Concave Pinhole-mirror for Near-eye Display

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. Abstract
Near-eye augmented reality display is one of the hot topics which has developed rapidly in recent years. Currently, various optical display systems couldn't meet the requirements with the light, convenience, large field of view for near-eye head-mounted display. We present a method of concave pin-mirror for near-eye augmented reality display based on the simple concave reflective mirror and pinhole imaging. This whole system has the same size as normal glasses, and it is convenient, as well as the field of view reaching 88 °. The proposed method provides a new idea for future near-eye display.

1.Background

Augmented reality near eye display system [1-10] is a kind of convenient head wear display system, which usually refers to spectacle or goggle type display system. Through the optical display device integrated on glasses or goggles, it provides virtual graphic signals or image information for the wearer to observe, mainly by imaging optical system, information processing system and tracking transmission. The basic principle of sensory system and operation control system is to enlarge the image source image and present the enlarged image source image to the human eye.

In recent years, the near eye display technology has achieved a leap forward development. The head mounted display system has begun to develop from the professional field to the civil field. At the same time, the near eye display equipment with many advantages, such as light weight, small size and strong function, has become a hot spot of scientific research. In recent years, Google, Facebook, Microsoft the boom of near eye display caused by technology giants is heating up, which also marks the coming of near eye display era.

In recent years, the rapid development of virtual reality display system for individuals has promoted the development of new display technology to the direction of "light, small and large field of view". This paper presents a light and small wearable large field of view augmented reality display system, which has the characteristics of "light, small, thin" and low manufacturing cost. Through the design of system parameters, a large field of view angle of 88 ° is obtained.

2.Method and Design

It is well known that the principle of pinhole imaging as shown in Fig 1. In an entire darkroom, let's open a keyhole as shown in Figure 1. The external scene can be imaged behind the pinhole. Generally speaking, the smaller the pinhole is, the clearer the image is. The larger the pinhole is, the less clear the image is. When the pinhole is large to a certain extent, the image cannot be imaged.

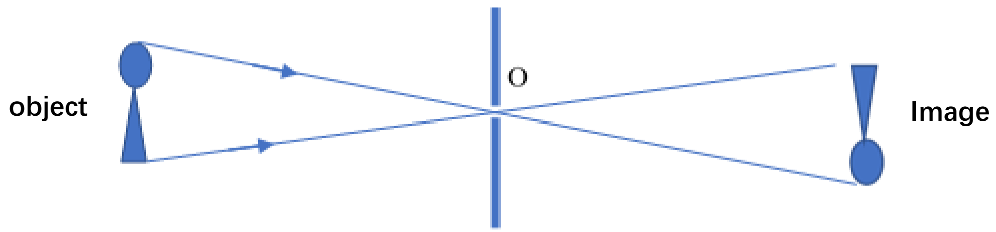


Fig. 1 Schematic view of a pinhole imaging.

In Fig. 1, if a mirror with a small angle of inclination is used instead of hole O, as shown in Fig. 2, the mirror hole will relfelct the light imaging at the same side of object, which is called mirror hole imaging.

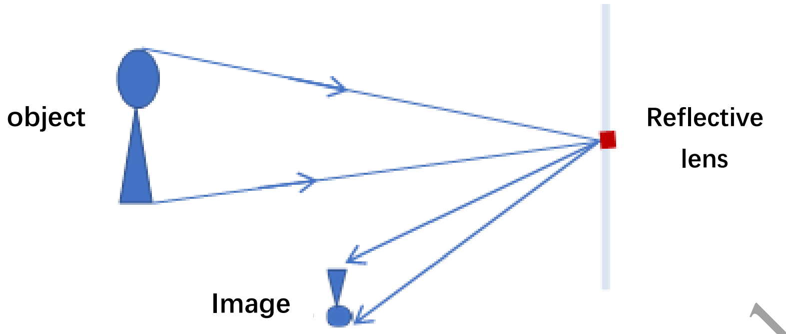


Fig. 2 Schematic view of a mirror pinhole imaging.

