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# Evaluation of Optical Performance of Low-Mounted Road Lighting Using Probeam Light Distribution

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***Abstract:*** *Ultimateobjective of road lighting is to provide the drivers with visual information for safe driving at night and from such a standpoint, installing the road lighting and securing the visibility are the optimal solution to reduce the traffic accident at night. Traditional pole lighting requires high installation cost for high lighting fixture and pole and energy consumption to raise the road luminance is high. To improve such a problem, low-mounted lighting system was developed but asymmetric light distribution at low level causes dazzling and higher cost than pole lighting is a fatal barrier. This study thus is intended to develop the road lighting system that illuminates forward at low height with the same principle as the car headlight in a bid to prevent dazzling and reduce the installation cost and energy consumption and as a result of evaluation, the problems including electrical charge, leakage light causing light pollution, dazzling and road spot were found to have been solved.*

***Keywords:*** *Probeam, light distribution, low-mounted lighting, energy*

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## I. Introduction

The death toll by road accident at nighttime is similar with that at daytime and given the traffic at nighttime is one third of the daytime, the risk of accident at night is considered extremely high.

Road lighting is ultimately intended to provide the drivers with appropriate visibility to ensure the drivers secure sufficient time and distance to avoid the risk when finding alignment change or obstacles ahead. The drivers obtain 90% of necessary information by visual organ and determine and take action for safe driving based on such information. For instance, when encounters the curved road ahead, the driver identifies the curved road with naked eye and determines the degree of curve and whether to reduce the speed and based on determination, the driver takes action by turning the wheel or stepping on the brake to reduce the speed. Besides, the driver sees with naked eye the obstacle or pedestrian on the road or distance to the car ahead and proper judgment and action are taken depending on situation. Thus the visibility on road at night has the close relations with the traffic accident. Viewing such a standpoint, installing the road lighting and securing the visibility of the driver are the optimal solution in reducing the traffic accident at night.

Traditional pole lighting requires high installation cost for high lighting fixture and pole and energy consumption to raise the road luminance is high. To improve such a problem, low-mounted lighting system was developed but asymmetric light distribution at low level causes dazzling and higher cost than pole lighting is a fatal barrier. This study thus is intended to develop the road lighting system that illuminates forward at low height with the same principle as the car headlight in a bid to prevent dazzling and reduce the installation cost and energy consumption.

## II. Development And Evaluation Of Low-Mounted Probeam Road Lighting

### II-I. Need for developing low-mounted probeam road lighting

Current road lighting criteria (CIE, 2010) evaluates the quality of road lighting (grade) based on luminance on road surface (mean luminance, uniformity factor) and most of countries adopt this criteria. Existing pole lighting designed in compliance with the relevant criteria adopts symmetrical lighting system at 9 to 15m height for reasons of economical and technical benefits which however results in many economical and technical problems such as low uniformity factor, need of high optical power, light pollution and road blocking.

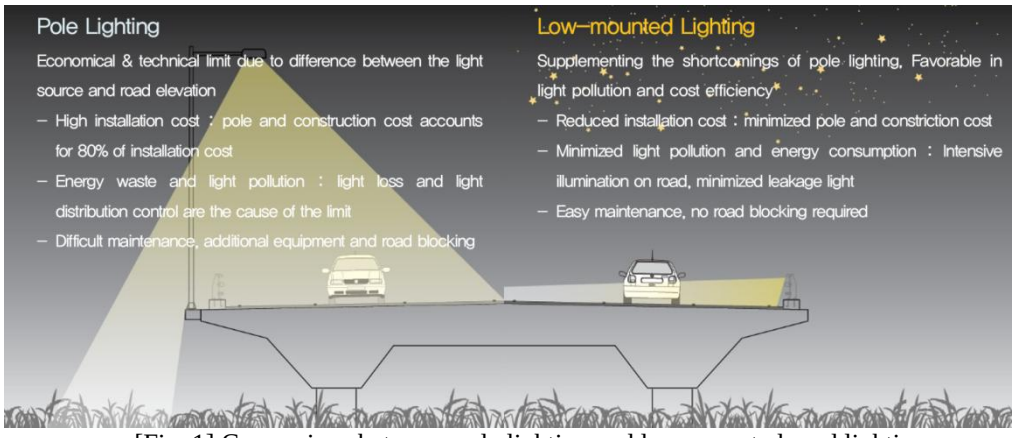
**Table 1** Grade of road lighting based on luminance, CIE 1152010

