Integrated of LiDAR Sensor with Smart Headlight

Y.P. Chang[1], **Andy Chen**[1], **Kenneth Li**[2]

[1]Taiwan Color Optics, Inc., Taichung City, Taiwan
[2]Optonomous Technologies Inc., Agoura Hills, CA 91301, USA

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ABSTRACT

Beside low cost, the automobile design will be a major factor for the mass adoption of the LiDAR in the autonomous vehicles. It will be advantageous to integrate the LiDAR together with the headlight such that the chassis design of the vehicle does not have to deviate from standard practices. This paper presents optical design of integrated LiDAR and smart headlight in a single module such that it replaces the current headlight without impact on the overall chassis design of the vehicle. Preliminary designs of such system and results will be presented.

1 INTRODUCTION

The direction towards autonomous vehicles prompted fast-paced developments of LiDAR ranging from rotating units on the top of the roof[1] to various hidden designs around the vehicles so as the LiDAR unit is hidden somewhere. Regardless how overall design is, the LiDAR needs to be exposed to the surrounding that requires an aperture, which would be visible to the outside world. To ease the limitations to the automobile designers, it would be advantageous to integrate the LiDAR together with the headlight, especially, a smart headlight such that the overall design does not have to be changed[2]. Such design allows two units of the LiDAR to be installed together with the headlight, which would also provide extra functions, such stereoscopic LiDAR vision, to be performed if both have a common field-of-view, or having smaller field-of-view for each such that the cost can be lowered. In one implementation, a patent-pending multiple rotating polygon scanner will be mounted on the same axis of the motor providing the smart headlight function, the IR laser scanning beam, and the receiver unit. Such integrated architecture can be made with fewer components, more compact, and with low cost. The initial system with preliminary results will be presented.

2 DESIGN OF THE INTEGRATED SYSTEM

Making the integrated LiDAR/LiDAR system compact with the least number of components, a 3-level scanning is designed with one lever for headlight, one level for IR laser scanning, and another level for the detection of the reflected LiDAR signal. The system is as shown in Figure 1. Light shields are used to block stray light from each level interfering with the other levels. Especially for the detecting of the return signal, which is very weak in nature, any leakage of the IR scanning LiDAR laser beam to the detector level, will interfere with the proper operation of the detection system. Each level includes a polygon scanner designed with the appropriate number of facets with consideration of the headlight and LiDAR resolutions. Each of the levels will be described in more details in the subsequent sections.

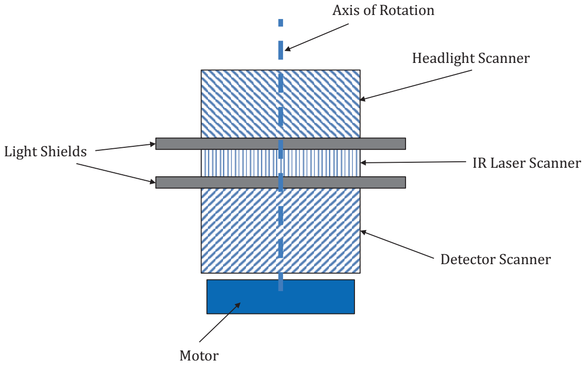

Fig. 1 Schematic Diagram of a 3-Level Integrated LiDAR/Headlight System

3 THE HEADLIGHT SYSTEM

The headlight is a laser scanning phosphor system as shown in Figure 2, in which a blue laser diode is used to excite the phosphor plate with the white light output to be projection onto the roadway.

