# Product Development of Ultra-Thin Headlights Using The RIR Optical System

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# PRODUCT DEVELOPMENT OF ULTRA-THIN HEADLIGHTS USING THE RIR OPTICAL SYSTEM

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## ABSTRACT

The demand for vehicles which conserve energy is increasing. Reducing the weight and power consumption of headlights is also required. Many of the concept cars developed by car manufacturers are designed with thin headlights. In this situation, Mitsubishi Electric Corporation has developed the RIR optical system as a new headlight module that can realize both an ultra-thin design and the high light use efficiency to meet these requirements. The RIR optical system developed was the first in the world to be used in headlights for motorcycles.

Keywords: optical system, lens design, LED, Headlight

## 1. INTRODUCTION

In order to reduce the energy consumption of vehicles from the viewpoint of lowering their environmental burden, $CO_2$ emissions and fuel consumption must be reduced. Accordingly, reducing the weight and power consumption of headlights is also required. Therefore, the use of LEDs (Light-Emitting Diodes) as the light source of headlights is being promoted [1] [2]. However, an LED is a surface emitting light source and cannot be regarded as a point light source. In addition, since the intensity distribution on the light emitting face of an LED is uniform, it is difficult to obtain the complicated light distribution that is required for headlights, and it is necessary to examine an optical system suitable for LEDs that is different from the conventional lamp light source.

Many of the concept cars appearing at auto shows use thin headlights. It is clear that the demand for thin headlights is strong [3][4]. However, the current headlight optical systems cannot completely achieve the requirements of such headlights.

We have devised and developed the RIR optical system as a new optical system for headlights that can achieve both an ultra-thin design and a high light use efficiency[5,6]. The RIR optical system is an optical system using a RIR lens consisting only of a refraction surface (R) and a total internal reflection surface (I) without utilizing reflection on an evaporated metal surface. The optical system using the RIR lens can realize both improved light use efficiency and ultra-thin design. It is believed that energy conservation and car design performance will be dramatically improved by this system. From 2021, the world's first RIR optical system will be installed in Kawasaki Heavy Industries' Ninja ZX-10R, completing its practical application.

## 2. THE RIR OPTICAL SYSTEM

This section explains the RIR optical system. Figure 1 shows the configuration of the newly development RIR optical system. The figure shows a side view of the RIR optical system. As shown in this figure, the system consists of an LED, a collecting lens and the RIR lens. The collecting lens collects the light of the LED efficiently by using a TIR (Total Internal Reflection) lens that is used for LED illumination. The system is most characterized by the RIR lens. The RIR

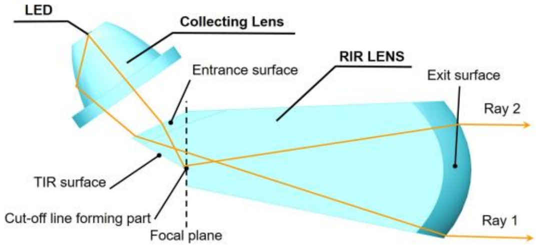


Figure 1. The RIR optical system

lens consists of a solid refractive material without an evaporated metal surface as a reflection surface and uses only the refracting surface and total reflection surface for light control.

The light emitted from the LED is collected by the collecting lens. The collecting lens can collect light at a higher light use efficiency by using the TIR lens. The light emitted from the collecting lens is concentrated near the cut-off line forming part of the RIR lens.

The incident light on the RIR lens is refracted by the free-form surface of the optimized entrance surface to form the desired light distribution. The incident light on the entrance surface passes the light path shown by Ray 1 and is projected from the exit surface. Part of the incident light on the entrance surface is reflected on the TIR surface of the RIR lens as shown by Ray 2. This reduces the light loss. Moreover, since the light along the light path of Ray 1 and the light along the light path of Ray 2 are superimposed near the cut-off line, the area near the cut-off line is brightly illuminated.

