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# Aerial Imaging Principle and its Commercialization and Future Developments

**Makoto Otsubo**

otsubo@asukanet.co.jp
Asukanet Co., Ltd., 3-28-14 Gion, Asaminami-ku, Hiroshima 731-0138, Japan
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**ABSTRACT**

*ASKA3D is a passive optical imaging panel that forms a real image in mid-air. ASKA3D contributes for noncontact interface for use by an unspecified number of people. This paper explains the basic principle of ASKA3D and introduces commercialization examples, application fields, and future development trends.*

## 1 Introduction

ASKA3D is a passive optical imaging panel that can form a real image in space, even in the air, underwater, or in a vacuum. Ten years have passed since our development of glass-type ASKA3D plate, and during that time, mass production of ASKA3d of resin-molding type has become possible and applications of ASKA3D has been increasing. In particular, in order to prevent the pandemic of COVID-19, there is increasing worldwide interest in its application as a non-contact interface for use by the general public.

In this paper, we explain the basic principle of ASKA3D and introduce commercialization examples, application fields, and future development trends.

## 2 Principle

### 2.1 Plane-symmetrical Imaging

A real image is formed by converging diverging light from a light-source object. Corner reflector is one of the typical optical components to change diverging light into converging light. Fig. 1 shows a unit in an array of dihedral corner mirrors. Mirror 1 and Mirror 2 are placed in 90 degrees. In TOP VIEW, the incident light is reflected twice at the mirrors. The double-reflected light travels reversely along the incident direction. In SIDE VIEW, the incident light is reflected at Mirror 2 and transmits the dihedral corner mirrors.

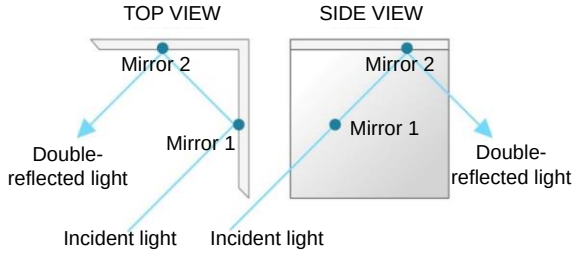


**Fig. 1 Double reflections in corner mirrors**

An array of corner mirrors in a plane converges diverging light from an object in mid-air, as shown in Fig. 2. The formed real image is plane-symmetrical of the source object with respect to the optical component plate. Note that the concavo-convex reversal occurs between the object and the image.

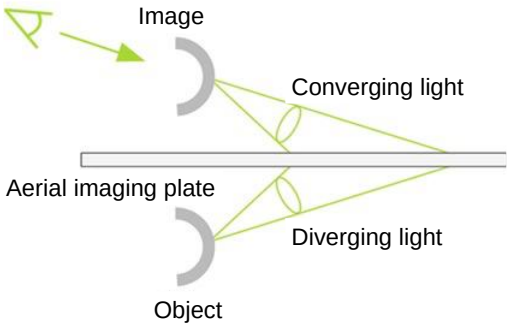


**Fig. 2 Basic concept of aerial imaging**

### 2.2 Principle of ASKA3D

In order to industrialize corner-mirrors array, mentioned above, advanced transfer technology is required for molding because the unit elements in micro-structure shall have optical flatness and precise angle. ASKA3D is consisted of two louver-mirror plates that overcomes the manufacturing issues in flatness and precise angle.

Fundamental structure of ASKA3D is shown in Fig. 3. Mirror 1 and Mirror 2 in Fig. 1 are placed in the first louver mirror plate and the second louver mirror plate, respectively. Note that the two louver mirror plates are stacked, rotated by 90 degrees, and adhered.

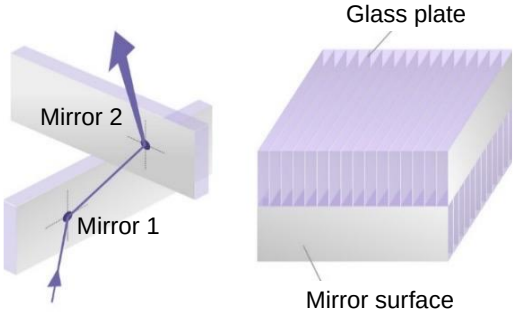


**Fig. 3 Principle of aerial imaging of ASKA3D plate**

### 2.3 Faced Mirror Structure

ASKA3D also features a faced mirror structure, as shown in Fig. 4. The face mirror structure performs a kind of light guide to transmit the incident light to the real image. Although incident light transmits through a faced mirror structure with a low aspect ratio, light guiding performance increases in the faced mirror structure with a high aspect. Thus, the high aspect ratio makes the image bright. The aspect ratio of ASKA3D plate of glass type is 3 and the transmittance at the central is close to 50% [1]. It is necessary to make the thickness of mirrors uniform in order to make the real image at the plane-symmetrical position.

