Analysis on the retro-reflection effective area of the truncated corner cubes

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It is well known that the conventional retro-reflection corner cube has the maximum retro-reflection efficiency of 67%. The truncated corner cube structures which have the incidence facet covered in the effective retro-reflection area of the conventional corner cube can have the effective retro-reflection efficiency up to 100%. In this paper, the effective retro-reflection area of the truncated corner cube is analyzed with the Zemax software and, as a result, the optimal design of the truncated corner cube is proposed.

Keywords- Geometric optical design, retro-reflection, corner-cube

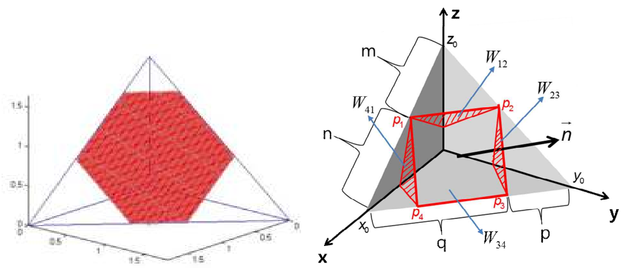
I. INTRODUCTION

The corner cube is an optical device for retro-reflection of incident light. The retro-reflection is the back-reflection of the incoming light to the exact reverse direction of the incidence. The important parameter of the corner cube is the effective retro-reflection area, which is the specified area on the incidence facet of the corner cube where the incident light can be correctly retro-reflected as indicated in Fig. 1(a). The effective retro-reflection area is interpreted as the efficiency of the corner-cube device and usually represented in terms of percentage. The optimal structure of the corner cubes with a maximum retro-reflective efficiency should be determined for the specified direction of the incident light since retro-reflection effective area varies with to the direction of the incident light. It is well known that the regular corner cube can have largest effective retro-reflective area of the hexagonal shape of 67% [1, 2] as shown.

In this paper, we propose the optimal structure of truncated corner cube that can have almost 100% retro-reflection efficiency by modifying the corner cube with the limited retro-reflective effective efficiency. The modeling and optimization are conducted with the ZEMAX software to make the truncated corner cube with the retro-reflection efficiency of 100%.

II. TRUNCATED CORENR CUBE

The structure of the truncated corner cube to maximize the retro-reflection effective efficiency for incident light in either direction is shown in Fig. 1(b). The truncated corner cube refers to the structure sculptured so that it has the incident surface of the square shape ($P_1P_2P_3P_4$) defined within the hexagon retro-reflection effective area of the regular corner cube. Three corners of the regular corner cube are cut out. The regular corner cube with tilt angle of 2.29 ° is considered, of which the effective retro-reflection area of a hexagonal shape is shown in Fig.1(a). Four vertices of the incident surface of the truncated corner cube are touched to and divide the three edges of the regular corner cube internally. The ratio of the internal division is set to m:n as shown in Fig. 1(b).



(a) (b)

Fig.1 (a) Retro-reflection effective area of the regular corner cube and (b) truncated corner cube

III. ANALYSIS ON EFFECTIVE AREA OF RETRO-REFLECTION

Because the truncated corner-cube has a plane of incidence in the hexagonal retro-reflection effective area of the regular corner cube, the truncated corner cube is expected to have a retro-reflection effective efficiency of 100%.

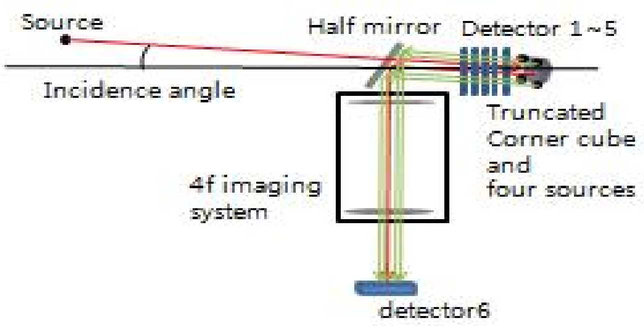
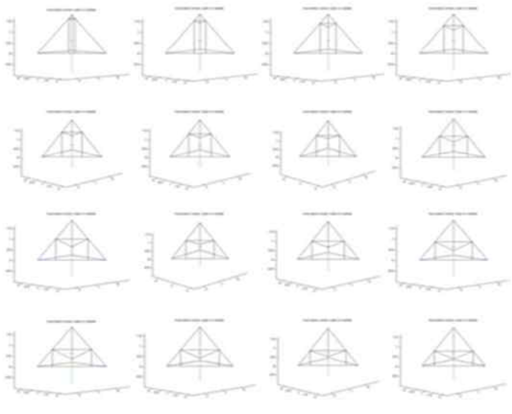


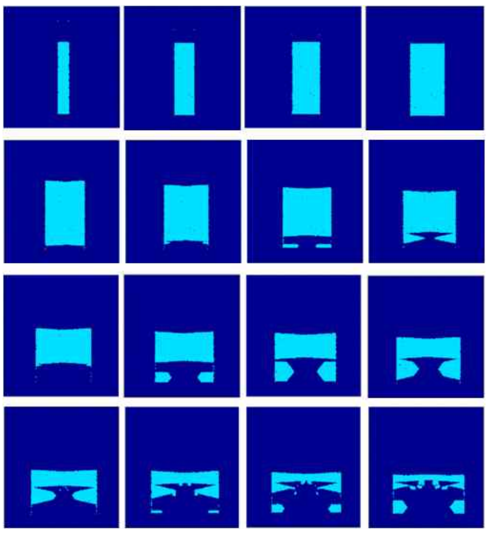
Fig 2. Zemax schematic.

To examine the expectation, the retro-reflection characteristics of the truncated corner cube are analyzed with the ZEMAX software. The schematic of the ZEMAX simulation is illustrated in Fig. 2. The light incident on the truncated corner cube, which is located at a distance of 1000mm from the point light source, is returned to the point light source by retro-reflection. The distribution of the light measured by the detector reflects the retro-reflection effective area of the truncated corner cube under the inspection.

In the analysis, 16 different truncated corner-cubes with various m:n ratios are examined. Here, n is fixed to 1, and m is varies from 0.1 to 1.6 with the variation interval of 0.1. In this example, m is constraint smaller than 1.6, because the truncated corner cube should include the apex point of the regular corner cube. The 16 truncated corner-cubes and their effective retro-reflection areas are presented in Fig. 3, respectively.



(a)



(b)

Fig.3 (a) 16 truncated corner cubes with various m:n ratios (various m from 0.1 to 1.6) (b) the retro-reflection area of the truncated corner cubes calculated for the illumination of the incidence angle of 4º.

The illumination of the incidence angle of 4° on the incidence facet of a truncated corner cube produce partially retro-reflection and some loss due to stray reflections by side walls of the truncated corner cube. The effective retro-reflection area is dependent on the structure parameterized by the parameter m.

IV. CONCLUSION

Unlike the initial expectation that the effective retro-reflection area of the truncated corner cubes would be near 100%, the stray reflection on the side walls of the truncated corner-cube hinders the perfect retro-reflection and as a result, the retro-reflection efficiency becomes strongly dependent on the structure. The simulation results in Fig. 3(b) show that the retro-reflection effective efficiency is highest at 98.9% when the value of m is 0.4.

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