

White Paper : Ultra-wide-angle optical diffuser for 3D-ToF sensors in automotive application

Executive Summary

3D sensing systems based on Time of Flight (ToF) is recently becoming more popular due to its compactness, less stress to CPU, and also functioning even in a dark place. The ToF principle is based on measuring the time it takes for a wave to travel from a source (a time-of-flight sensor) to an object and back.

Our "Platanus®" for ToF sensors is a proprietary optical diffuser that controls light distribution so that light emitted from a light source is reflected back into the light-receiving camera to measure the distance. This white paper introduces the state of the art wide horizontal FOI of 140° and its in-vehicle applications.

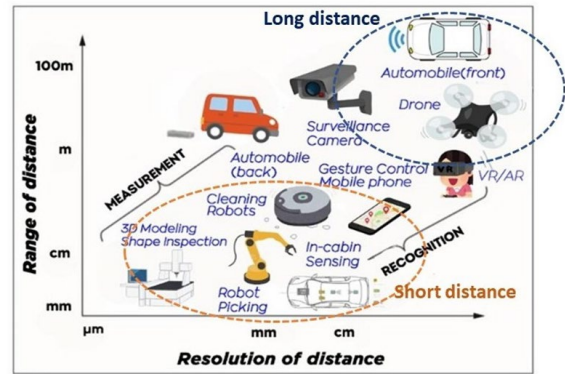


Fig. 1 Measurement distance, resolution and application fields of 3D sensing

1. Introduction

In the recent advancement of automotive industry especially enhancing safe driving and autonomous driving brought up the needs to check the status of the driver and passengers. In Europe, it will be mandatory requirement to be equipped with a DMS(Drive Monitoring System) to grant 5-star safety rating for the new cars after the year 2023. A schematics of ToF system illustrated in Figure 2, is used for monitoring 3D information in the vehicle. Pulsed wave of light emitted from a surface emitting laser (VCSEL) through the optical diffuser as Tx module illuminates the objects to be measured. In the light receiving section (Rx module), the light reflected from the objects is detected by the camera to calculate the distance based on the time delay of the returned pulse light to the input pulse.

In limited space budget inside a car to capture the movement of the driver and passengers both in the front and rear seats is the challenge, The wide-angle illumination with a wide-angled diffuser is required to meet this requirement.

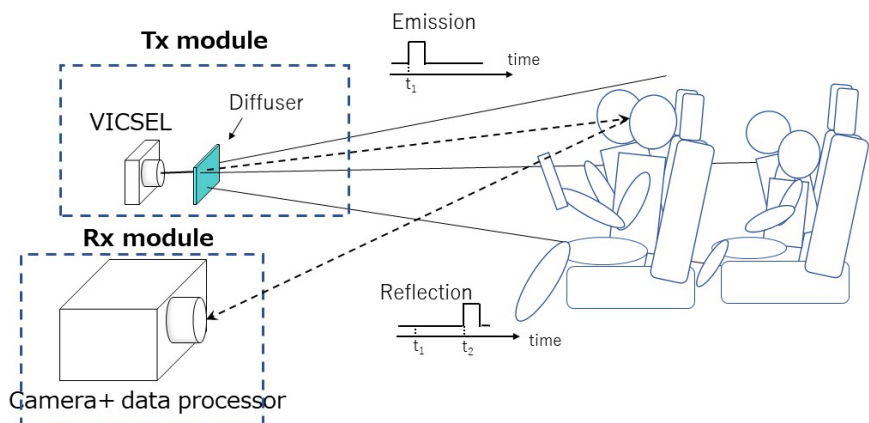


Figure 2 Drive Monitoring System (DMS) with 3D-ToF)

2. Thesis Questions

Micro lens array(MLA) is known as one of the approaches to diffuse the light. But there are a number of drawbacks especially when achieving the wider diffused angle. (Figure 3)

As we want to achieve the wider angle of diffuser with the low refractive index material, the structure becomes very steep convexity, as a result, a part of the light incident on the lens is internally reflected on the opposite side of the lens, resulted the higher intensity at a low exit angle. And it caused the orientation distribution, which is called "bat wing" (from the shape of a bat spreading its wings), where the intensity is originally stronger at larger angles, won't be achievable.

