White Paper : Platanus® Diffuser for 3D-TOF Sensors

1. Introduction

3D sensing technology is a technology to acquire not only 2D images but also depth (distance information) as image data. In recent years, technology for measuring the distance of objects reflected with a camera has been widely used not only in conventional industrial measurement applications, but also in consumer applications such as automated driving, augmented reality (AR) and virtual reality (VR) game devices mounted on smartphones, and robot home appliances, as shown in Figure 1.

Among 3D sensing technologies, Time of Flight (TOF) sensing is a measurement technique that calculates the distance between a camera and an object based on the time it takes for irradiated light to be reflected back to the object. This technology has advantages such as smaller system size, less CPU load during data acquisition, and the ability to be used in dark areas.

The optical diffuser for TOF sensing discussed here is an optical element that controls the light distribution so that the light emitted from the light source and transmitted through the element is irradiated with the desired intensity distribution in the field of view of the light receiving camera. Its characteristic optical performance and applications are described below.

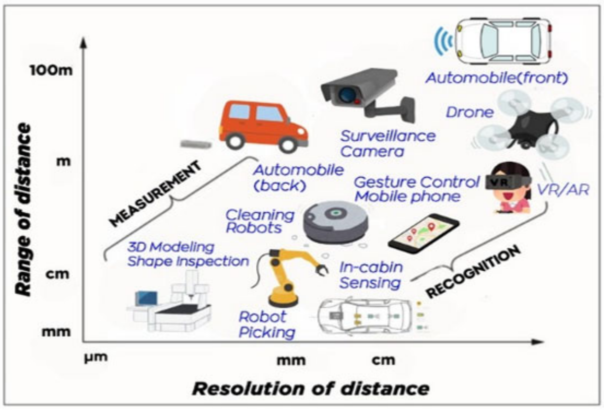


Figure 1: Measurement distance, resolution and application fields of 3D sensing

2. Diffuser for TOF System

Figure 2 shows the relationship between a TOF system and an optical diffuser. The TOF system consists of a light source and a receiver. In the light source section, pulsed light emitted from a surface emitting laser (VCSEL) passes through an optical diffuser consisting of a diffractive optical element (DOE) or a microlens array (MLA), and the area to be measured is irradiated with this diffused light. In the light receiving section, the light receiving camera detects the light reflected from the subject and calculates the distance of the subject from the delay of the reflected light.

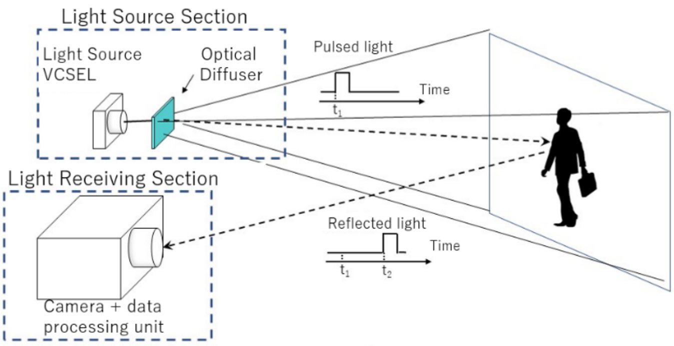
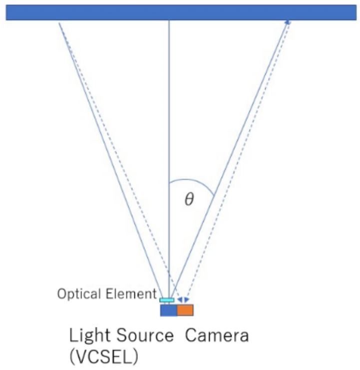
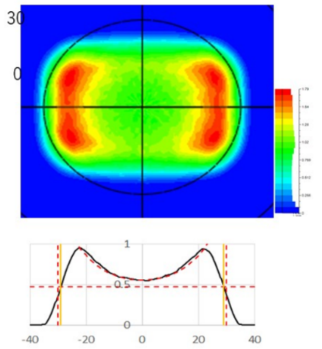


Figure 2: 3D sensing by TOF (Time of Flight)

Optical diffusers control the light distribution intensity as shown in Figure 3. In order to measure the distance accurately, the intensity of the light emitted from the light source, reflected by the object, and returned to the light receiving sensor of the camera should be uniformly close to the incident direction, as shown in (a). However, if we consider that the light is diffusely reflected (Lambert reflection) on a flat surface as shown in Fig. 3(a), the larger the camera's viewing angle Θ is, the weaker the reflected light that reaches the camera. To compensate for this, an optical diffuser is used to make the correction. The ideal condition for sensing, where light is uniformly incident on the light receiving sensor across the angle Θ, is said to be the intensity distribution P(Θ) ∝ cos-7 in the far field, and optical diffusers are designed so that the light transmitted through them approaches this condition. However, it is difficult to make the distribution completely proportional to (cosθ)-7 when the light is irradiated to a very wide viewing angle, so the camera sensitivity is adjusted by making the distribution proportional to (cosθ)-n (1<n<7). (b) is an example of the light distribution intensity transmitted through an optical diffuser designed in this way, in terms of contour and cross-sectional intensity distributions