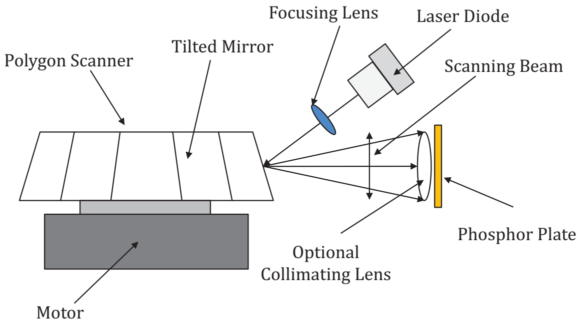

Fig. 2 Laser Scanning Phosphor Headlight

The laser diode used is a TO-9 blue laser integrated with a collimated lens. The output is then focused on the phosphor plate. A collimating lens or field lens is used in this case. The beam is scanned by the rotating polygon onto the phosphor plate. The facets on the polygon are tilted such that multiple horizontal lines can be produced and scanned onto the phosphor plate. Since the number of facets can be physically limited, in order to produce more lines as required by certain applications, multiple lasers diode can be used as shown in Figure 3 in which 4 lasers are used in the current design. The 4 lasers are lined up in the vertical plane such that reflected beams from the polygon mirrors form 4 scanned lines on the phosphor plate at one time for each tilted facet of the polygon instead of 1 scanned line for a single laser system. The total number of scanned lines will then be 4 times the original number of scanned lines.

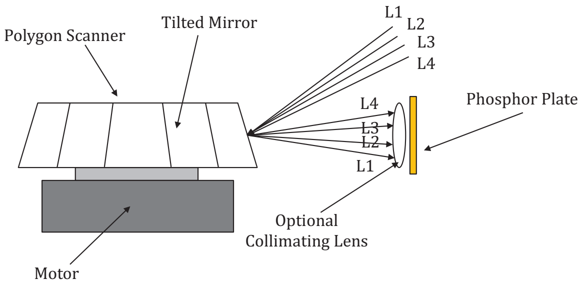

Fig. 3 Multiple Laser Headlight System

Figure 4 shows a scanning scheme where the 4 lasers outputs form a bundle of beams as a group and scan onto the phosphor plate as adjacent lines. The outputs from each facet is then scanned one after another to fill up the phosphor plate with equal spacing.

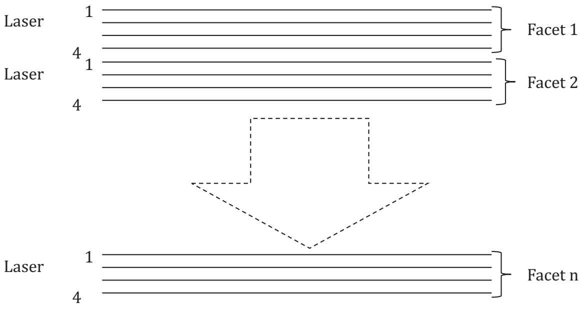

Fig. 4 Scanning with 4 Laser as a Group

Figure 5 shows another scanning scheme where the 4 lasers outputs are spread out onto the phosphor plate such that the outputs from each facet is shifted by a small amount such that the full phosphor plate is filled as shown with equal spacings.

The scanned pattern of the phosphor can be programmed as pixels such that the laser diode can be turn on and off according to the patterns desired. In general, the pixels for the high beam, low beam, selective dimming, special symbols, text, etc., can be determined by software and sent to the laser diodes synchronized with the rotation of the polygon.

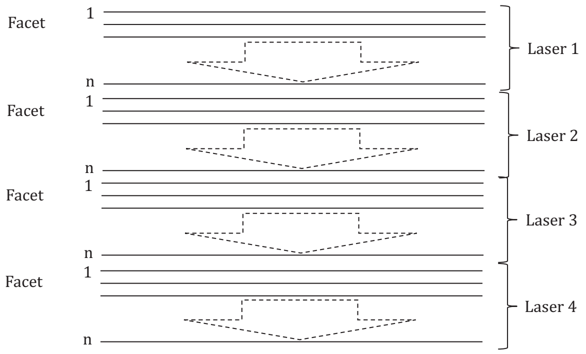

Fig. 5 Scanning with n Facets as a Group

4 THE IR LASER SCANNING SYSTEM

The laser used in the system is a 905 nm infrared laser diode with an output power of 70 W driven at full current. The output dimension of the laser diode is 225 um x 10 um. Using a collimating lens with focal length of 40 mm, the output divergence of the beam is approximately 0.3° x 0.014°, giving a spot size of 80 cm x 4 cm at a distance of 150 meters. In this study, 4 IR lasers are used such that 4 lines can be scanned at one time. The number of polygon facets are still to be determined based on the bandwidth of the detection and analyzing system such that the returned signal can be used properly within the limitations.

