

# The Design of Asymmetrical TIR Optics with Micro-Structure for Museum Exhibition Lighting

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**Abstract**—An analysis of asymmetrical lenses with microstructures for museum exhibition lighting is proposed. According to simulation results, using an asymmetrical light shape will increase the illumination uniformity more than 13.1% relative to the standard lambertian light shape.

**Keywords**—Asymmetrical lens, microstructure, museum lighting.

## I. INTRODUCTION

Due to the source characteristics of LED, which include long lifetime, high efficiency and low UV and IR pollution features[1][2], LEDs are commonly used in museums[3]. Therefore, the secondary optics design is important for lighting control. Because spot lights are often unsuitable for high quality museum exhibition lighting due to their shape, there exist many different asymmetrical light shape designs[4][5] for different-sized exhibits, such as statues or paintings. In this study, a new design for total internal reflection (TIR) optics with microstructures is proposed. This well-designed asymmetrical light shape for exhibits will significantly improve lighting and thereby exhibition quality.

## II. OPTICAL SIMULATION

The design process for creating the total internal reflection (TIR) optics with microstructure is shown in Fig. 1. Ray tracing for the optics model is constructed in TracePro. The museum exhibition environment (modeled in Dialux) with three exhibits was performed. The design parameters, the shape of the microstructure and the tilt angle of the inclined plane are listed in TABLE 1. For fabrication considerations, the width (W) and pitch (P) of the microstructure are fixed to 1.4 mm and 0.1 mm.

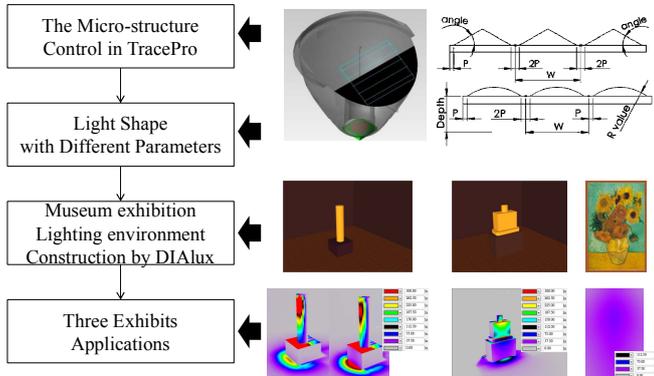


Fig. 1 The design of the asymmetrical TIR optics

TABLE 1. DESIGN VARIABLES

|                             |  |
|-----------------------------|--|
| Shapes of micro structure   | triangle、semi-circular                     |
| Variable of micro structure | number (N)、 angle、 arrangement、 radius (R) |

In TracePro, the light source is lambertian. The lens material is PMMA. To fit the common lens holder, the diameter of the TIR lens was set to 8.9 mm. The microstructure is constructed with the RepTile feature to cut down on iteration time. Our simulation was run for three types of different light shapes, as shown in Fig. 2.

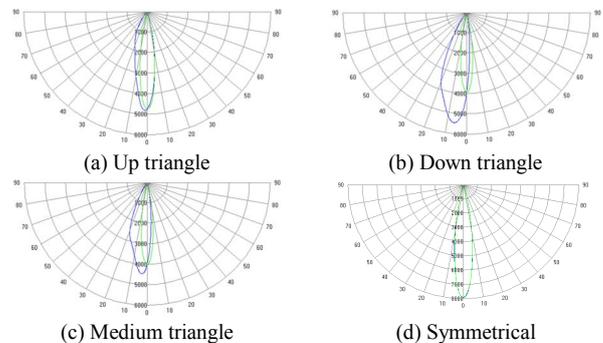


Fig. 2 The light shape's control over the TIR optics

## III. EXHIBITION LIGHT ENVIRONMENT RESULTS

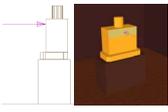
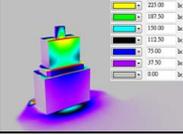
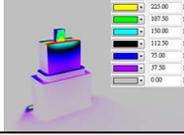
The light shapes exported by the optical model, as shown in Fig. 2, were imported and compared with a symmetrical lens in DIALux to evaluate their effects on three exhibits: Buddha, Tower and painting. According to the code (GBT 23863-2009) for the lighting design of museums[6], the maximum illuminance limit in low light sensitivity exhibits (e.g., metalwork, glass products, ceramics) is 300lx, and the high sensitivity exhibits (e.g., paintings, silver products, undyed leathers) illuminance limit is set to 150lx. However, it is important to note that in actual museum exhibits, the lighting illuminance will be lower than estimated. In our simulation, we set the illuminance maxima of the Buddha and Tower exhibits to 200lx and of the painting exhibit to 100lx. Specifics are discussed in the following.

### Buddha exhibit

The size of the Buddha exhibit, which is a low light sensitivity exhibit, is  $1.2 \times 0.6 \times 1.85 \text{ m}^3$ . The Down triangle light shape was selected for this exhibit. The observation surface S was used to evaluate the illumination uniformity.