The cut-off line forming part refers to the ridge of the cut-off line formed at the end of the total reflection surface of the RIR lens. This cut-off line forming part is in a conjugate relationship with the projected light distribution on the screen.

Therefore, the cut-off line forming part coincides with the focal position of the exit surface. The RIR lens can project the light distribution pattern formed on the focal plane including the cut-off line forming part.

## 3. PROPERTIES OF THE RIR OPTICAL SYSTEM

This section explains the properties of the RIR optical system compared with the conventional headlight optical system.Figure 2 shows the outline of the optical system of a conventional type of projector headlight.

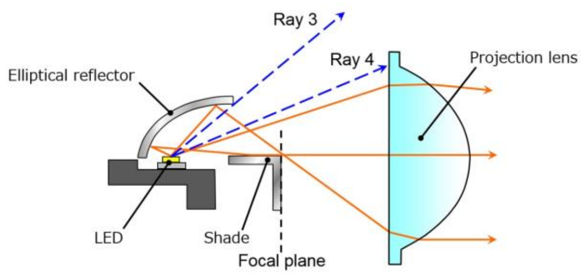


Figure 2. Projector headlight (Conventional optical system)

In the projector headlight, the elliptical reflector concentrates the light from the LED near the shade. The shade blocks the light to form a light distribution pattern having a cut-off line. Last of all, the projection lens projects the light distribution pattern formed on the focal plane. A projector headlight generally consists of three optical parts, an elliptical reflector, a shade and a projector lens. On the other hand, the RIR optical system consists of two optical parts, a collecting lens and an RIR lens. The RIR optical system can prevent the decrease in the light use efficiency because it has a smaller number of parts and a smaller optical boundary surface compared with the conventional projector headlight. The elliptical reflector used in the projector headlight has areas as shown by Ray 3 and Ray 4 where light cannot be captured in principle. In addition, the evaporated metal surface of the reflector whose reflection rate is 90% or less causes a reduction in the light use efficiency. To reflect light, the RIR optical system uses not the reflection on an evaporated metal surface, but the total reflection. The light reflection rate by total reflection is almost 100% in principle, and, therefore, reduction in the light use efficiency does not occur.

Figure 3 shows graphs which compare the light use efficiencies of the conventional projector headlight and the RIR optical system at various lens heights. For the comparison, the same LED was used as the light source, and the headlights were designed with the same light distribution pattern.

It is clear from Figure 3 that the RIR optical system has a higher light use efficiency compared to the projector headlight. When the lens height is 20 mm, the efficiency of the RIR optical system is about 1.8 times that of a projector headlight. This means that the system can realize ultra-thin headlights while maintaining high light use efficiency.

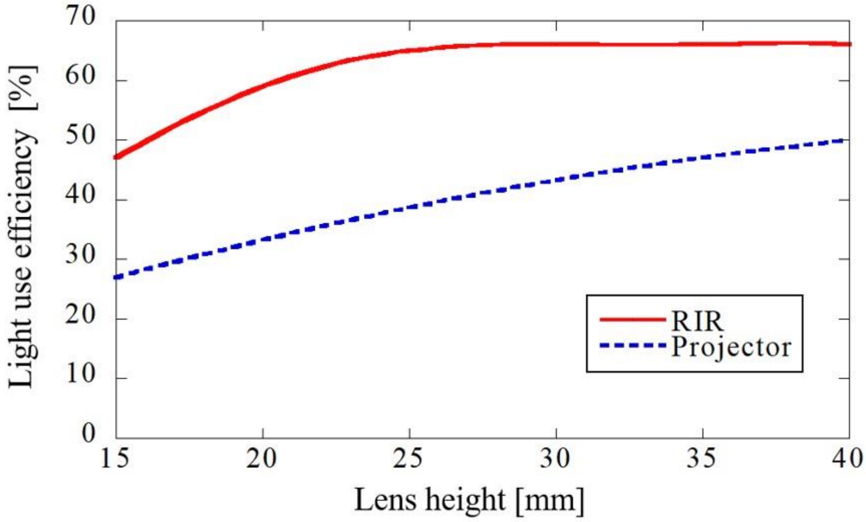


Figure 3. Comparison of light use efficiency between projector headlight and RIR optical system