(a) Optical system



(b) Intensity distribution in far-field

Figure 3: Light Distribution Intensity through an Optical Diffuser

3. Thesis Questions

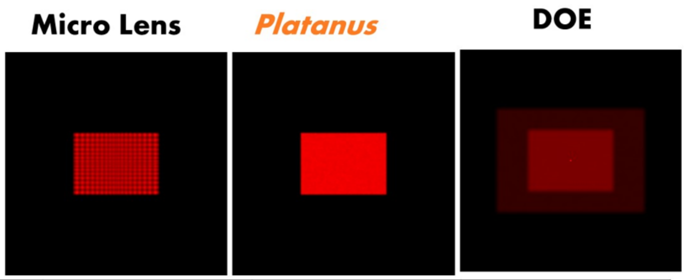
MLA and DOE, which are conventionally used as optical diffusers, are known to have their own challenges in their use. DOE, which control the phase distribution of light emitted from a light source by means of a pattern of elements, have the advantage of high design flexibility and easy control of the orientation distribution of the emitted light. On the other hand, there is a certain amount of light whose optical path cannot be completely controlled due to evanescent light seeping at the position where the local phase change occurs. This results in the generation of zero-order light that travels straight from the light source without diffraction and stray light that is randomly scattered outside the irradiated area and becomes background light, reducing the accuracy of measurement and the efficiency of light use.

On the other hand, MLA, which utilize light refraction, do not generate zeroth-order light or stray light, and provides extremely high light utilization efficiency. However, depending on the positional relationship between the lens and the light source, interference and other phenomena may prevent uniform irradiation. In addition, the degree of freedom of the light distribution of the emitted light is inferior to that of DOE, and there is a limit to the irradiation at high angles.

4. Solutions

In order to solve the respective problems of diffractive optical (DOE) and refractive optical (MLA), SCIVAX has devised a hybrid optical system of diffractive and refractive systems and developed a unique optical diffuser, Platanus®.

Figure 4 shows a comparison of the characteristics of conventional MLAs and DOEs with those of our Platanus®, which effectively utilizes both diffractive and refractive properties of light to achieve high light use efficiency equivalent to or higher than that of MLAs, and light distribution with a high degree of freedom and evenness equivalent to that of DOEs.



	Micro Lens	Platanus	DOE
Efficiency	◎ (> 85%)	◎ (> 85%)	△ (< 80%)
Uniformity	△ (Artifact, Moiré)	◎ (Speckle free)	○ (Need to remove 0th order)

Figure 4: Characteristics of our optical diffuser Platanus

5. Products Info

Figure 5 shows some examples of diffuse optical elements in SCIVAX catalog products. Taking advantage of Platanus®'s highly flexible structure in terms of light distribution intensity, SCIVAX can cover a wide variety of Field Of Illumination (FOI) from narrow angle to the industry's widest ultra-wide angle, and provide 3D-TOF an optical diffusers optimized for customer applications such as industrial measurement, mobile, robotic home appliances, and automated driving. In addition to the catalog products, we can also design and manufacture custom products to meet your needs.

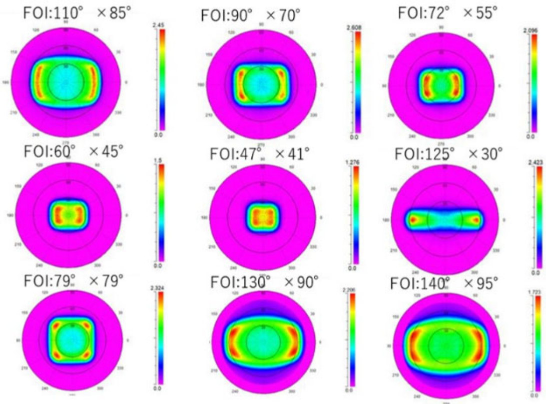


Figure 5: Light distribution of our optical diffuser Platanus in the catalog

FOI: FWHM of Imax

6. Conclusion

As described above, optical diffusers for 3D-TOF manufactured with our unique concept and Nanoimprint technology are beginning to be adopted in a wide range of products, and SCIVAX is developing a business of providing optical diffusers customized with optimal properties for each application.