Laser Phosphor Light Source with Hot Spot for Intelligent Headlight using DMD for Ultra-High Beam Applications

Kenneth Li[1], Y. P. Chang[2]

[1]Optonomous Technologies Inc., Agoura Hills, CA, USA
[2]Taiwan Color Optics, Inc., Taichung City, Taiwan
Keywords: Intelligent Headlight, Crystal Phosphor, Hot Spot, and Laser Phosphor

ABSTRACT

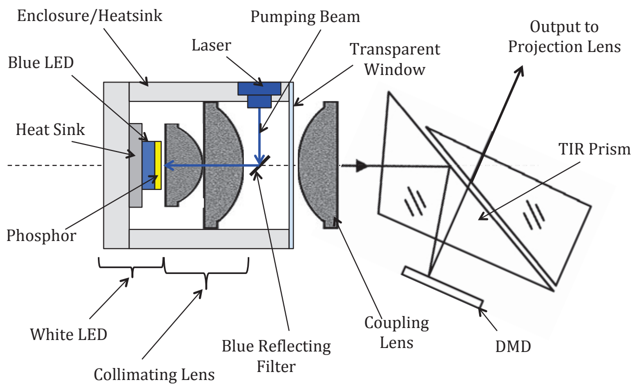
An intelligent headlight using a single DMD and a laser pumped crystal phosphor plate producing a hot spot for extreme high beam has been designed and develop. Initial experiment results using a DMD projection engine will be presented.

1 Introduction

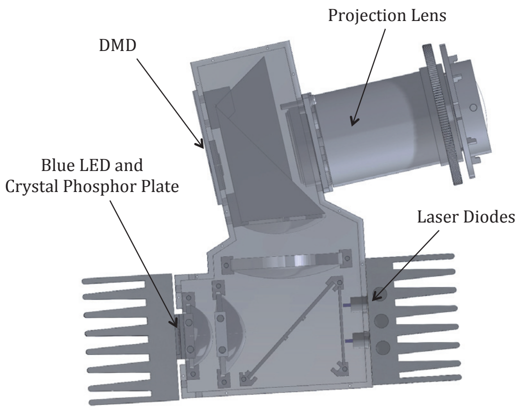
For intelligent automotive headlight applications, a digital projector type of architecture is commonly used such that the illumination on the roadway can be controlled by the pixels of the imager, such as a DMD. Selective areas can be illuminated or dimmed such that it provides better illumination for the driver and less blinding glares for the on-coming vehicles. In order to provide a wide field of view (FOV) for low beam and high on-center brightness for high beam, the illumination source luminance for the on-center portion of the FOV must be much higher than the rest of the area. Simply increasing the overall brightness for illuminating the DMD would be very inefficient as most of the illuminated area around the hot spot will be dimmed electronically, which is wasting power. Effectively, the area dilution of the brightness from increasing the FOV must be counteracted by an increase in source luminance (for the center hot spot section only). For example, if only 1% of the total area at the center needs to have a higher brightness, without a hot spot, it would require the whole area to have a higher brightness, increasing the total output power, making it impossible to implement. This paper discloses an optical configuration in which the center portion of the light source, e.g. a LED, is pumped using a laser such that a hot spot is formed in the center section, with a sharp roll-off to a relatively lower luminance in outer section of the light source. are the details about the file format, the composition, and the text contents in the manuscript.

2 Basic Structure of an Intelligent Headlight

Figure 1 shows a basic structure of an intelligent headlight. The white LED is made up of a blue LED covered with a layer of phosphor material. Most of the blue light is absorbed by the phosphor and re-emitted as yellow light. Together with the leftover blue light from the LED, the output becomes white light. The output is very much Lambertian in distribution and is collected and collimated using a pair of collimating lenses. The output is then coupled to the DMD through the TIR prisms using the coupling lens as shown. The overall combination of the collimating and coupling lenses is to image the emission of the LED onto the DMD with the required magnifications. As a result, the intensity profile of the light on the DMD is the same as that of the LED, which is mostly uniform. The output from the DMD is projected onto the roadway using the projection lens. With such an arrangement, the maximum intensity of the output will be the projected intensity of the LED surface. The DMD can only reduce the intensity as required, but cannot increase the intensity for the high beam applications.



