

Research on Lamp System for Vision Sensor Support

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KEY WORDS: Electronics and control, Light, Vehicle sensor, High-Definition Lighting, Micro-LED, ADAS, Camera (E1)

1. Introduction

Nighttime performance of camera-based advanced driver-assistance systems (ADAS) is strongly influenced by headlamp illumination. Conventional low- and high-beam systems illuminate broad areas ahead of the vehicle; however, their beam patterns may not align with the driving path on curved roads. In addition, reflected light from roadside structures, such as median barriers, guardrails, and electronic signs, can introduce optical noise into camera images and degrade lane-detection performance.

This study evaluates the effectiveness of a high-resolution micro-LED headlamp system for improving nighttime lane detection. The system uses HD modules capable of independently controlling 25,600 pixels per module and selectively illuminates lane-marking areas according to road geometry. The objective was to investigate whether targeted illumination can improve lane-detection performance while reducing the adverse effects of unnecessary illumination and reflected light.

2. Experimental Method

Tests were conducted on five courses containing straight and curved road sections. The test vehicle was driven at 60 km/h on straight sections and 50 km/h on curved sections. The evaluated lighting conditions were:

Low beam / Low beam + high beam / HD module-based lane illumination

The test courses included left- and right-hand curves with radii of curvature of $R = 500$ m, $R = 250$ m, and $R = 60$ m, as well as a straight highway section with a median barrier, guardrails, and illuminated electronic signs. Lane-detection distance was evaluated using the vehicle's built-in camera.

3. Results and Discussion

The HD module-based lane illumination improved lane-detection performance, particularly on curved roads. On the left-hand curve with a radius of curvature of $R = 500$ m, targeted illumination of the left lane increased the detection distance by approximately 20 m compared with the low-beam-only condition. On the right-hand curve with a radius of curvature of $R = 250$ m, the HD module improved left-lane detection distance by approximately 6.5 m (17%) compared with low beam and by 4.9 m (10%) compared with high beam.

On the sharp curve with a radius of curvature of $R = 60$ m, no statistically significant differences were observed among the lighting conditions. This result indicates that, under very sharp-curvature conditions, the headlamp beam cannot sufficiently follow the road geometry, limiting the effectiveness of illumination control.

On the straight highway course, high-beam illumination reduced detection performance near median barriers and electronic signs because reflected light and high-luminance external light acted as optical noise in the camera image. In contrast, HD module-based illumination maintained relatively stable lane-detection performance by concentrating light on the lane area and reducing unnecessary illumination of surrounding structures.

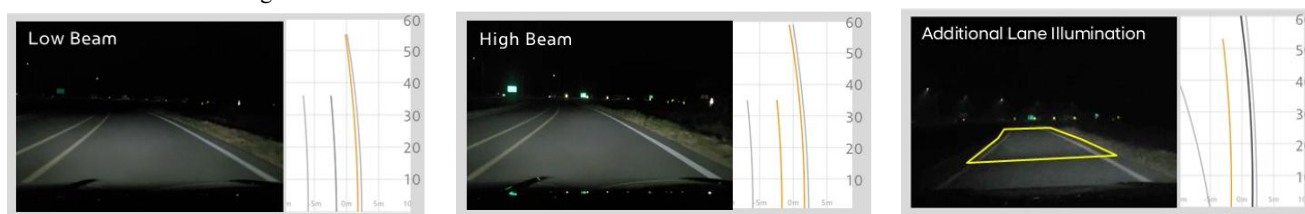


Fig.1 Road Illumination Conditions (Low beam / Low beam + high beam / HD module-based lane illumination)

4. Conclusion

The experimental results demonstrate that high-resolution micro-LED headlamp control can improve nighttime camera-based lane detection by directing illumination toward relevant lane-marking areas. Targeted HD illumination was particularly effective on moderate curves and was more robust than conventional high beams in environments containing reflective barriers and illuminated signs.

These findings indicate that road-curvature-based dynamic beam control and selective suppression of illumination toward reflective structures are important for improving the reliability of camera-based ADAS perception systems. Future work will investigate sensor-lighting fusion control algorithms and real-time beam-pattern optimization under diverse driving and environmental conditions.