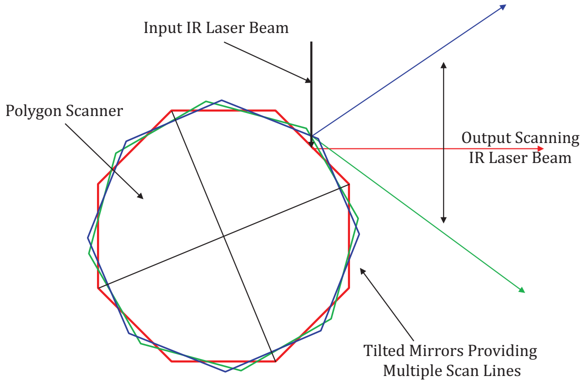

Fig. 6 Scanning IR Laser System

5 THE DETECTOR/RECEIVER SYSTEM

Although IR laser level is shielded from the detector level, the outgoing IR laser beam scanning direction has to be synchronized with the input beam direction of the detector in general. There will be a slight timing difference between the outgoing laser pulse and the detected laser pulse, which is used to calculate the distance, the exact location of the target will be determined based on time difference and the scanning speed of the polygon and there is a need to make sure that the return signals from one pulse is not mixed with another pulse as the distances of the object detected may not be continuous in nature and can have a large jump in distance from one pulse to another. Figure 7 shows the schematic diagram of the scanning polygon system together with the collection lens and the detector. The incidence angle and the width of the beam received is changing with the angle of detection and as a result, the collection lens has to collect the inputs and focus them into the same detector. Since the beam widths are different, the collected power will also be dependent on the incident angles. A shade is added to the system such that the wider beam will be made narrower and allowing the narrow beam to pass through without much change so as to equalized the input power without saturating the detector system. The output from the detector is then amplified and fed to the electronic analyzer for processing. The output could consist of a 3D sketch of the surrounding, identification of objects and types of objects.

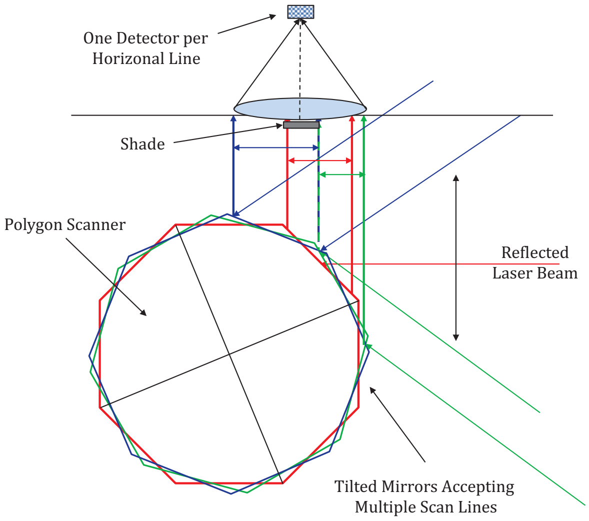

Fig. 7 Scanning Detector/Receiver System

6 THE INTEGRATED SYSTEM

Figure 8 shows the complete system with details on the headlight system with the projection lens position designed to have the same output plane as the IR laser and detector system. This allows the most efficient use of space with the smallest profile. As shown, the lasers for exciting the phosphor plate is placed on the left-hand side of the system and the output is reflected towards the back of the headlight and then redirected towards the front where the projection lens is pointing. This arrangement allows the placement of the projection lens to be place behind the output plane of the complete integrated system.

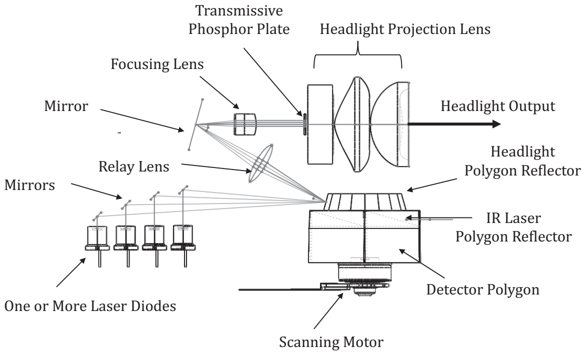

Fig. 8 Integrated LiDAR/Headlight System

The system is being designed and constructed. The final design and measurement results will be presented.

7 CONCLUSIONS

A design for the integration of the LiDAR and headlight systems are presented. This system will provide a compact and low-cost solution for smart headlight and LiDAR for autonomous vehicles where automobile design can design the product without additional constraints of the LiDAR system.

REFERENCES

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