In this process, the pinholes can be imaged but not magnified. If the pinholes of the mirror are arranged according to the surface position of the concave mirror, each pinhole of the mirror can act as the corresponding pinhole imaging, as shown in Fig. 3. Suppose that the eye is the receiving surface, and the place without mirror (small hole) is transparent parallel glass. The human eye can see the outside information through the flat glass. Each mirror respectively images the information from different perspectives into the human eye. The image is not only magnified, but also does not affect the eye's observation of the outside information through the transparent parallel glass when the size of each mirror is around 2 mm. In this way, the human eye can observe the external world through transparent parallel glass, and at the same time can observe the enlarged information displayed on the concave small hole imaging micro display.

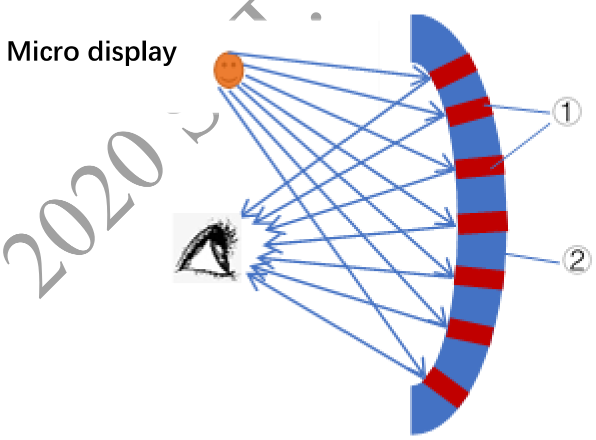


Fig. 3 Schematic view of a concave pinhole imaging, ① denotes mirrors, and ② represents parallel transparent glass.

3.principles and systems

As an example, let's design a concave mirror aperture for augmented reality display system. As shown in Fig. 4, where 1 is a micro display loaded with an optical signal source, generally OLED or LED micro display. 2 is a small hole reflector with a diameter of 2mm. 3 is parallel transparent curved glass, through which you can see the outside world.

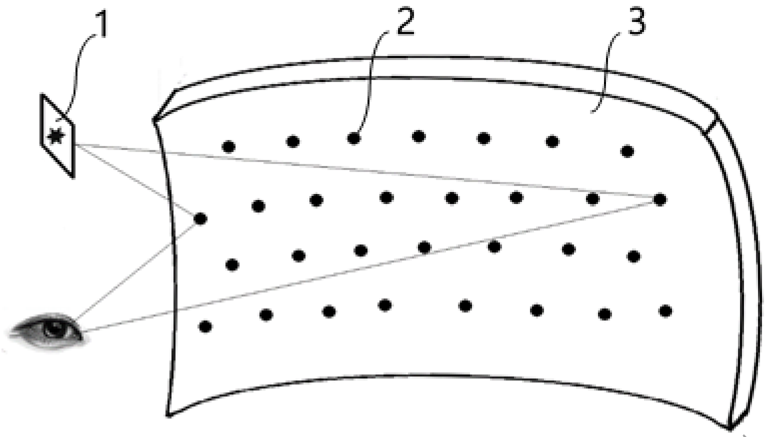


Fig. 4 Schematic view of a concave mirror aperture for augmented reality display system.

Now let's design the system based on geometrical optics. The micro display is a 0.61 inch OLED with a length width ratio of 16:9, corresponding to a display with a length width of 1.35cm and 0.76cm respectively. If the required field angle is 88 °, the corresponding horizontal and vertical field angles are 77 ° and 43 ° respectively. According to this requirement, we will design the image at a distance of 25 cm, as shown in Fig. 5. We consider two different cases: convex lens and concave mirror.

(A) Convex lenses

For convex lenses, as shown in Fig. 5 (a), the imaging formulas:

$$\frac{1}{f} = \frac{1}{L} + \frac{1}{L'} \quad (1)$$

$$L = \frac{h}{tan\theta} \quad (2)$$

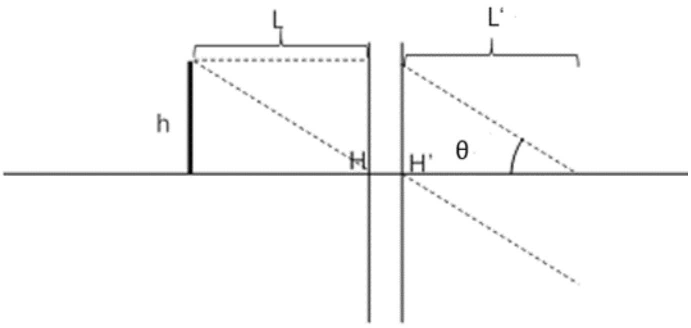
where h is the half height of the diagonal length of the micro display, L is the object distance, L' is the image distance of 250mm, and θ is the diagonal half FOV(field of view) of 44 °.

