Laser Converter Lighting System using Compound Recycling Reflectors

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ABSTRACT

Compact laser converter lighting system using diffuser and phosphor plates have been designed and being developed. With the addition of light recycling using a compound parabolic reflector, the brightness will be increased with a small output angle for ease in coupling.

1 Introduction

Laser light sources provide higher luminance compared to LED light sources and are important for applications such as projectors, automotive headlights and spotlights. The fact that laser converted emissions using diffuser and phosphor are Lambertian in nature makes efficient collection and coupling very challenging. At the same time, the easiest way to use a laser converted emission system is to use the transmissive mode in which the laser beam enters from one side of the plate and emission exits the opposite side. The optical configuration for such transmissive mode is relatively simple, but with one major disadvantage in the heat sinking of the plate, which cannot be mounted on an opaque heat sink. On the other hand, a reflective mode laser converter system would provide a better heat sink as the phosphor plate could be mounted on top of an opaque heat sink. On major disadvantage is that a more complicated optical system has to be used as the laser source and the emission from the diffuser or the phosphor are on the same side of the plate. This paper describes a laser converter system using diffuser and phosphor plates in which the plates are mounted on heat sinks and used in the reflective mode with very good thermal extraction. In addition, the high angle light from the plate is recycled back to the plate for added brightness and the total low angle light can be coupled efficiently using standard lenses. All the components are logically integrated into a very compact light source for a wide variety of applications.

2 Basic Structure of a Laser Phosphor Light Source with Light Recycling

Figure 1 shows the basic configuration of the laser converter system with recycling using a parabolic reflector and a conical reflector. The plate, which is a diffuser plate or a thin layer of silicone phosphor, ceramic phosphor, glass phosphor, or crystal phosphor plate, mounted on top of a heat sink, and is placed at the proximity of the focus of the parabolic reflector. One or more lasers with collimated outputs are mounted on the heat sink such that the output beams pass through the openings in the heat sink and the conical reflector towards the parabolic reflector. The laser beams are reflected by the parabolic reflector and directed towards the plate at the focus. The focused spot on the plate emits light with a Lambertian distribution. The lower angle light will exit the aperture contributing to the output of the light source within the exit angle determined by the diameter of the aperture and its distance from the focus of the parabolic reflector. The high angle portion of the output will be collected by the parabolic reflector and collimated towards the conical reflector, next to the opposite side of the conical reflector, next to the parabolic reflector and focused back to the plate, completing the recycling process. Portion of this recycled light will be re-emitted in small angle contributing to the increased in output brightness. The high angle portion of this recycled light will be recycled again and the process repeats contributing further to the output of the system. The diameter of the parabolic reflector could be design to optimize between the total recycling efficiency and the physical dimension. With the outputs being Lambertian, most of the output will be within a half angle of about 60 degrees. In this case, the diameter could be reduced to reduce the overall dimension of the system. We are also working on increasing the efficiency of the diffuser and phosphor plates with different surface structures. Since both the plate and the lasers are mounted on the same heat sink, a single heat dissipating structure could be used, simplifying the design and cost of the system.

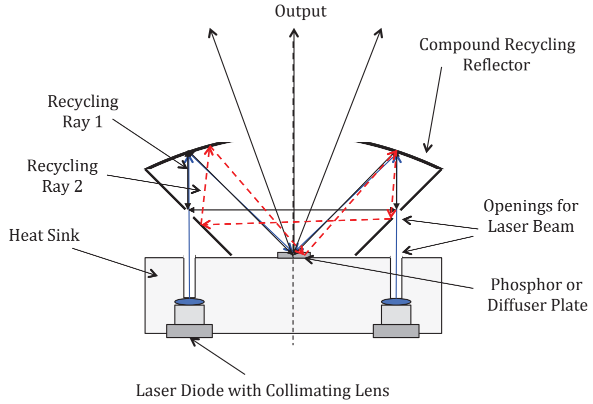

Figure 1 – Schematic Diagram of a Laser Converter System with Light Recycling

One feature of this compound recycling reflector is the self-alignment. In the complete process of recycling, the initial output goes through 4 reflections. Referring to multiple reflection systems, an even number of reflection produces an image in the original orientation (upright image), not the mirror image (inverted image) as commonly referred to on reflections from a single (odd number) reflection. As shown in the figure, recycling ray 1 shows the paths of the recycling rays from the focus. Recycling ray 2 shows the paths of the recycling rays from a point at a small distance from the focus where the end point coincides with the starting point. This shows the system produces an upright image. This means that the location of the starting light spot does not have to coincide with the focus to allow efficient recycling. The practical consequence of this property is the large tolerance in alignment of the system, allowing simple and low cost manufacturing

3 A High Power Configuration with Multiple Lasers

Figure 2 shows the bottom of the heat sink showing one ring of lasers. The outputs are collimated and exit through the top of the heat sink directed towards the parabolic reflector. When higher power is required, addition ring of lasers could be added. The lasers can also be placed in other configurations such that the desired light spot at the phosphor plate is obtained.

