Investigation on RGB Laser LCoS High-resolution Headlamps

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Laser diodes and twisted nematic LCoS provide a solution to realize a high-resolution headlamp, which is able to generate white light illumination with pixel light and chromatic projection. Functionalities of such a headlamp will be discussed in this paper and a system concept using RGB laser diodes and a LCoS will be presented and testified.

1 Introduction

High-resoultion headlamps integrating with projection technologies can generate dynamic pixel beams, with which functionalities like precise glare avoidance and on-road projection can be achieved. In order to make the on-road projection content visible not only during the nighttime but also during the daytime, combining light sources with different emitting colors are considered. For this, RGB (red, green and blue) colors are commonly used.

Although white light with the color temperature of approximately 6500 K, which is close to the day light, creates good illumination in normal situations, past research indicated that the illumination light with lower color temperatures has a better visibility than those with higher color temperatures for both drivers and other road participants in adverse weathers [1]. The use of RGB light source is possbile to enable a color temperature-steerable white light as well to adapt to different weather conditions.

2 Laser diodes as light source

Laser diodes have the potential to reach a better power coversion efficiency in high power applications in comparison with LEDs in the visible spectrum range [2]. Due to this reason they are considered to be used in vehicle headlamps. Apart from the efficiency potential, laser diodes still have several important emission properties. A laser diode has a tiny emission surface and relatively small divergent angles in both horizontal and vertical axes with nearly Gaussian emissions, this allows small optical elements to be used to design a compact system. Besides, a laser diode emits the laser beam in a linealy polarization direction, which is parallel to the slow axis. This emission property requires considerations in the optical system design, where components that are sensitive to polarization states (e.g. liquid crystal devices) are used. In this case, when other optical elements that are used in the system destroy the polarization state, it may have a negative impact on the optical performace.

3 LCoS introduction

Twisted nematic LCoS (liquid crystal on silicon) is a reflective high-resolution amplitude light modulator. An LCoS is composed of a liquid crystal layer with a reflective layer underneath. The reflective layer is integrated with components like transistors and wires to control each pixel. This structure enables a high pixel aperture ratio, thus the LCoS can have a high reflectivity and consequently a high efficiency.

A twisted nematic LCoS modulates the polarization states of the incident light. It is typically used with a PBS (polarizing beam splitter), which normally reflects the S-polarized incident light and let the P-polarized light passes through. The working priciple of the LCoS with the PBS is shown in Fig. 1.

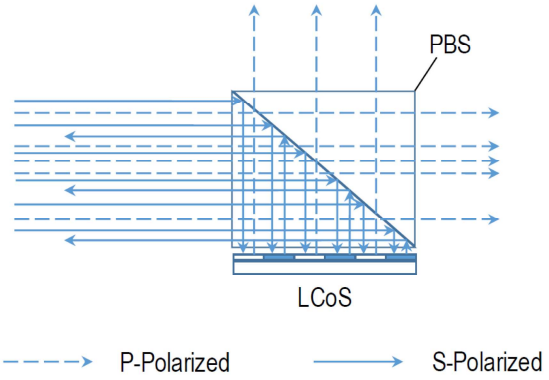

Fig. 1: Working principle and structure of a twisted nematic LCoS with a PBS.

4 System concept

The linear polarization state of light emitted by laser diodes fits the principle of the LCoS well. This means additional polarizers, which are used in liquid crystal projection devices with other light sources to generate polarized light, are no longer needed. Thus, the system efficiency of laser systems is significant

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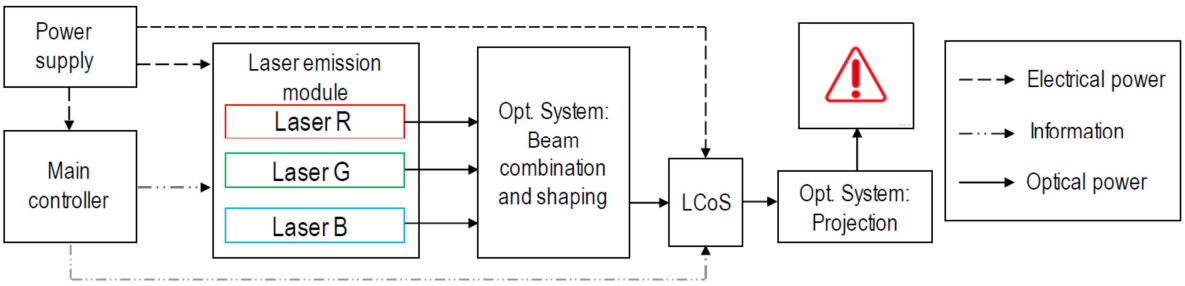

Fig. 2: Projection system concept with RGB laser diodes and a LCoS.

higher than those in other liquid crystal projection systems without the lose of contrast. A projection concept using RGB laser diodes in combination with an LCoS and necessary elements are presented in Fig. 2.

5 System investigation

A demonstrator according to the aforementioned system concept is set up for function validation. PWM (pulse width modulation) is adopted to drive the laser diodes for a better wall plug efficiency than adapting the forward current [3].

5.1 Projection result

PWM driving method is suitable to synchronize the RGB laser diodes with the LCoS for chromatic projection in CS (color sequential) mode as well. A controller can generate PWM signals for laser diodes and pixel control signals for LCoS at the same time. By doing so, RGB mixed high-resolution white light illumination and chromatic projection are achieved as shown in Fig. 3.

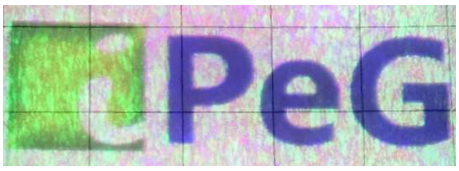

Fig. 3: Projection result of the demonstrator.

5.2 Color temperature control

The adjustment of the output power of each laser diode in the system enables the realization of the steerable color temperature within the ECE white definition [4]. Two parameters of PWM can be modulated, namely frequency and duty cycle. The influence on the laser output power of changing the modulating frequency depends highly on different laser drivers that are used. Thus the duty cycle is adopted to investigate the output adjustment. The input voltage and frequency are maintained the same during the whole measuring process, and the result is shown in Fig. 4.

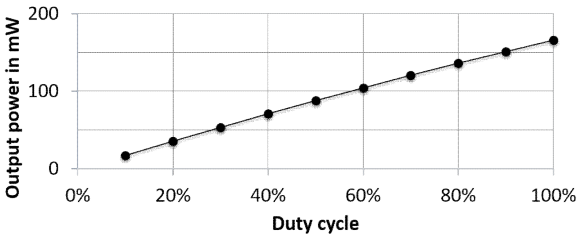

Fig. 4: Laser diode output power vs. Duty cycle.

A nearly linear growth of the laser output power through adjusting the duty cycle is observed. Therefore, controling the color temperature by adjusting the duty cycle is reasonable.

6 Conclusion

In this paper a high-resolution projection system using RGB laser diodes and a twisted nematic LCoS for investigating the functionalities of high-resolution headlamps in the future has been presented.

7 Acknowledgment

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