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The optical simulation of an air-guide edge-lit

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ABSTRACT

The air-guide edge-lit without a light guide panel has been developed to meet the low manufacturing cost of a surface illuminator. The performance of the light guide inside the air layer between the curved reflector, used as the rear surface, and a flat light diffuse plate, at the front surface, depends on the shape of reflector curve and the BRDF (bidirectional reflectance distribution function) of the material of reflector. The goal of this study is to develop a ray-tracing simulation model in order to design the curve shape of the air-guide edge-lit meeting the luminance uniformity. In the present study, the BRDFs of reflector materials were measured and calibrated. The simulation accuracy in the luminance uniformity of the model was examined, and the influence of BRDF at the high angle of incidence on simulation accuracy was discussed.

1. Introduction

Recent research in surface illuminator technology has been focused on the design of a bright, slim, lightweight and low cost illumination system. As a potential design, the air-guide edge-lit [1] was proposed; the mechanism of this edge-lit is shown in Fig. 1. The edge-lit is composed of a curved reflector at the rear side, a light diffuse plate at the front side, and two light diffuse films as optical films. White LEDs are arrayed into a bar shape, and two LED bars are positioned at the top and bottom of the edge-lit. At the entrance region of the light source, a silver-coated mirror tape help the light guide, allowing the light to propagate inside the air layer located between a curved reflector and a flat light diffuse plate. The luminance uniformity of the edge-lit depends on the curved shape and the bidirectional reflectance distribution function (BRDF) [2] of the reflector material. In particular, for a high angle of incidence (AOI) of 75–85°, the BRDF plays an important role in the brightness control at the central region of the illuminator. Therefore, to meet the luminance uniformity for a reflector of a given material, the curve profile of the material should be carefully designed considering its bidirectional scattering distribution function.

A ray-tracing optical simulation technique has the potential for cost-effective development. The goal of the present study is to develop a ray-tracing simulation model with high prediction accuracy in luminance uniformity.

In order to examine the simulation accuracy, a calibration of the measured BRDF data was undertaken to compensate for the technical difficulties that arise when measuring the BRDF at a high AOI. For instance, a commercial BRDF measurement system shows poor reliability in BRDF measurements at the high AOI of 85°.

2. Optical measurement for accurate simulation of edge-lit

2.1. Reflector

As the reflector material, three reflector films (R1–R3) with different BRDFs were used. The BRDFs were measured using the IS-SA measurement system (Radiant Corporation). The measurements were undertaken for an AOI ranging from 0° to 80° with a resolution of 5°. The BRDF measurement at an AOI of 85° was however impossible to obtain, since the measuring machine demonstrated poor reliability in the results. As shown in Fig. 2(a) and (b), R3 had a strong specular reflection component; R2, a moderate specular reflection component; and R1, an almost diffuse reflection component. Further, as shown in Fig. 2(c), the peak intensity value increases with the AOI increase, as does the difference in the peak intensities between the reflectors.

The curved geometries of the two profiles of the reflectors (C1 and C2) were drawn by Auto-CAD software, as shown in Fig. 3. C1 and C2 showed the same profiles at both ends; however, C1 was a little steeper than C2 at the center.

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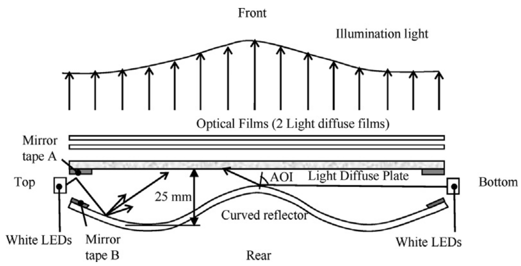

Fig. 1. Air-guide edge-lit [1].