## 4. PROPERTIES OF THE RIR OPTICAL SYSTEM

We have equipped the headlights of the Kawasaki Heavy Industries' Ninja ZX-10R with the world's first RIR optical system, making it practical for motorcycle headlights. The destination is all over the world. The halogen headlights of the conventional model weighed 1,650g, but the development of the RIR optical system reduced the weight to 1,200g. In addition, the lens height of the low beam is 20mm, which is overwhelmingly thinner than the conventional optical system (Figure 4[7]). Furthermore, the power consumption is 8.3 [W] for the low beam and 16.6 [W] for the high beam, achieving high energy-saving performance. Figure 5 shows the light distribution of the Ninja ZX-10R's low beam. The maximum luminous intensity is 9,250 cd, and the light distribution width in the horizontal direction is more than ±30 degrees. All of these specs were able to secure sufficient performance for motorcycle headlights.

Figure 4. Ninja ZX-10R headlight exterior [7]

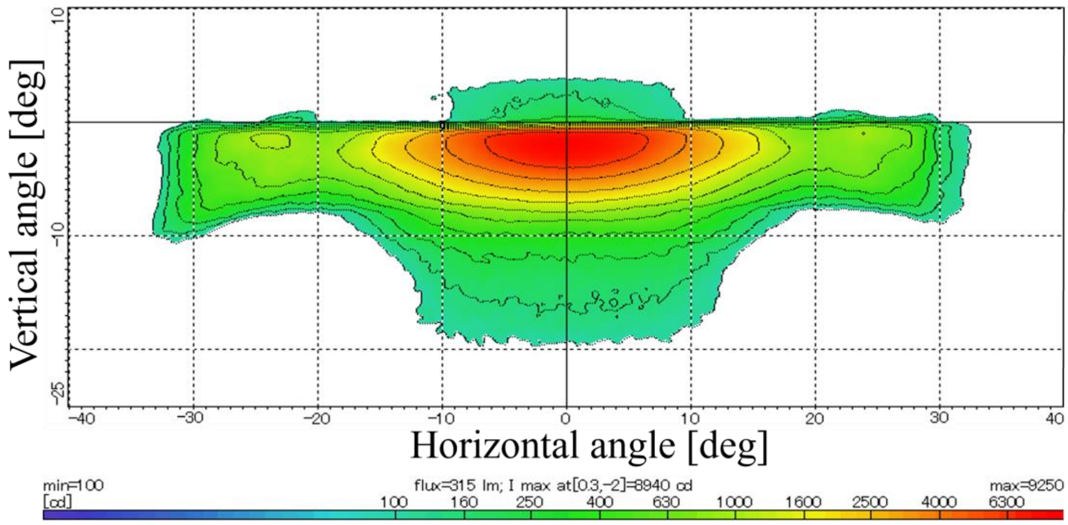


Figure 5. Light distribution of low beam

## 5. CONCLUSION

We have devised a new headlight optical system called "RIR optics" and developed an ultra-thin headlight, which has a higher light use efficiency than conventional systems, enabling a significant thinning of the lens height. This RIR optical system was the first in the world to be applied to a headlight for motorcycles and put into practical use. The low beam of the developed headlight has an ultra-thin body with a lens height of 20 mm and low power consumption of 8.3 W, but achieves high irradiation performance.

The RIR optical system can be applied not only to the motorcycle headlight that has been put to practical use, but also to various automotive lighting products such as automobile headlights and fog lamps, and can flexibly meet the design requirements of each automobile manufacturer.

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