| Lighting class | Road surface | | | | Threshold increment | Surround ratio |
|---|---|---|---|---|---|---|
| | Dry | | | Wet * | | |
| | $L_{av}$ in cd·m$^{-2}$ | $U_o$ | $U_l$ | $U_o$ | $f_{TI}$ in % | $R_s$ |
| M1 | 2,0 | 0,40 | 0,70 | 0,15 | 10 | 0,5 |
| M2 | 1,5 | 0,40 | 0,70 | 0,15 | 10 | 0,5 |
| M3 | 1,0 | 0,40 | 0,60 | 0,15 | 15 | 0,5 |
| M4 | 0,75 | 0,40 | 0,60 | 0,15 | 15 | 0,5 |
| M5 | 0,50 | 0,35 | 0,40 | 0,15 | 15 | 0,5 |
| M6 | 0,30 | 0,35 | 0,40 | 0,15 | 20 | 0,5 |

*Applicable in addition to dry condition, where road surfaces are wet for a substantial part of the hours of darkness and appropriate road surface reflectance data are available.

The study on development of new type of road lighting to cope with the problems with existing pole lighting system is underway now. One of the methods developed recently is the lighting system illuminating the road surface from the road edge at driver's eye level. Low-mounted lighting system is designed to illuminate the road surface only. As low-mounted lighting system is intensively illuminate the road surface at low level and at reduced interval, light velocity required is less and energy efficiency is high and furthermore, installation and maintenance is easy. Such lighting system has been installed at expressway interchange, bridge and the access to the airport or other locations where low-mounted lighting system is more beneficial. LED is commonly used as the light source. Existing low-mounted lighting system cause more dazzling because of symmetric light distribution which distributes the light to the driver also and is costly because of dense installation and many spots on road were inevitable due to LED and optical design technologies behind.

Low-mounted lighting system using probeam light distribution (hereinafter called "Low probeam lighting") in this study was developed to cope with the economical technical limit which existing pole lighting system and symmetric light distribution have. Low-mounted lighting system is superior to pole lighting system in terms of cost, power consumption, light pollution and maintenance efficiency and probeam light distribution illuminates in car-running direction to create positive contrast that illuminates more the obstacles than road surface and is more favorable in maximizing the luminance contrast, reducing the dazzling and distinguishing the objects.



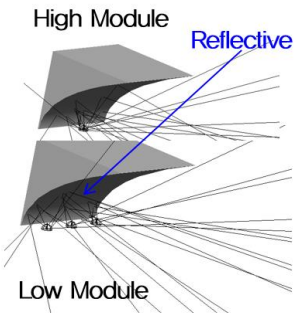
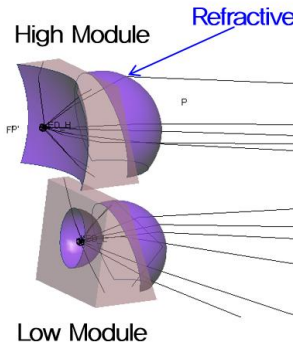
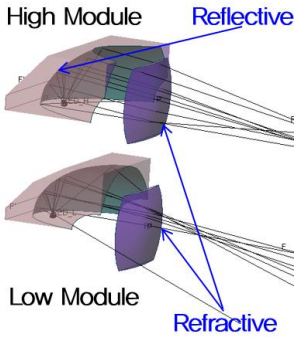

[Fig. 1] Comparison between pole lighting and low-mounted road lighting

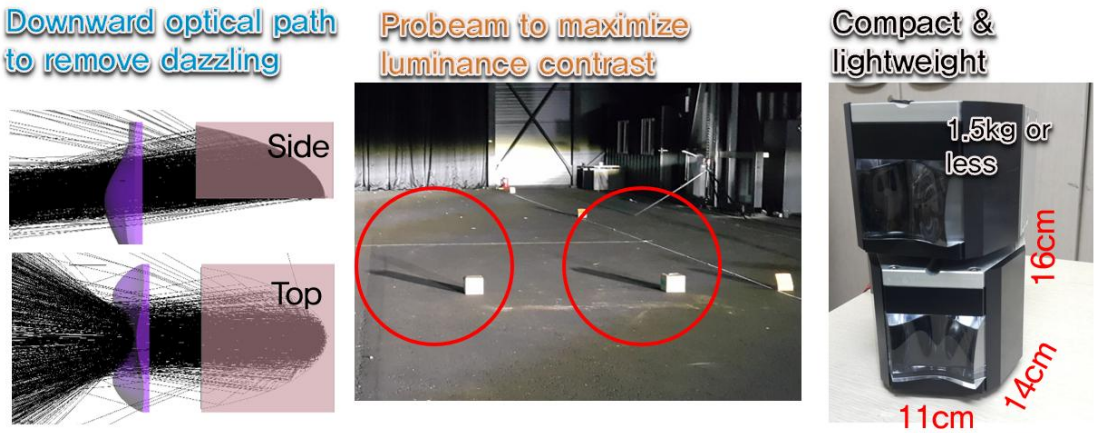
**II-II Development of low-mounted probeam road lighting**