Comparison of ASKA3D plate with corner-mirrors plate is shown in Table 1. ASKA3D have less restriction in reflection position and a higher aperture ratio in faced mirror structure.

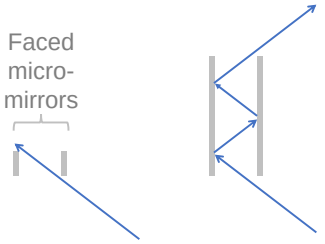


**Fig. 4 Comparisons of faced mirror structures with (a) a low and (b) a high aspect ratio**

**Table 1 Device comparison**

| | *ASKA3D* | *Corner mirrors* |
|---|---|---|
| *Structure* | Two-layered crossed arrays of mirrors | Array of square-well mirrors |
| *Reflection mode* | Metal coating reflection | Total reflection |
| *Reflection positions* | Double reflections in the two layers | Double reflections in each well |
| *Aperture ratio* | 99% | 90% |
| *Faced-mirrors structure* | Yes | No |

## 3 Commercialization of ASKA3D Plate

### 3.1 General

There are two modes in reflection: metal-coating mode and total-reflection mode. In this paper, we explain ASKA3D plates in metal-coating mode.

### 3.2 Laminated Glass Method

Manufacturing process in laminated glass method is shown in Fig. 5. Glass plates are polished to make both surfaces flat and parallel. One or both surfaces of the glass plates are coated with metal. Metal-coated glass plates are laminated and adhered. The fabricated ingot is sliced with a certain thickness like a wafer and polished on both sides. Finally, the two louver mirror plates are transparently adhered so that they are orthogonal to each other.

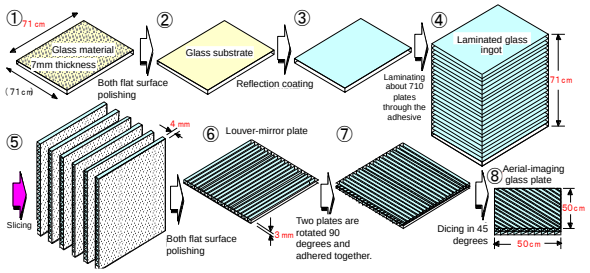


**Fig. 5 Manufacturing process of ASKA 3D plate of glass type in glass lamination method**

### 3.3 Resin Molding Method

Schematic diagram of ASKA3D of resin type is shown in Fig. 6 (a). In order to injection molding, the cross section of a louver mirror plate is in sawtooth shape. Vertical walls are selectively coated with metal. Two louver mirror plates are transparently adhered so that they are orthogonal to each other. Because the gaps are filled with resin, the fabricated plate becomes transparent as shown in Fig. 6 (b).

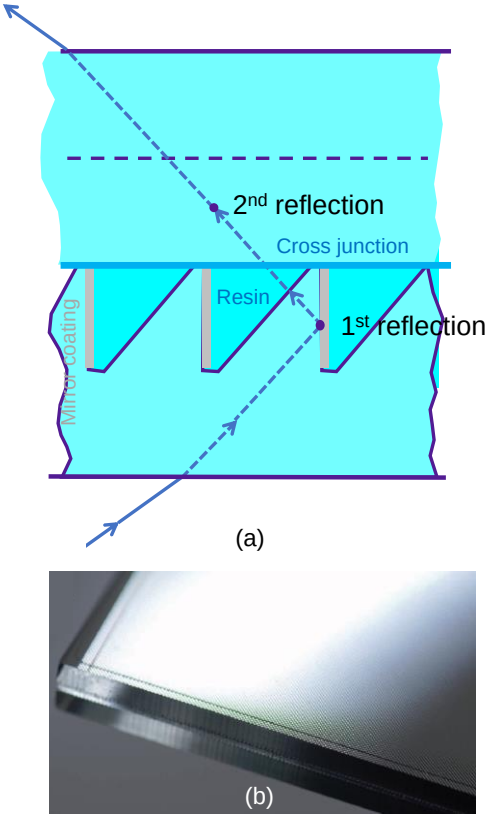


**Fig. 6 (a) Structure and (b) photograph of ASKA3D plate of resin type**

Resin molding method is suitable for mass production. Although the working distance of ASKA3D of resin type is shorter than that of glass type, the aerial image of a small and middle (7–10 inches) panel can be formed by use of the resin type.