(a)



(b)

Figure 1 – Structure of a Laser Assisted Intelligent Headlight with Hot Spot

To overcome such deficiency and producing a hot spot, one or more lasers with collimated laser beams can be placed at the collimated side of the light source such that the output beams are directed into the collimated beam region and reflected into the LED direction using a blue reflecting filter, while the yellow light can pass through. The laser beams are then focused by the collimating lenses onto the phosphor layer of the LED forming a hot spot. Similar the outputs of the combined LED/Laser emissions are focused onto the DMD for projection onto the roadway

3 Desired Intensity Profile of the Light Source

Figure 2 shows the desired intensity profile of the light beam on the DMD in which the intensity is not uniform and has a very high intensity area, the hot spot, near the center of the DMD, which will be used for the very long distance, high beam application. While the center hot spot can be turn on and off by the DMD, the rest of the area with lower intensity can be controlled independently with normal operations without excessively reduction in intensity if the whole DMD is illumination with the intensity level of the hot spot. In practice, it will be difficult to created a profile as shown in Figure 2. Instead, the intensity profile as shown in Figure 3 can be achieved using laser assisted pumping of the phosphor layer.

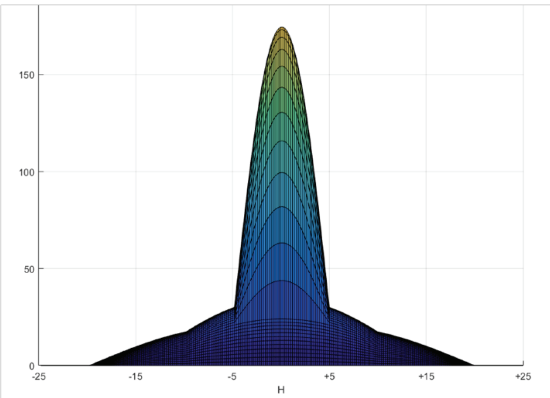


Figure 2 – Desire Intensity Profile on the DMD

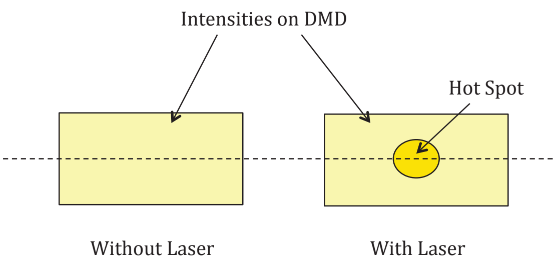


Figure 3 – Laser Assisted Intensity Profile on DMD

4 The Hot Spot LEDs

Depending on the construction of the white LED, many of the phosphor layers does not have the power capacity to handle the high intensity of the laser beams. As a result, a white LED is constructed using a blue LED together with a phosphor layer, which is a crystal phosphor plate fabricated at temperature in the range of 1,750°C. With this crystal phosphor plate, a high intensity hot spot can be produced.

Figure 4 shows another structure in which the white LED has an additional layer of crystal phosphor on top of the original phosphor layer. This layer can be glued onto the phosphor layer such that it becomes an integral part of the LED. The advantage of such structure is that the crystal phosphor has a much higher temperature rating compared to the standard silicone phosphor and is transparent to yellow light compared to ceramic or glass phosphor layers. As a result, the yellow portion of the LED light will pass through this layer of crystal phosphor with very little loss. The blue portion of LED light will be partially absorbed by this crystal phosphor layer lowering the color temperature of the output. The LED can be designed with extra blue light output such that the amount of blue will be obtained after it passes through the crystal phosphor layer. Using this additional layer, the output of the laser can be increased, as the laser light will be absorbed by the crystal phosphor layer with higher rating on both the operating temperature and the power density, thus allowing a much higher intensity hot spot on the LED.

