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Inventor(s)	Chan; Han-Sung et al.

Floating image display device

Abstract

A floating image display device, configured to generate a floating image, is provided. The floating image display device includes an image module and at least one transflective optical element. The image module is configured to provide a first image. The transflective optical element includes a first reflective surface and a second reflective surface. The first image is located between the first reflective surface and the second reflective surface. Each of the first reflective surface and the second reflective surface includes a curved surface and has no opening on an optical axis thereof. The second reflective surface is a transflective surface. The first reflective surface and the second reflective surface are configured to re-converge rays from the first image to form a second image. The second image is a floating image.

Inventors: **Chan; Han-Sung (New Taipei, TW), Huang; Yi-Hsiang (Changhua County, TW), Lin; Chun-Ting (Taipei, TW), Liu; Yu-Hsiang (Chiayi, TW), Lin; Chia-Ping (Taipei, TW)**

Applicant: **Industrial Technology Research Institute** (Hsinchu, TW)

Family ID: **1000008767886**

Assignee: **Industrial Technology Research Institute (Hsinchu, TW)**

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Primary Examiner: Won; Bumsuk

Assistant Examiner: Sridhar; Samanvitha

Attorney, Agent or Firm: JCIPRNET

Background/Summary

CROSS-REFERENCE TO RELATED APPLICATION

(1) This application claims the priority benefit of Taiwan application serial no. 111108367, filed on Mar. 8, 2022. The entirety of the above-mentioned patent application is hereby incorporated by reference herein and made a part of this specification.

BACKGROUND

Technical Field

(2) The disclosure relates to a display device, and particularly relates to a floating image display device.

Description of Related Art

(3) Along with advancement of display technology, floating image displays have been developed. Floating image display technology may be applied to various occasions. For example, a user may interact with a floating image to achieve certain operations of an electronic device. When interacting with the floating image, a finger of a user may move to a position of the floating image floated in the air without touching a surface of the display, thus causing no contamination of the finger or the surface of the display. This application situation may be applied in a kitchen to prevent bacteria or viruses on the surface of the display from contaminating food, or prevent food from contaminating the display.

(4) On the other hand, along with the epidemic of coronavirus pneumonia, non-contact operations are gaining more and more attention. The floating image display used in collaboration with sensors may realize non-contact switches or virtual keys, such as floating virtual elevator buttons, floating virtual bell buttons or floating light switches, etc.

(5) However, the floating image of a general floating image display has a trade-off limit between an image size and a floating height, i.e., the image will be cropped when the floating height exceeds the limit. In addition, another type of floating image display adopts two curved reflectors to reflect an image beam by multiple times to form a floating image, and the curved reflector in a light output direction has an opening in a center (i.e., at an optical axis), so that the image beam may be emitted out of the device and imaged outside the device. However, since the center of the reflector has the opening without functions of reflection and imaging, when the user's eyes are located on or near the optical axis, the floating image cannot be seen, and the user may see the floating image at a large viewing angle, which limits applicability of the floating image display.

SUMMARY

(6) An embodiment of the disclosure provides a floating image display device configured to generate a floating image. The floating image display device includes an image module and at least one transflective optical element. The image module is configured to provide a first image. The transflective optical element includes a first reflective surface and a second reflective surface, where the first image is located between the first reflective surface and the second reflective surface, and each of the first reflective surface and the second reflective surface includes a curved surface and has no opening on an optical axis thereof. The second reflective surface is a transflective surface. The first reflective surface and the second reflective surface are configured to re-converge rays from the first image to form a second image, where the second image is a floating image.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) The accompanying drawings are included to provide a further understanding of the disclosure,

and are incorporated in and constitute a part of this specification. The drawings illustrate embodiments of the disclosure and, together with the description, serve to explain the principles of the disclosure.

(2) FIG. **1**A is a schematic three-dimensional view of a floating image display device according to an embodiment of the disclosure.

(3) FIG. **1**B is a schematic cross-sectional view of the floating image display device of FIG. **1**A.

(4) FIG. **2** is a schematic three-dimensional view of a floating image display device according to another embodiment of the disclosure.

