White Paper : Ardisia®, dot projection lens for 3D ToF sensing application

1. Introduction

With the increasing demands of 3D sensing in recent years, in various fields such as home electric appliances, gaming, factory automation, mobile device, automotive shown in Fig. 1, Computing the depth information with image data is the basics of the 3D sensing technology. ToF(Time of Flight) is one of the most progressing methods for obtaining the depth information due to the simplicity and the capability to cover the both shorter and longer(>10meter) distance. We discuss our state-of-the-art dot projection lens, called "Ardisia®" comparing with the conventional DOE(Diffractive Optical Elements).

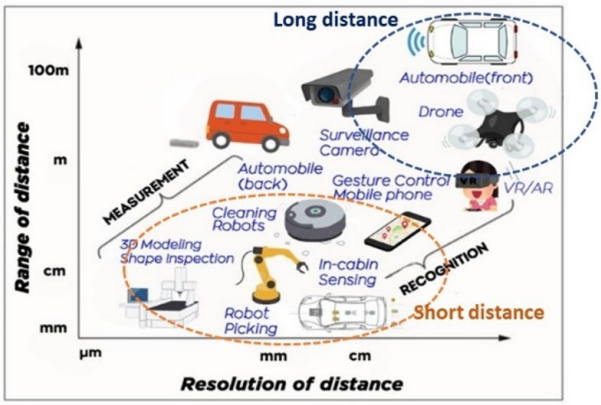

Fig.1 Measurement distance, resolution and application of 3D sensing

2. Lens type for illumination source

ToF system computes depth information from the delay between output and input light. Output light from Tx(transmitter) module, which is constructed with VCSEL through lens to form arbitrary shape of light, reflects back from the objects. The reflected light is detected in optical sensors such as CMOS image sensors and photo diodes in Rx(receiver) module and the system calculates the depth information based on the time for the emitted light to reach from Tx to Rx module.

We illustrated two typical cases with diffuser and dot projector for 3D-ToF sensing as shown in Fig. 2(a) and (b), respectively. In case of diffuser (Fig.2(a)), it is suitable to obtain detail information of object with its high resolution flood illumination pattern, while the distance was limited to 5m or less due to the attenuation of the intensity of illumination On the other hand, the dop projector(Fig.2(b)) has a capability to control the resolution by adjusting the density of each dots, moreover, it's suitable for the longer distance (more than 10m) measurement application because the condensed power in each dots mitigated the decay of intensity of illumination even at the farther distance.

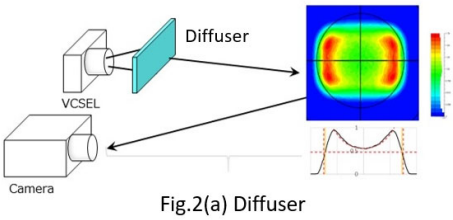

Fig.2(a) Diffuser

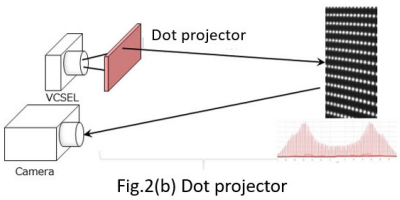

Fig.2(b) Dot projector

3. Challenges with conventional DOE lens

DOE (Diffractive Optical Elements) is commonly used as optical components for the dot projector, which created the phase difference when the incoming light went through the DOE pattern on top of either plastic or glass substrate. As a result, the diffraction of the light generated the designed multiple dot patterns. In case of DOE, the incoming light from VCSEL to DOE needed to be collimated with the collimation lens. And also there was some limitation in the placement of the dot and the illumination profile.

4. Solutions

SCIVAX has developed the new breakthrough optical components, called “Ardisia®” by using both Refractive and Diffractive function of light to solve various disadvantages with the common DOE. Ardisia®could integrate the collimator lens in one component so that it could achieve the compactness and the reduction of BOM cost. (Fig.3) Power efficiency was another benefit with Ardisia®