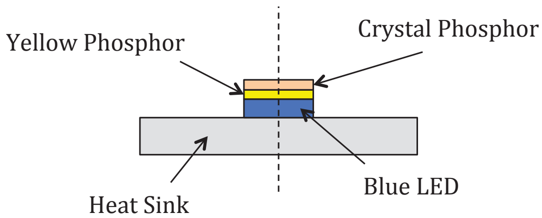


Figure 4 – White LED with Yellow Phosphor and Crystal Phosphor Layers

Figure 5 shows another embodiment of the LED where the crystal phosphor layer is placed with a gap between the phosphor of the LED and the crystal phosphor plate. In this configuration, the original LED is not physically "touched" by the additional components, thus preserving the integrity of the original LED. Since there are tremendous amount of research and developments done in improving the performance of white LEDs and it is important to capitalize these development efforts in making improvements. With a small gap between the standard white LED and the crystal phosphor plate, the best commercially LED can be used providing the best possible system for this "hot spot" LED using laser pumping. Similar to the LED as shown in Figure 5, the LED can be designed with extra blue light output such that the amount of blue will be obtained after it passes through the crystal phosphor layer. Using this additional layer, the output of the laser can be increased, as the laser light will be absorbed by the crystal phosphor layer with higher rating on both the operating temperature and the power density, thus allowing a much higher intensity hot spot on the LED.

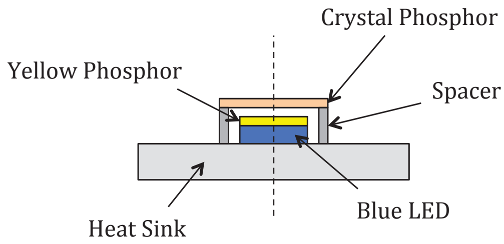


Figure 5 - White LED with a gap between Yellow Phosphor and Crystal Phosphor

5 Initial Experimental Results

Figure 6 shows the results of such a hot spot LED with crystal phosphor plate. Figure 7(a) shows the combined image of the blue LED and laser pumped crystal phosphor plate showing a low intensity of the LED pumped area and the high intensity of the laser pumped hot spot. Figure 7(b) shows the laser pumped hot spot with the LED turned off. The laser pumped hot spot location and dimensions can be controlled by the direction and the collimation of the laser diode. This architecture can also accept multiple lasers with different amount of collimation and directions such that multiple hot spot can be created on the crystal phosphor plate such that each hot spot can be targeted for different purposes. For example, two hot spots can be place at the two sides of the LED and the output can be directed towards the two side of the roadway to preview the road conditions before turning. The system can also be extended such that the laser beam can be steered using a beam scanner such that the hot spot can be directed to the appropriate locations based on inputs from the driver or based on inputs from CCD cameras using artificial intelligence as feedback control.

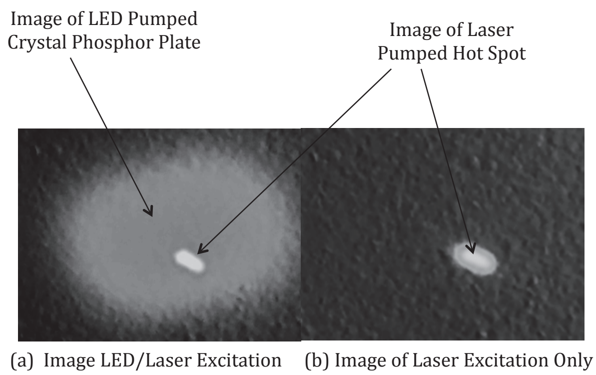


Figure 6 – Output Images of LED+Laser and Laser Only

6 Conclusions

An intelligent headlight using a single DMD and a laser pumped crystal phosphor plate producing a hot spot for extreme high beam has been designed and develop. Initial experiment results show the feasibility of producing such hot spot using high temperature a crystal phosphor plate. A complete prototype headlight has been design and being fabricated.