(5) FIG. **3**A, FIG. **3**B and FIG. **3**C are schematic front views of transflective optical elements viewing along an optical axis direction according to three embodiments of the disclosure.

(6) FIG. **4** is a schematic cross-sectional view of a floating image display device according to another embodiment of the disclosure.

(7) FIG. **5** is a schematic three-dimensional view of a floating image display device according to still another embodiment of the disclosure.

(8) FIG. **6** is a schematic three-dimensional view of a floating image display device according to still another embodiment of the disclosure.

(9) FIG. **7** is a schematic three-dimensional view of a floating image display device according to another embodiment of the disclosure.

DESCRIPTION OF THE EMBODIMENTS

(10) FIG. **1**A is a schematic three-dimensional view of a floating image display device according to an embodiment of the disclosure, and FIG. **1**B is a schematic cross-sectional view of the floating image display device of FIG. **1**A. Referring to FIG. **1**A and FIG. **1**B, a floating image display device **100** of the embodiment is used to generate a floating image. The floating image display device **100** includes an image module **110** and at least one transflective optical element **200** (one transflective optical element **200** is taken as an example in FIG. **1**A and FIG. **1**B). The image module **100** is used for providing a first image **101**. In the embodiment, the image module **100** is, for example, a real object, a flat-panel display, an integrated imaging display, a projector, a holographic display, a volumetric display, or other suitable displays, which is not limited by the disclosure.

(11) The transflective optical element **200** includes a first reflective surface **201** and a second reflective surface **202**, where the first image **101** is located between the first reflective surface **201** and the second reflective surface **202**. Each of the first reflective surface **201** and the second reflective surface **202** includes a curved surface and have no opening on an optical axis A thereof. The second reflective surface **202** may be a transflective surface, and in this embodiment, and in the embodiment, the first reflective surface **201** may also be a transflective surface. The first reflective surface **201** and the second reflective surface **202** are configured to re-converge rays **114** from the first image **101** to generate a second image **102**, and the second image **102** is a floating image. The first image **101** and the second image **102** may be planar images or three-dimensional images.

(12) In the embodiment, the first reflective surface **201** is disposed between the image module **110** and the second reflective surface **202**, and the image module **110** is configured to provide an image beam **112**. The second reflective surface **202** is a transflective surface, which means that when the image beam **112** is transmitted to the second reflective surface **202**, a part of the image beam **112** may pass through the second reflective surface **202**, and the other part of the image beam **112** may be reflected by the second reflective surface **202**. Similarly, the first reflective surface **201** is a transflective surface, which means that when the image beam **112** is transmitted to the first reflective surface **201**, a part of the image beam **112** may pass through the first reflective surface **201**, and the other part of the image beam **112** may be reflected by the first reflective surface **201**. In an embodiment, a transmittance of the first reflective surface **201** and the second reflective surface **202** is, for example, about 50%, and a reflectance of the first reflective surface **201** and the

