be exploited further, to achieve off-axis, asymmetric and precisely non-uniform light distributions which are impossible with standard axially invariant components. Furthermore, we also report on potential strategies to transform macroscopic freeform components into freeform microlens arrays, FMLAs, hence exploiting the high potential for the continuously increasing demands for device miniaturization and their compatibility with cost-effective large-area manufacturing.

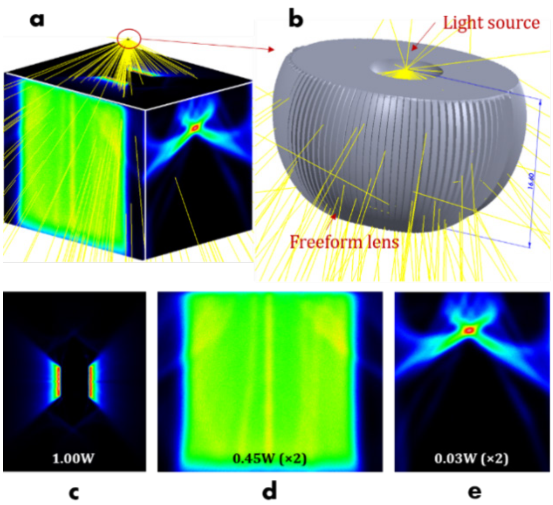

Figure 1: a) Uniform Irradiance distribution achieved using a freeform lens; b) designed at CSEM. The Irradiance distribution are presented and quantified in -c, -d and -e.

Freeform lenses: Uniform vertical illumination

The horizontal Illuminance is only an adequate criterion for working environments where the working plane is horizontal. However, in today office spaces many tasks include non-horizontal surfaces which influence worker's visual and physiological assessment. Indeed, our perception of brightness is mainly determined by what we see in our field of view and hence, by the vertical Illuminance levels. For example, increasing wall Illuminance leads to more stimulating rooms and lower preferred desktop illumination. In shop-retail applications, rack-lighting solutions that lit shelves uniformly produce more attractive product presentation and facilitate the shoppers to survey the range. It is also known that highly uniform luminance levels on walls enhance the impression of room spaciousness and increases visual clarity making well-lit shopping malls more attractive to customers than poorly illuminated ones.

Specifying vertical Illuminance distribution as the merit function for lens design is highly inconvenient from the perspective of a lens designer. Especially for freeform optics, it is more convenient to specify the horizontal Illuminance distribution instead. Vertical Illuminance distributions can nevertheless be dealt with by reversing the problem. From the specific geometric of the problem the position and k-vector of each ray can readily be calculated. The wall source, defined by the collection of emitting points and their k-vectors, is then ray-traced and the Illuminance distribution over the horizontal upper plane obtained and finally used as the (equivalent) horizontal target. The calculated freeform lens was ray-traced using ANSYS SPEOS optical simulation software. The results, presented in Figure 1, clearly indicate that the Illuminance over the target walls is fairly uniform compared to that produced by the bare (Lambertian) light source. In addition, the total power hitting the (two) walls is 90% of the power emitted by the source compared to the very modest figure of 28% obtained with the uncorrected light source.

Freeform microlens arrays, FMLA

There is a strong need for precise light management in continuously miniaturized devices and systems and the standard freeform macro-optical solutions/industry will only be able to partially address the current and future challenges and requests for solutions featuring miniaturized optics.

CSEM has developed a design method based on the complex arrangement of relatively simple individual microstructures (such as, *e.g.*, microspheres, microprisms, microaspheres, etc.). A big advantage of this method is its compatibility to large-area light sources. An extended collimated light source illuminates the FMLA (Figure 2 top left) and produces a batwing intensity distribution (Figure 2 bottom left). As a result, the far-field Irradiance is much more uniform than that produced by a Lambertian source (see the Irradiance distributions shown in the right part of Figure 2).

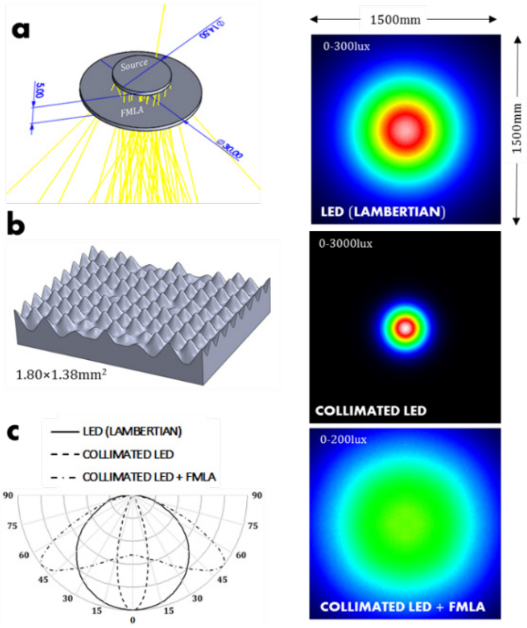

Figure 2: CSEM FMLA for uniform lighting. (left) FMLA 3D CAD model (top) and normalized (polar) luminous intensity distribution, LID (bottom; the Lambertian and the LID of the collimated incoming light are shown for comparison); (right) The corresponding Irradiance distributions over a 1'500x1'500 mm² planar detector located 1'000 mm away from the source; those produced by a Lambert and the collimated incoming beam are shown for comparison.

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