The diagonal half height of the micro display is: $h = 0.61 \times \frac{25.4}{2} = 7.747\text{mm}$

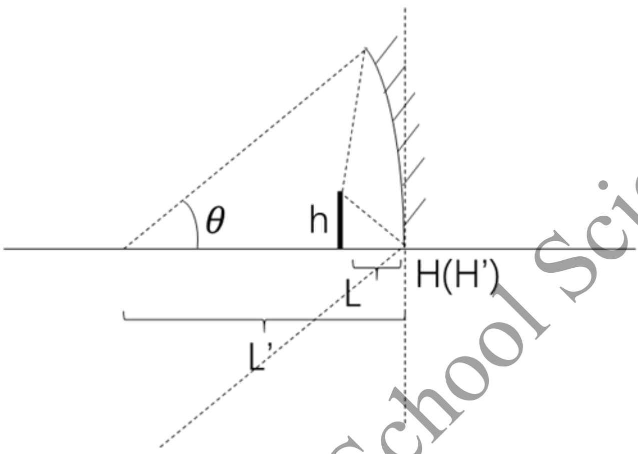
So object position L: $L = \frac{h}{\tan\theta} = \frac{7.747}{tan44°} = 8.022$

Substitute into Eqs(1) and (2), we obtain the focal length: $f = \frac{1}{\frac{1}{L'}+\frac{1}{L}} = 7.773\text{mm}$

In all, the focal length of the lens is 7.773 mm when the system's display angle is 88°.



(a)



(b)

Fig. 5 Schematic view of two cases: (a) convex lens and (b) concave mirror.

(B) Concave mirrors

Now let's consider the concave mirrors, as shown in Fig. 5 (b). Consider the Eqs. (1) and (2). When θ is half of the diagonal FOV with 44 °:

The diagonal half height of the micro display is: $\mathrm{h} = 0.61 \times \frac{25.4}{2} = 7.747\mathrm{mm}$;

The object position L: $\mathrm{L} = \frac{\mathrm{h}}{\tan\theta} = \frac{7.747}{tan44°} = 8.022$;

Substitute into Eqs(1) and (2), we obtain the focal length: $\mathrm{f} = \frac{1}{\frac{1}{L'}+\frac{1}{L}} = 8.288\mathrm{mm}$

In brief, the focal length of concave mirror is 8.288 mm when the system's display angle is 88°, which is easier to produce than convex lens which is 7.773mm.

4.Results and discussion

We now design the system of FOV with 88° where the focal length of convex lens is 7.773mm, which is not difficult to fabricate. We study the relationship between the half field angle and the focal length of the system (the full field angle is twice the half field angle). The calculation results are as shown in Fig. 6 (a) and (b), where (a) and (b) respectively calculate the relationship between the focal length of the transmission convex lens and the reflection concave mirror and the half field of view. The comparison of both cases is shown in Fig. 6(c). It can be seen that with the increase of the field angle, the smaller the focal length is, the greater the change of the surface shape of the mirror is. The change of the surface shape of the reflection concave mirror is more moldable than that of the transmission convex lens, and the reflection concave mirror is easier to be produced when the same field angle is achieved.