On the other hand, if the high refractive index material is used, the height of lens can be lowered and the above-mentioned reflection issue can be mitigated, while the light utilization efficiency is degraded due to the increase of the Fresnel reflection at the bottom of the lens.

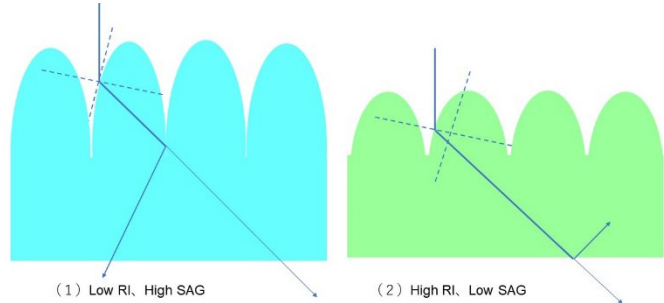


Figure 3: Challenges when using microlens arrays for ultra-high FOI illumination

3. Solutions

We propose the new light diffuser, Platanus® which was designed based on the hybrid optics of diffractive and refractive as a solution.

Figure 4 shows the optical characteristics of the ultra-wide angle Platanus®, optical diffuser FOI of $140^\circ \times 110^\circ$. 140° for the lateral direction of diffused light with the preferred bat wing shape and high light transmission (75%) was confirmed. Such higher efficiency is the unique feature of Platanus® especially in wider diffused angle.

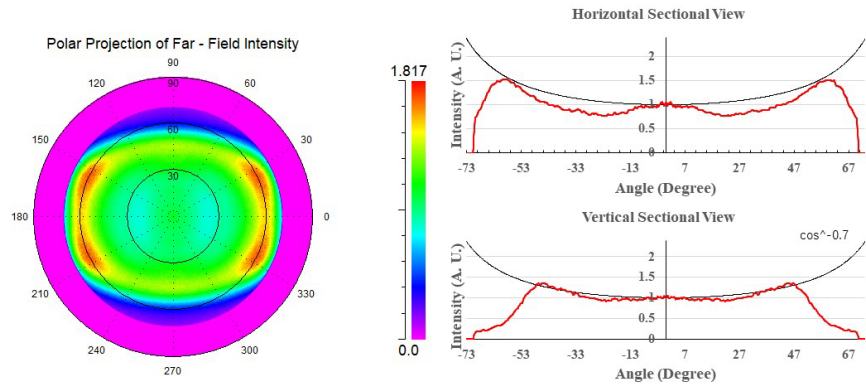


Figure 4 Orientation distribution of $140^\circ \times 110^\circ$ ultra-wide-angle optical diffuser

4. Application for DMS

Figure 5 shows a 3D image obtained with a TOF sensor system from MELEXIS, Inc. using $140^\circ \times 110^\circ$ Platanus® diffuser.

(a) The distance of the sensor with the illuminator from the human's face was only 50cm while it clearly measured the ends of stretched arms. (b) Also demonstrated the capability of monitoring both driver and passenger's seat with the single diffuser lens.

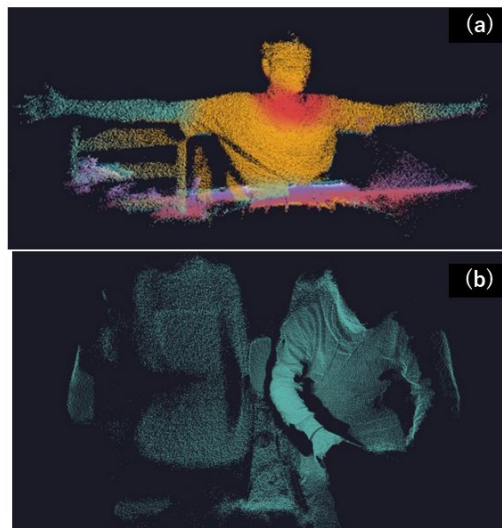


Figure 5 3D image measured by a sensor 50 cm away from the subject (a) Person with outstretched hand (b) Driver's seat (b) Courtesy of MELEXIS

5. Conclusion

Platanus®, the optical diffuser with wider angle of illumination for ToF sensor is applicable for variety of emerging applications such as automotive and VR. All of our optical components from SCIVAX are made by the cost efficient imprinting method. Our Foundry Service provides the

design customization, process development, and mass production service with your own customized optical diffuser for various applications.