second reflective surface **202** is, for example, about 50%. In the embodiment, after the image beam **112** passes through the first reflective surface **201**, the first image **101** is formed between the first reflective surface **201** and the second reflective surface **202**.
(13) In the embodiment, the first reflective surface **201** and the second reflective surface **202** are paraboloids or paraboloid-like surfaces (i.e., surfaces close to paraboloids), and the rays **114** from the first image **101** converge and form the second image **102** outside the transflective optical element **200** after being reflected by the first reflective surface **201** and the second reflective surface **201** by multiple times. In the embodiment, the second reflective surface **202** is located between the first image **101** and the second image **102**.
(14) In the embodiment, the first reflective surface **201** and the second reflective surface **202** are continuous curved surfaces without openings. The transflective optical element **200** includes a first reflector **210** and a second reflector **220**, and the first reflective surface **201** and the second reflective surface **202** are respectively two surfaces of the first reflector **210** and the second reflector **220** facing each other. In the embodiment, the second reflective surface **202** is formed by a continuous transflective film **222** without an opening, and the first reflective surface **201** is formed by a continuous transflective film **212** without an opening. In addition, in the embodiment, a concave surface of the transflective film **212** that forms the first reflective surface **201** and a concave surface of the transflective film **222** that forms the second reflective surface **202** face each other. In addition, in the embodiment, two surfaces of the first reflector **210** and the second reflector **220** facing away from each other may be provided with anti-reflective films **214** and **224**. However, in other embodiments, the first reflector **210** and the second reflector **220** may not be provided with anti-reflective films.
(15) In the embodiment, the first reflector **210** includes a light-transmitting material **216** that allows the image beam **112** to pass through, the second reflector **220** includes a light-transmitting material **226** that allows the rays **114** to pass through. The transflective film **212** and the transflective film **222** may be respectively disposed on two surfaces of the light-transmitting material **216** and the light-transmitting material **226** that face each other, and the anti-reflective film **214** and the anti-reflective film **224** may be respectively disposed on two surfaces of the light-transmitting material **216** and the light-transmitting material **226** that face away from each other.
(16) In other embodiments, the transflective film **212** of the first reflective surface **201** and the transflective film **222** of the second reflective surface **202** may also be replaced by optical microstructures, and the optical microstructures also have the effects of partial penetration and partial reflection of the light beam **112** or the rays **114**. In addition, the transflective films **212**, **222** or the optical microstructures may have the same structure or different structures at a portion close to the optical axis A and a portion away from the optical axis A.
(17) In the floating image display device **100** of the embodiment, the first reflective surface **201** and the second reflective surface **202** are used to make the rays **114** from the first image **101** to be reflected by multiple times inside the transflective optical element **200**, so as to form the second image **102** (i.e., the floating image) outside the transflective optical element **200**, where a floating distance D**1** of the second image **102** (i.e., a distance between the second image **102** and the second reflector **220**) is greater than 0, and the integrity of the second image **102** is maintained. In addition, the second reflective surface **202** may be a transflective surface, and the first reflective surface **201** and the second reflective surface **202** have no openings on the optical axis A, so that paraxial rays and abaxial rays may exist between the first reflective surface **201** and the second reflective surface **202**, and when the user's eyes are on or near the optical axis A (i.e., at a central viewing angle), the user may still view the floating image (i.e., the second image **102**), which may enhance applicability of the floating image display device **100**. The floating image display device **100** of the embodiment may increase the floating distance D**1**, and a complete and uncropped floating image may be viewed at various viewing angles (including the central viewing angle and a large viewing angle), which may meet the application requirements of large viewing angles, so as to be applied to

various carriers (such as public carriers) such as virtual buttons (for example, elevator buttons), advertising templates, road indicators or map models, etc.

(18) In the embodiment, the first reflector **210** may have a straight trimming edge **211**, and the second reflector **220** may have a straight trimming edge **221**. In other words, a side surface of the first reflector **210** has a planar surface **213**, and a side surface of the second reflector **220** has a planar surface **223**. In this way, a volume of the transflective optical element **200** may be reduced without affecting the quality of the floating image, thereby reducing a volume of the floating image display device **100**. Moreover, the trimming edges of the first reflector **210** and the second reflector **220** do not affect shape quality of the second image **102**, but affects a brightness of the second image **102**. Therefore, an area ratio of the second image **102** to the floating image display device **100** may be increased by adopting the edge trimming method.

(19) An effective focal length of the first reflective surface **201** is, for example, within a range of 60 mm to 100 mm, and an effective focal length of the second reflective surface **202** is, for example, within a range of 10 mm to 50 mm, and a distance between the first reflective surface **201** and the second reflective surface **202** on the optical axis A is, for example, within a range of 20 mm to 60 mm. In the embodiment, the effective focal length of the first reflective surface **201** is, for example, 80.38 mm, the effective focal length of the second reflective surface **202** is, for example, 30.07 mm, and the distance between the first reflective surface **201** and the second reflective surface **202** on the optical axis A is, for example, 40 mm. In addition, at least part of the first reflective surface **201** and at least part of the second reflective surface **202** are circularly symmetrical, for example, the parts of the first reflective surface **201** and the second reflective surface **202** within a radius smaller than the straight trimming edge **221** are circularly symmetrical with respect to the optical axis A, and a shape thereof may be expressed by a following aspheric equation (Equation (1)):