This study is intended to define the optical system which is applicable to a 4-lane road for application to the lighting system developed. Optical system adopts the combination of reflection board and lens in consideration of compact type and efficiency and 3.5mm x 3.5mm high power LED PKG was used.

The lighting system developed finally could be installed higher and wider (1.3m high and at 6.0m interval) than existing low-mounted lighting system and as compact type (11*14*16cm$^3$) and lightweight (1.5kg or less)

**[Table 2]** Comparison of optical system design concept

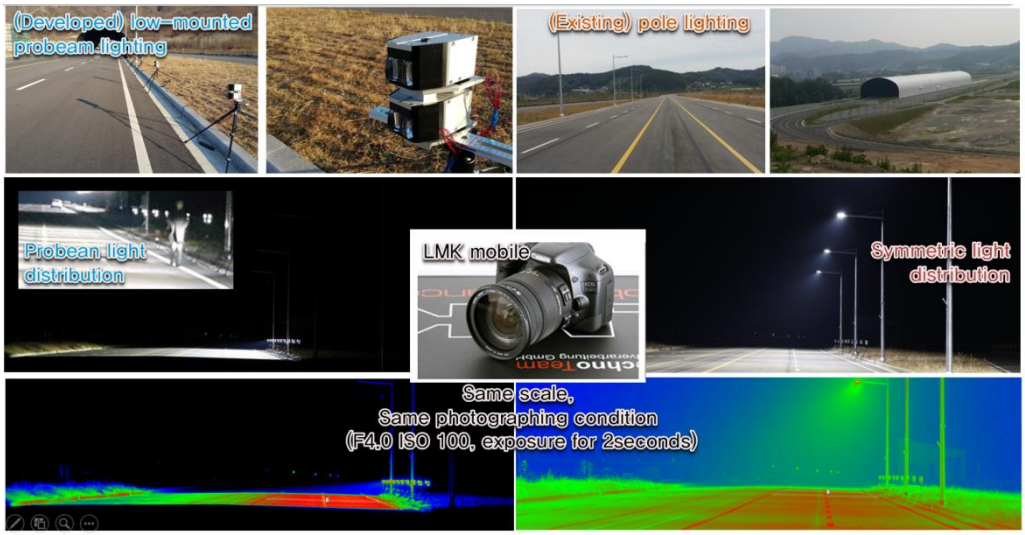
| Optical system | Reflective Optics (LED+reflection board) | Refractive Optics (LED+lens) | Hybrid Optics (LED+R/B+lens) |
|---|---|---|---|
| Optics |  |  |  |
| Features | -Upward light Cut-off<br>-Difficult to control horizontally<br>-Difficult to make optical system compact | -Compact module<br>-Upward light (Need for Aiming)<br>-Need of optical system to control vertically | -High system efficiency<br>-Easy design of reflection board and lens<br>-Higher cost than a single optical system |




[**Fig. 2]** Features of light system developed

**II-III Evaluation of optical performance of low-mounted probeam road lighting system**

To evaluate the optical performance of developed lighting system, lighting category, light pollution and power efficiency were measured on real-road test bed which was then compared with existing pole lighting system. Optical performance was measured using luminance meter (L. MK, Germany TechnoTeam Company)

