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## **Quasi-retroreflection from corner cubes** with refractive free-form surfaces

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**Abstract:** Quasi-retroreflection from corner-cube structures with a refractive free-form surface is studied. It is shown that adjustment of the structural parameters of the free-form surface allows control of quasiretroreflection. Quasi-retroreflection cornercube array sheets with specified quasi-retroreflection angle are modeled, and their quasi-retroreflection characteristics are analyzed.



Automobile traffic application of quasi-retroreflection: entrance and observation angles are denoted by  $\alpha$ ,  $\beta$ , respectively.

## <u>Geometric Model of Quasi-Retroreflection Corner Cube</u>





Classification of Retroreflection with respect to Table 1.

Case	Entrance	Exit	Retroreflection
$egin{array}{c} 1 \\ 2 \\ 3 \\ 4 \end{array}$	F1	F1	Perfect
	F1	F2	Quasi
	F1	F3	Quasi
	F2	F1	Quasi

Quasi-retroreflection patterns in horizontal gratings for various base angles,  $\phi$ , (a)  $\phi$ = 0°, (b)  $\phi$  = 0.15°, (c)  $\phi$  = 0.30°, and (d)  $\varphi = 0.45^{\circ}$ . The relation of the observation angle to the base angle is represented graphically.

Quasi-retroreflection patterns in vertical gratings for various base angles, φ, (a) φ = 0.25°, (b)  $\phi$  = 0.30°, (c)  $\phi$  = 0.35°, and (d)  $\varphi = 0.40^{\circ}$ . The relation of the observation angle to the base angle is represented graphically.



(a) Perfect retroreflection in a corner-cube structure. (b) Proposed quasi-retroreflection corner-cube structure with trapezoid free-form surface. (c) Generation of perfect and quasi-retroreflections according to the combination of entrance-exit pair at the trapezoid free-form surface.



Observation angle distribution versus base angle of the free-form surface. (b) Geometry for analysis of Case 3. (c) Angle deviation of  $\delta$  for the normal incidence angles.



Quasi-retroreflection power ratios for (a) horizontal configuration and (b) vertical configuration of the surface free-form structure.

## **Quasi-Retroreflection Corner-Cube sheets**



Source point

(a) Perfect retroreflection in a corner-cube structure. (b) Quasi-retroreflection by a corner-cube structure with a triangular surface relief.





w/o free-form

 $\omega = 0.5^{\circ}$ 

The proposed quasi-retroreflection structure is modeled and analyzed by ZEMAX software. Rays emitted from a point source are illuminated on the entrance facet of the pair of two triangular pyramid corner cubes with free-form surface array. Here, the unit of the free-form surface array is assumed to be a trapezoidal form parameterized by base angle φ and flat plane width m. Width m corresponds to the flat facet F2. The reflected rays are measured by a flat rectangular power detector distant from the structure.



ZEMAX modeling and simulation results of the quasi-retroreflection corner-cube structures with (a) vertical and (b) horizontal prism arrays on their entrance facets.



200 mm.

## Conclusion

(a) Perfect retroreflection with base angle of  $\varphi = 0^{\circ}$  and quasiretroreflection with base angles of (b)  $\phi = 0.5^{\circ}$ , (c)  $\phi = 1.0^{\circ}$ , and (d)  $\varphi = 1.5^{\circ}$ . The source is distant by d = 20,000 mm.

The quasi-retroreflection from a corner-cube structure have analyzed with a trapezoid refractive free-form surface structure and shown that the adjustment of the surface freeform structure allows control of the quasi-retroreflection profile and its efficiency. The optimal quasi-retroreflection corner-cube sheet for specified observation angle can be designed based on the proposed method. In practice, the proposed structure is feasible for manipulating high-performance retroreflection sheets.



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