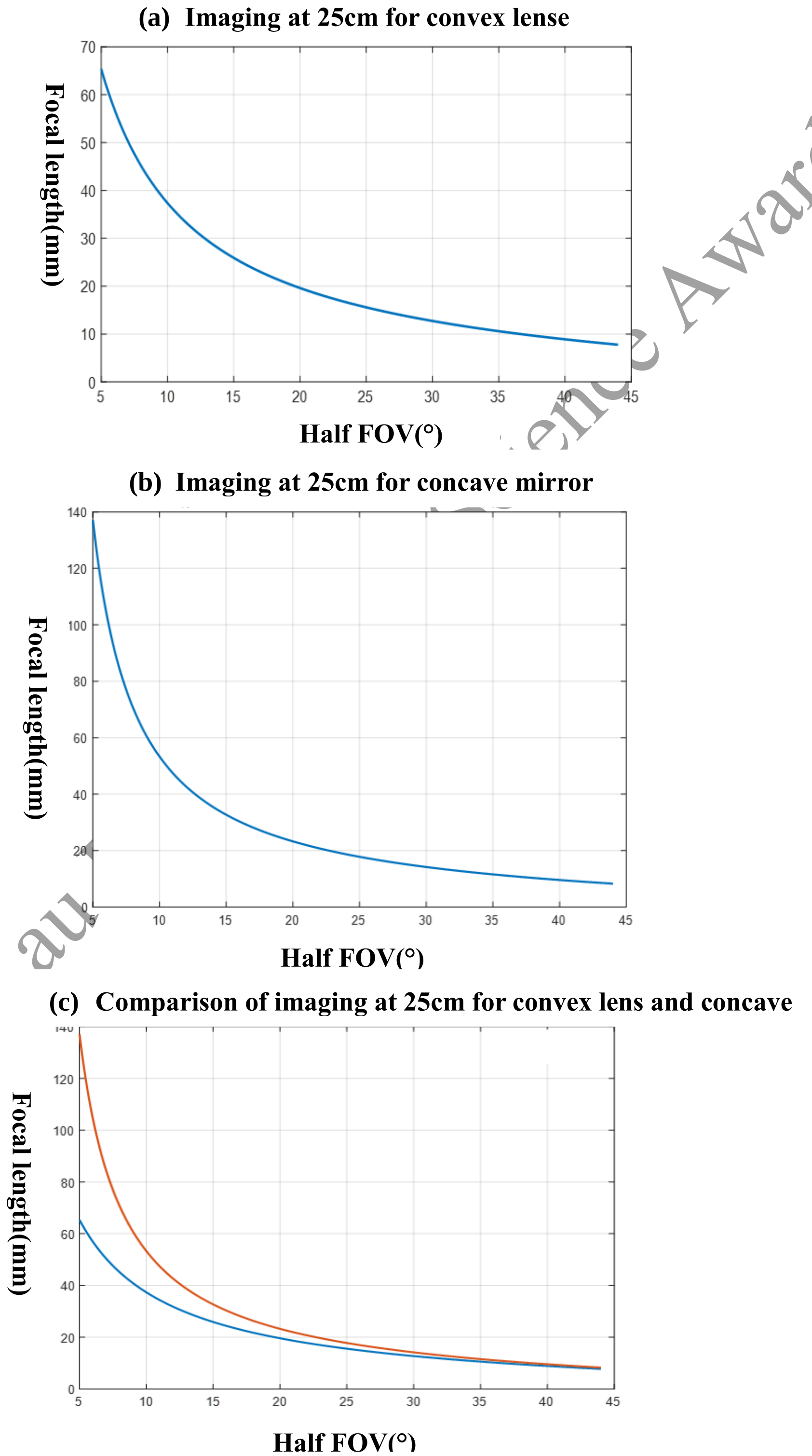


Fig. 6 The relationship between the half FOV and the focal length for two cases (a) convex lens and (b) concave mirror, and (c) their comparison.

In order to further study the relationship between the field of view angle, exit pupil distance and focal length, their dependence is calculated for the two cases of the transmissive convex lens and the reflective concave mirror, as shown in Fig. 7 (a) and (b). It can be seen that the larger the exit pupil distance is, the larger the field of view angle is when the focal length is not changed; when the field of view angle is not changed, the larger the focal length is, the larger the exit pupil distance is. It is mentioned that the reflective concave lens has a larger field angle than the transmissive convex lens with the same parameters.