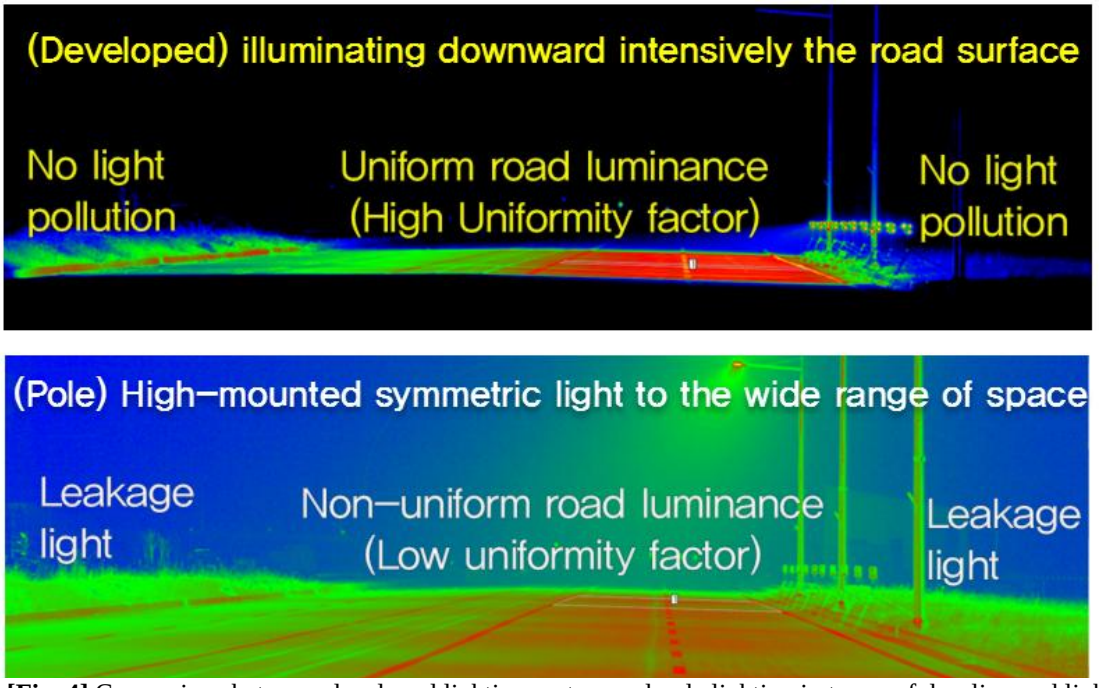



**[Fig. 3]** Measurement by comparing developed lighting and pole lighting system

As a result of evaluation, developed lighting system appeared be the highest grade exceeding M1 level which is applicable to all road conditions while existing pole lighting system was at between M2 and M3, that is, M3. And developed lighting system using probeam system that illuminates downward in car-running direction (upward light is completely cutoff) caused no dazzling in both directions, forward and backward, and as it illuminates intensively on road surface, no leakage light or light pollution was monitored. Consequently, optical performance of developed lighting system was found to be superior to existing pole lighting system.

**[Table 3]** Comparison between developed lighting system and pole lighting system

| Lighting Class | Road surface | | |
|---|---|---|---|
| | Dry | | |
| | Lav in cd/m$^2$ | Uo | Ul |
| **Developed system > M1** | **3.2** | **0.5** | **0.8** |
| M1 | 2.0 | 4.0 | 0.7 |
| M2 | 1.5 | 0.4 | 0.7 |
| **M3 < pole lighting < M2** | **1.4** | **0.7** | **0.7** |
| M3 | 1.0 | 0.4 | 0.6 |
| M4 | 0.75 | 0.4 | 0.6 |
| M5 | 0.5 | 0.35 | 0.4 |




**[Fig. 4]** Comparison between developed lighting system and pole lighting in terms of dazzling and light pollution

Thanks to technical advantages of high efficiency optical system, low-mounted lighting system, intensive lighting on road surface and minimized leakage light of the developed lighting system, M2 lighting grade (road luminance 1.5cd/m$^2$) on a 4-lane 30m-long road could be achieved with 62.5W power and energy-saving effect by 42% comparing to pole lighting system (150W) could be obtained.

## III. Conclusion

The number of the road without lighting system is more than the road with lighting system throughout the world (88% in Korea) and the traffic accident at night is the serious challenge to the society and thus the effort to increase the road with lighting system is more than important. Main cause of the road abandoned without lighting system is the financial burden to the government for installation and maintenance of the system and thus development of low cost and low energy consumption lighting system is a dire need.

The lighting system developed in this study has technical and economical advantages which are outlined as follows.

- Minimized cost for pole and foundation which is the major cause of high cost, compact and lightweight system and reduced cost burden.
- Low power consumption through optimized light distribution, the half the cost of existing pole lighting system

- Prevention of leakage light and light pollution
- Solution to intensive installation (narrow interval, 2-3m), dazzling to the driver and spots on road which are the shortcomings of existing road lighting system.
- Satisfying existing requirements, reduced resistance by road manger and manufacturer, good global marketing potential

Low-mounted lighting system has the price competitiveness which is eligible to government subsidy for non-lighting road section and existing lighting road section and based on such benefits, it's expected to make commitment to expanding road lighting as well as securing the safety of the drivers in the coming days.

## Acknowledgements

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