(20) $$\mathrm{Sag}(r) = \frac{cr^2}{1+\sqrt{1-(1+k)c^2r^2}} + a_2r^2 + a_4r^4 + a_6r^6 + a_8r^8 \quad \text{(Equation1)}$$

(21) Where r is a vertical distance between a point on an aspheric surface and the optical axis A; Sag(r) is a sag of the aspheric surface parallel to the optical axis A, i.e., a depth of the aspheric surface (i.e., a vertical distance between a point on the aspheric surface that is spaced from the optical axis A by a distance r and a tangent plane tangent to a vertex of the aspheric surface on the optical axis A), c is a curvature of the aspheric surface near the optical axis A; k is a conic constant; and a2, a4, a6 and a8 are respectively a 2nd, a 4th, a 6th and an 8th order aspheric coefficients. In an embodiment, c of the first reflective surface **201** is, for example, 0.0062 mm.sup.−1, k is, for example, 0.6244, and a2, a4, a6 and a8 are, for example, 0, 8.94e-008, −3.16e-010 and 8.03e-013, respectively; c of the second reflective surface **202** is, for example, 0.0166 mm.sup.−1, k is, for example, −2.1779, and a2, a4, a6 and a8 are, for example, 0, 4.14e-008, −5.46e-009, and 1.40e-011, respectively.

(22) In other embodiments, at least part of the first reflective surface **201** and at least part of the second reflective surface **202** may also be elliptically symmetrical, for example, the first reflective surface **201** and the second reflective surface **202** are elliptically symmetrical with respect to the optical axis A at portions within a range where the radius is smaller than the straight trimming edge **221**.

(23) In the embodiment, the first image **101** may be located between the first reflective surface **201** and a midpoint m between the first reflective surface **201** and the second reflective surface **202** (as shown in FIG. **1**B).

(24) FIG. **2** is a schematic three-dimensional view of a floating image display device according to another embodiment of the disclosure. Referring to FIG. **2**, a floating image display device **100***a* of the embodiment is similar to the floating image display device **100** of FIG. **1**A. The floating image display device **100***a* of the embodiment includes, for example, a plurality of transflective optical elements **200** arranged in a one-dimensional array. In these transflective optical elements **200**, two adjacent first reflectors **210** may lean against each other through the straight trimming edges **211**,