The illumination uniformity is defined as the minimum illuminance divided by the average illuminance at the observation surface. As in TABLE 2, the illumination uniformity at the observation surface S for the down triangle is 0.788 and is 0.68 for the symmetrical lens shape. The observation S size is  $0.8 \times 0.2 \text{ m}^2$ .

TABLE 2. SIMULATION RESULTS OF BUDDHA EXHIBIT

|   | <i>Down triangle</i>  | <i>Symmetrical</i>  |
|---|---|---|
|  |  |  |
| Illumination uniformity at observation surface S                                  | 0.788   | 0.68  |

*Tower exhibit*

The size of the Tower exhibition, which is a low light sensitivity exhibition, is diameter 0.3 m and highness 1.4m. Since the code (GBT 23863-2009) for the lighting design of museum exhibitions does not explicitly define how to calculate illumination uniformity, we defined it as follows.

The Tower exhibit is long and narrow, so the observation points were changed to twelve-point, and the illumination uniformity are 0.41. As such, to an observer the Symmetrical light shape would appear to have reflected glare on the glass surface, but the Up triangle light shape does not, as shown in Fig. 3. As a result, the Up triangle is better than Symmetrical light shape because it will not produce reflected glare.

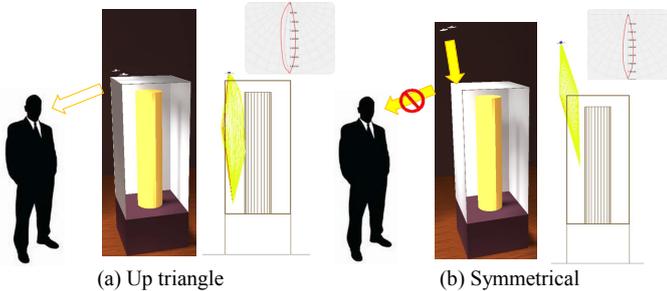
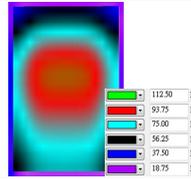
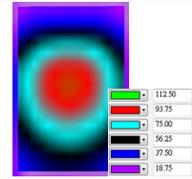


Fig. 3 Comparing (a) up triangle with (b) symmetrical light shapes

*Painting exhibit*

The size of the painting is  $0.59 \times 0.9 \text{ m}^2$ . It was classified as a high light sensitivity exhibition, so the plane exhibition illumination uniformity should be upwards of 0.8 according to the museum lighting standard. We use the nine-point method to calculate uniformity. The illumination uniformity is defined as for the Buddha exhibit. According to simulation results, the illumination uniformity of the lens with the Medium triangle is 0.84, and the symmetrical lens gives 0.73 (TABLE 3). The uniformity of the Medium triangle shape is better than the Symmetrical light shape; therefore, the Medium light shape is more suitable than the Symmetrical light shape for exhibiting the painting.

TABLE 3. SIMULATIONS RESULTS OF PAINTING

|                                 | <i>Medium triangle</i>  | <i>Symmetrical</i>  |
|---------------------------------|---|---|
| Light environment of simulation |  |  |
| Pseudo Color                    |  |  |
| The average illuminance         | 76(lx)  | 63(lx)  |
| The minimum illuminance         | 64(lx)  | 46(lx)  |
| Illumination uniformity         | 0.84  | 0.73  |

IV. RESULTS AND CONCLUSION

In this study, the design of asymmetrical TIR lenses with microstructure for museum exhibition lighting for three exhibits of low and high light sensitivity is discussed. It was found that the down triangle light shape is suitable for the Buddha exhibit; the Up. The Up triangle light shape is appropriate for the Tower exhibit and decreases the reflected glare; and, the Medium triangle light shape is suitable for the painting, giving a uniformity improvement of more than 13.1% relative to the symmetrical light shape. It seems that asymmetrical microstructure optics are promising for high quality museum exhibition lighting designs in the future.

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REFERENCES

- [1] T. Perrin, J. Druzik, and N. Miller, “SSL ADOPTION BY MUSEUMS: SURVEY RESULTS, ANALYSIS, AND RECOMMENDATIONS,” Department of Energy, U.S., Nov. 2014.
- [2] Lin Chang, “The Feasibility of Light Emitting Diode Use in Museums and the Blue Light Hazard,” *Museol. Q.*, vol. Volume 28, no. 4, pp. 121–132, Oct. 2014.
- [3] M. Fontoynt, J. Pierre Miras, M. Angelini, J. Chanussot, C. Marty, G. Duchêne, L. Novakovski, K. Makita, and T. Moriyama, “Lighting Mona Lisa with LEDs: details concerning innovating techniques(TOSHIBA Lamp – 2013).”
- [4] J. C. Minano, W. Falicoff, P. Benitez, W. A. Parkyn, J. P. Chaves, and Y. Sun, “Asymmetric TIR lenses producing off-axis beams,” US6924943 B2, 02-Aug-2005.
- [5] W. A. Parkyn and D. G. Pelka, “Cylindrical irradiance-mapping lens and its applications to LED shelf-lighting,” US7273299 B2, 25-Sep-2007.
- [6] *GBT 23863-2009 lighting design of museum.* 2009.