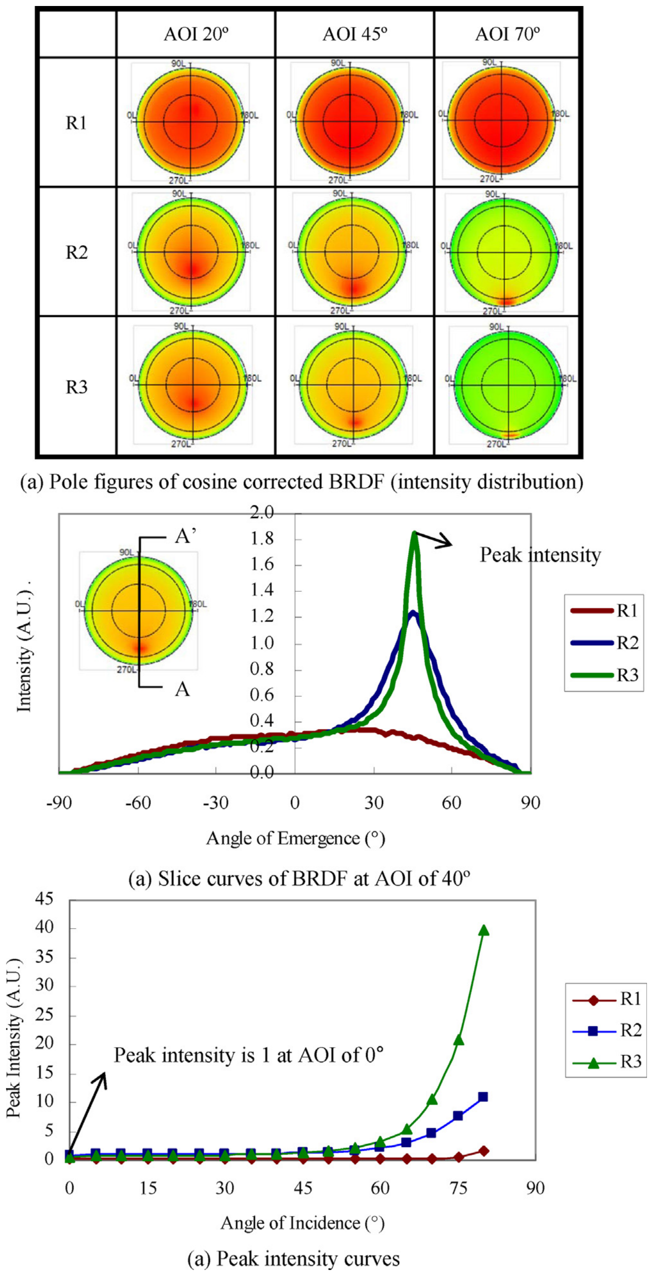

Fig. 2. Measured BRDF of the reflectors.

2.2. Edge-lit

An edge-lit mockup of 706 mm × 400 mm in size was constructed based on the design shown in Fig. 1. Two curved blocks were used, and the three reflection films (R1–R3) were attached along the block surface with adhesive tape. The total optical gap between the reflector and the diffuse plate was 25 mm. 56 White LEDs in the 6030 package, with a viewing angle of 124°, were equally spaced along a bar measuring 706 mm, and the two bars were located at both edges. A 2.0 mm thick light diffuse plate with a transmittance of 65% (DQ, Bayer Material Science Corporation) was used, and two light diffuse films (SD743, Shinhwa corporation) were used as the optical films. The bidirectional scattering distribution functions (BSDF) of a diffuse plate and a diffuse film were measured. Silver-coated mirror tapes A and B (20 mm and 40 mm in length, respectively) were used at the entrance region of the light source. The reflectance of the mirror tape was measured with a spectrophotometer.

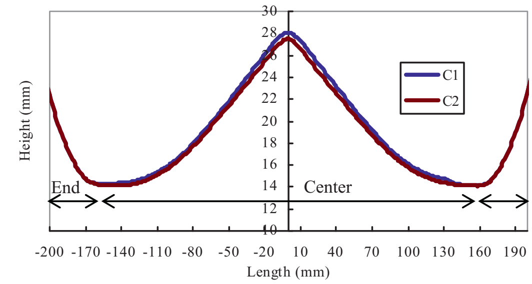

Fig. 3. Curved profiles of the reflectors.

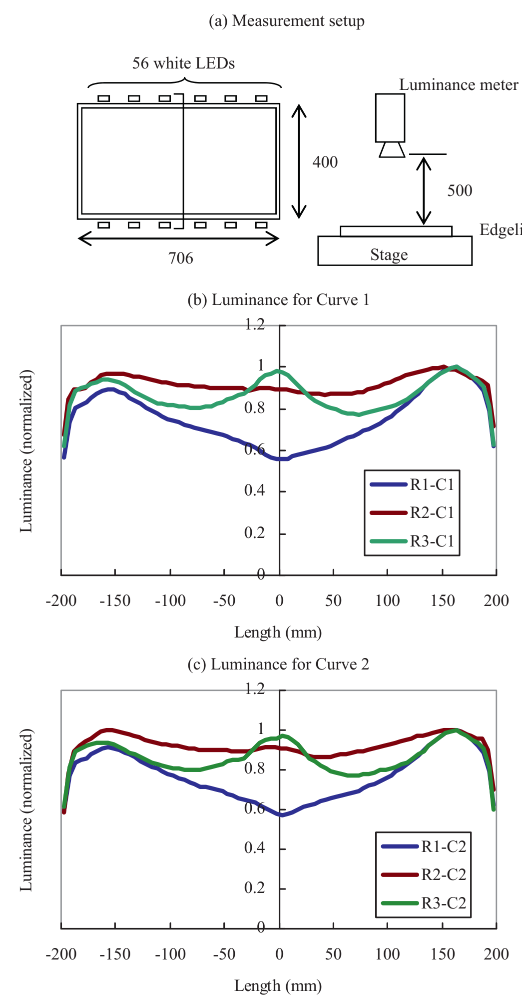

Fig. 4. Measurement of luminance uniformity of edge-lit mockup.