## 4 Applications of ASKA3D

### 4.1 Prospective Application Fields

Use cases of aerial image are shown in Fig. 7. Aerial image enables us to operate ATM, car navigation panel, and medical terminal without touching the physical hardware and even with a wet hand. Aerial signage will attract viewer's attentions. Furthermore, aerial image will be combined with optical equipment such as microscope, telescope, camera, and smart glasses.

(a) (b) (c)

**Fig. 7 Prospective applications of ASKA3D for (a) ATM, (b) automobile, and (c) medical uses**

### 4.2 Noncontact Interface Panel

Today, the need for non-contact operation is increasing due to the COVID-19 pandemic. Non-contact operation is expected for operation panels such as elevator push buttons, ticket vending machines, ATMs, and public tablets for unspecified number of people. A non-contact operation panel is realized in combination of an aerial image with a sensor that detects the finger position. An example of aerial sub-monitor with sensing function is shown in Fig. 8. Finger position is detected with a near-infrared sensor and the device is connected via USB.

**Fig. 8 Aerial sub-monitor with sensing function**

### 4.3 Aerial Interface for Automobile

Aerial images are utilized for interfaces in car entertainment operation in motor show and show room, as shown in Fig. 9. Aerial image plays the important role in user experience in intelligent car cockpit and guests in rear seats.


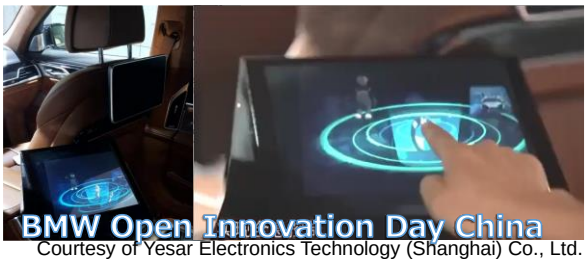


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**Fig. 9 Examples of ASKA3D in automobile show**

### 4.4 Aerial Signage and Touchless Operation in Bank

Social implementation of ASKA3D is realized in a bank in Hiroshima Prefecture, as shown in Fig. 10. Aerial image shows information more attractively for customers. Non-contact aerial interface, a modified version of Fig. 8, is utilized for non-contact ATM operation.

## 5 Future Development Trends

### 5.1 Wide Viewing Angle

In order to realize an extremely wide viewing angle, mirror walls surround the source object in radial and concentric circles, as shown in Fig. 11. Such structure is fabricated in the resin injection molding method.

### 5.2 Front View

Aerial image that is visible in front of imaging optics features compatibility with the current touch panel and reduced foot space. Fig. 12 shows a structure of aerial imaging plate in transmissive structure. After the triple reflections at points P, Q, and R in retro-reflection structure, the fourth reflection at point S is added. These four reflections make the real image in front of the optical plate. Note that the reflection point S is located in a spatially-separated mirror region or in the half-mirror coating of whole surface.


(a)


(b)

**Fig. 10 Social implementation of ASKA3D for (a) aerial signage and (b) touchless interface in bank**

## 6 Conclusion

ASKA3D plate is an aerial imaging plate that forms the real image in space. ASKA3D of glass type features high aperture ratio and precision. ASKA3D of resin type is mass productive. Non-contact interface panel has become socially implemented in banks and automobile show. Future trends include a wide viewing angle and front view.

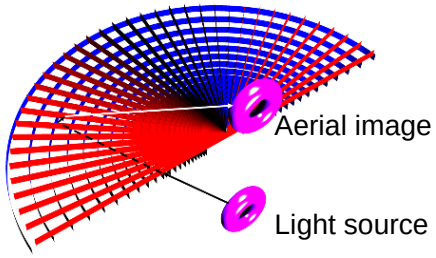


**Fig. 11 ASKA3D in mirror disc structure for an extremely wide viewing angle**

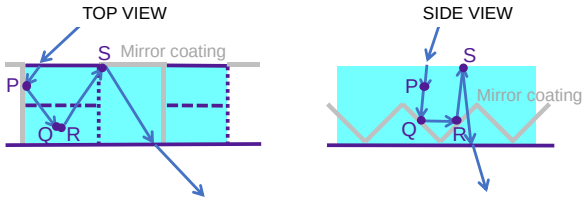


**Fig. 12 ASKA3D in transmissive structure**

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