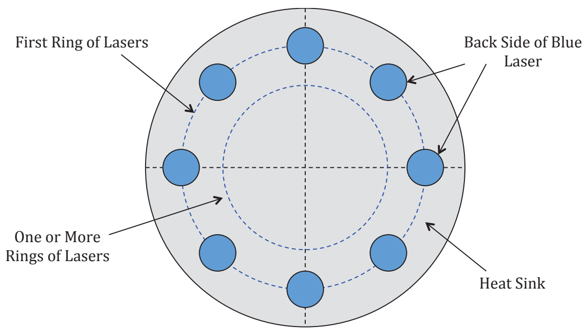

Figure 2 – The Locations of the Lasers at the Bottom of the Heat Sink

Figure 3 shows the topside of the heat sink in which there are openings with each one place above the laser placed at the back. A plate, which could round, square, rectangular, etc. in shape, is place at the center of the heat sink where the focus of the parabolic reflector is. The conical reflector is attached to the heat sink, which could be a broadband reflector with matching holes with the laser output opening.

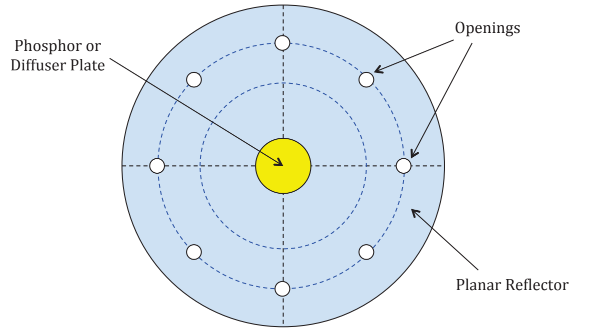

Figure 3 – The Top View of the Heat Sink with the Plate and Holes

4 A Compact Prototype with 4 Lasers

Figure 4 shows a configuration in which 4 TO-9.0 lasers are used and they are mounted in a heat sink of 25 mm in diameter. Figure 5 shows the top view of the heat sink showing the 4 openings with 1.5 mm in diameter and center plate with 2 mm in diameter. A prototype of this system is being built and the results will be presented.

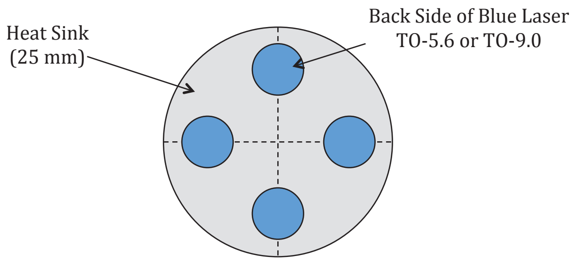

Figure 4 – The Bottom View of a Small Laser Converter System with 4 Lasers

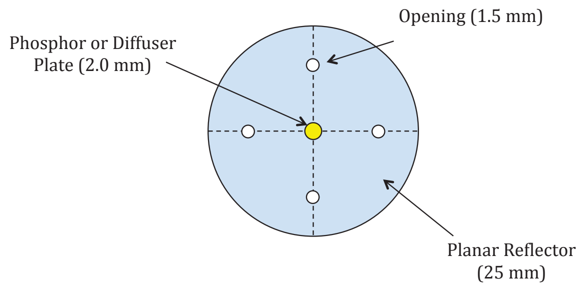

Figure 5 – The Top View of a Small Laser Converter System with 4 Lasers

5 A Focusing Light Source with Reflectors Only

Figure 6 shows another configuration where a second parabolic reflector is used such that the output is not a divergent beam from the plate. Instead, image of the plate is transferred from the physical plate location to the aperture of the parabolic reflector through reflection from the first and second parabolic reflectors.

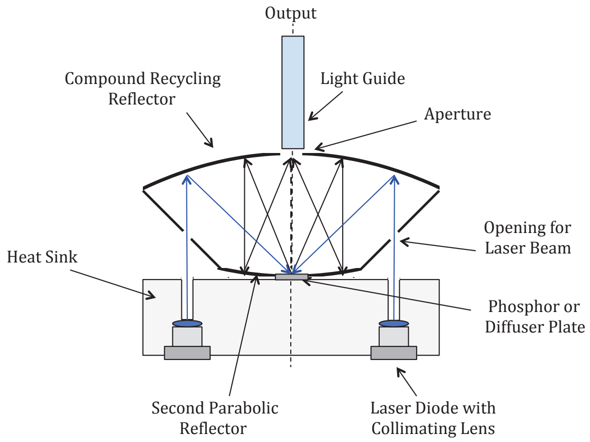

Figure 6 – Schematic Diagram of a Laser Converter System with Light Recycling and a Focusing Output Suitable for Fiber Optics

The plate is placed at the focus of the first parabolic reflector and the aperture is place at the focus of the second parabolic reflector. The image of the plate at the aperture could be used for direct coupling into a light guide, light pipes of projection systems, etc. This eliminates the need for high NA coupling lenses, which are expensive, inefficient, and do not focus well. This light-recycling portion of the system is similar to that of Figure 1 as described above

6 Conclusions

A compact laser converter system been designed and being developed. With the addition of light recycling using a compound parabolic reflector and a planar reflector, the brightness will be increased with a small output angle for ease in coupling. A prototype is being and the results will be presented.