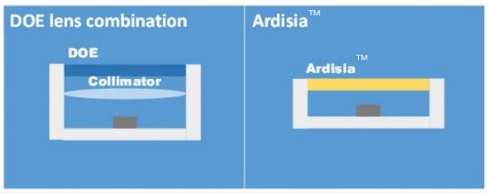

Fig.3 Tx Module of structure of DOE and Ardisia™

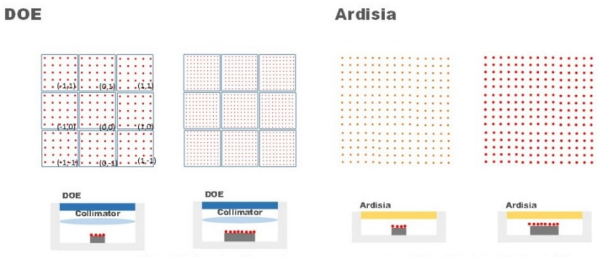

Fig.4 Relationship between the number of projected dots and the number of emitters

If we wanted to measure the longer distance with DOE comprising ToF system, increasing the power of VCSEL light source was the only viable solution. On the other hand, in case of Ardisia®, with increasing the number of emitters of VCSEL simply resulted the higher intensity of the projected dots, while the number of dots was independent of the number of emitter. For reference, if we do the same with DOE, it just caused increasing the number of dos but no effect on the level of intensity. (Fig.4)

Regarding the controllability of the light distribution profile with FOI, there is a stringent requirement to arbitrarily align the profile such as batwing shape to the characteristics of Rx module. DOE system can support controlling the light distribution profile only by the stepped manner where the level of intensity could be controlled according to the points of diffraction. Contrally Ardisia® had greater flexibility in designing the smoother light distribution profile such as the one correlated to cos-7 θ . (Fig.5)

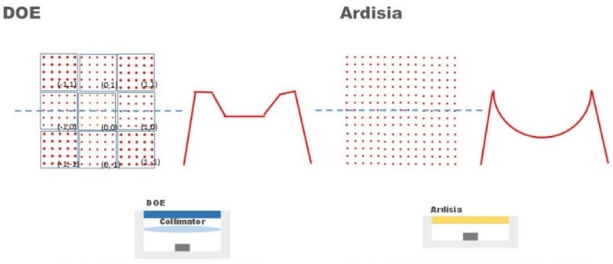

Fig.5 Comparison of light distribution profile

5. Product Info

Table 1 summarized the key characteristics of Rx module with Ardisia® comparing with DOE in terms of form factor, design flexibility, performance and cost. SCIVAX listens to the VoC to be able to design the customized Ardisia® lens for various 3D sensing application.

Table.1 Comparison with Tx module with DOE and Ardisia™

	DOE	Ardisia™
Number of Optics	2pcs(DOE+ Collimator lens)	1pc only (Ardisia™)
Max FOI	100deg	＞ 100deg
Thickness of module	Thick(e.g. >3mm)	Thin(e.g. <3mm)
Efficiency	Around 65% (depends on collimator lens)	Around 65%
Dot intensity	Limited by the power of emitters (can not increase the intensity by increasing the number of emitters)	Increased by the number of emitters or the power of emitters.
Light distribution profile	Stepped profile	Smoother profile
Placement of dots	Random and periodic both possible	Periodic only
0th order light	Visible	None
Cost of Tx module	High	Low

We demonstrated the far distance (10meter from VCSEL to the object) illumination with the testing Tx module assembled with Ardisia® lens with 2w power VCSEL. As a result, we could clearly illuminate the object at high contrast with the calculated power density of 0.33W/m^2 with a dot diameter of 0.084m.
The experimental set up was shown in Fig.6. CCD images taken from under visible and infrared(940nm) lights are displayed in Fig.7 (a) and (b), respectively. The dot projector illuminated the wall in the room having 10m in distance and the person as an object was clearly recognized.

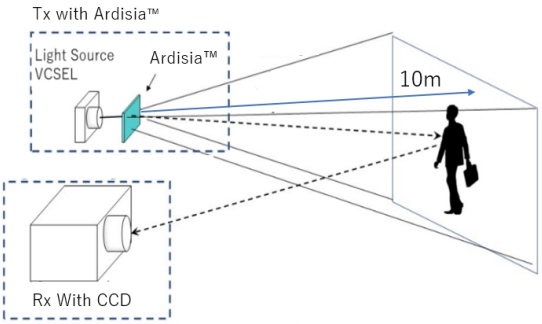

Fig.6 Experiment setup


Fig.7 (a) image with visible light


Fig.7 (b) image with infrared (940nm)

6. Conclusion

Scivax can support the high volume production of Ardisia® lens though high quality foundry service using our competitive nanoimprinting technology. The commercialization of Ardisia® lens product was attainable through the close collaboration of the internal Optical Design/Simulation experts with the Process Development experts. We provide the optimum illumination solution for designing the 3D ToF sensor system.