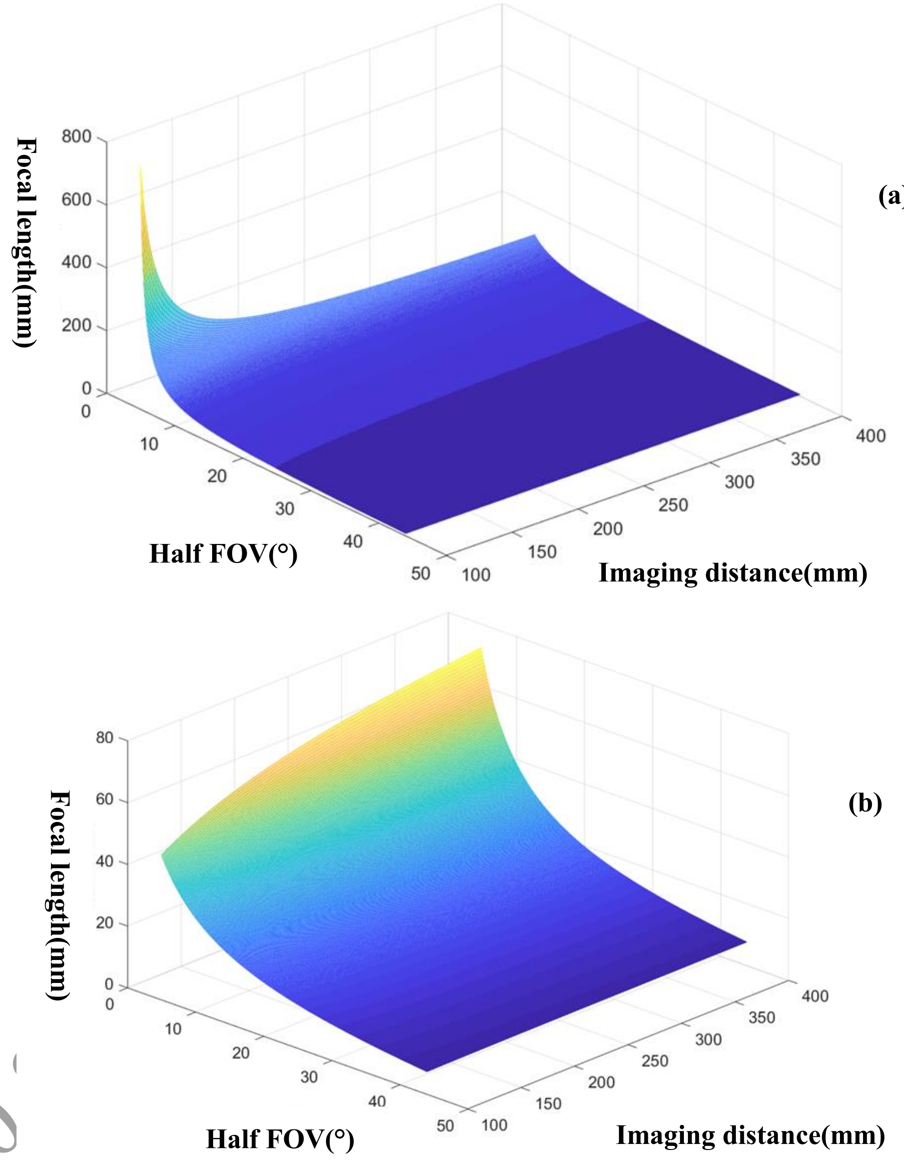


Fig. 7 Relationship between FOV, imaging distance and focal length for two cases: (a) convex lens and (b) concave mirror.

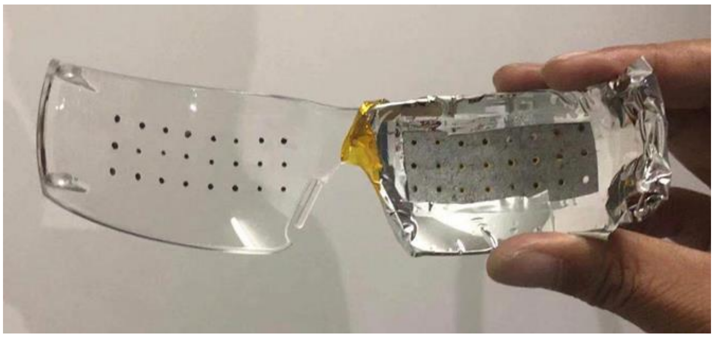


Fig. 8 Prototype of pinhole concave mirror AR glass.

According to the design parameters, we further fabricate the AR glasses structure, as shown in Fig. 8. The display results will be exhibited in the near future.

5. Conclusion

In a word, we propose a method and system for the display of pinhole augmented reality of concave mirror. The system can achieve a light and wearable display, and the FOV of the display can be as high as 88 °. In principle, the theory can effectively expand the field of view. In the future, a shorter focal length of concave mirror can be designed to achieve a wider field of view. The designed system is simple to produce and cheap to manufacture. This method might provide a new scheme for the future augmented reality display.

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