i.e., through the planar surfaces **213**, and two adjacent second reflectors **220** may lean against each other through the straight trimming edges **221**, i.e., through the planar surfaces **223**. In this way, the plurality of second images formed by the transflective optical elements **200** may be combined to form a larger floating image.
(25) On the other hand, the floating image display device **100***a* may include a plurality of image modules **110** arranged in a one-dimensional array to respectively correspond to the transflective optical elements **200**. However, in other embodiments, the floating image display device **100***a* may also include one image module **110**, which covers a larger area, so as to respectively form a plurality of first images in the transflective optical elements **200**.
(26) The disclosure does not limit the transflective optical elements **200** to be arranged in the one-dimensional array. In the embodiments of FIG. **3**A, FIG. **3**B and FIG. **3**C, the transflective optical elements **200** may also be arranged in a two-dimensional array. FIG. **3**A, FIG. **3**B and FIG. **3**C are schematic front views of transflective optical elements viewing along an optical axis direction according to three embodiments of the disclosure. In the embodiment of FIG. **3**A, the first reflectors **210** and the second reflectors **220** of the transflective optical elements **200** respectively form square reflectors through the straight trimming edges **211** and **221**, the adjacent first reflectors **210** lean against each other through the straight trimming edge **211**, and the adjacent second reflectors **220** lean against each other through the straight trimming edge **221**, so that these transflective optical elements **200** are arranged in a two-dimensional square array, and the corresponding image modules **110** may also be a plurality of image modules arranged in a two-dimensional square array, or may be one image module covering a larger area.
(27) In the embodiment of FIG. **3**B, the first reflectors **210** and the second reflectors **220** of the transflective optical elements **200** respectively form rectangular reflectors through the straight trimming edges **211** and **221**, the adjacent first reflectors **210** lean against each other through the straight trimming edge **211**, and the adjacent second reflectors **220** lean against each other through the straight trimming edge **221**, so that these transflective optical elements **200** are arranged in a two-dimensional rectangular array, and the corresponding image modules **110** may also be a plurality of image modules arranged in a two-dimensional rectangular array, or may be one image module covering a larger area.
(28) In the embodiment of FIG. **3**C, the first reflectors **210** and the second reflectors **220** of the transflective optical elements **200** respectively form hexagonal reflectors through the straight trimming edges **211** and **221**, the adjacent first reflectors **210** lean against each other through the straight trimming edge **211**, and the adjacent second reflectors **220** lean against each other through the straight trimming edge **221**, so that these transflective optical elements **200** are arranged in a two-dimensional polygonal array, and the corresponding image modules **110** may also be a plurality of image modules arranged in a two-dimensional polygonal array, or may be one image module covering a larger area. The disclosure does not limit a trimming shape and an array arrangement of the first reflectors **210** and the second reflectors **220** are symmetrical, which may be set according to actual needs of use.
(29) FIG. **4** is a schematic cross-sectional view of a floating image display device according to another embodiment of the disclosure. Referring to FIG. **4**, a floating image display device **100***b* of the embodiment is similar to the floating image display device **100** of FIG. **1**B. In the floating image display device **100***b* of the embodiment, the side surfaces of the first reflector **210** and the second reflector **220** have a curved surface **213***a*, a curved surface **223***a* or a tenon structure **225***a*. For example, the side surfaces of the first reflector **210** and the second reflector **220** may have a curved surface and neither have a tenon structure, or the sides surfaces of the first reflector **210** and the second reflector **220** may have a tenon structure and have a curved surface or a planar surface, or a side surface of one of the first reflector **210** and the second reflector **220** has a tenon structure (as shown in FIG. **4**). In an embodiment, when the floating image display device **100***b* has the transflective optical elements **200** arranged in a one-dimensional array or a two-dimensional array,

the tenon structures help to fit the adjacent first reflectors **210** to each other, or fit the adjacent second reflectors **220** to each other to achieve a more stable structure.
(30) FIG. **5** is a schematic three-dimensional view of a floating image display device according to still another embodiment of the disclosure. Referring to FIG. **5**, a floating image display device **100***c* of the embodiment is similar to the floating image display device **100** of FIG. **1**A. In the floating image display device **100***c* of the embodiment, the image module **110** is located between the first reflective surface **201** and the second reflective surface **202**, which may still generate the first image **101** located between the first reflective surface **201** and the second reflective surface **202**, and the rays from the first image **101** form the second image **102** outside the transflective optical element **200** after being reflected by the first reflective surface **201** and the second reflective surface **202** by multiple times. In the embodiment, the first reflective surface **201** may be formed of a continuous reflective film **212***c* without an opening, and a concave surface of the reflective film **212***c* forming the first reflective surface **201** and a concave surface of the transflective film **222** forming the second reflective surface **202** face each other, where the reflective film **212***c* may reflect the rays from the first image **101** but prevent the rays from the first image **101** from passing through.
(31) In the embodiment, the image module **110** is located between the first reflective surface **201** and the second reflective surface **202**, which may reduce a volume of the floating image display device **100***c* and increase a brightness of the second image **102**. In one embodiment, the first image **101** may also be located on the image module **110** without necessarily having a floating distance relative to the image module **110**.
(32) FIG. **6** is a schematic three-dimensional view of a floating image display device according to still another embodiment of the disclosure. Referring to FIG. **6**, a floating image display device **100***d* of the embodiment is similar to the floating image display device **100** of FIG. **1**A. The floating image display device **100***d* of the embodiment further includes an imaging medium **120** disposed between the first reflective surface **201** and the second reflective surface **202**, where the image beam **112** emitted by the image module **110** is projected on the imaging medium **120** to form the first image **101** after passing through the first reflective surface **201**. In other words, the imaging medium **120** may provide an effect similar to a projection screen, so that after the image beam **112** irradiates thereon, the first image **101** may be projected, which helps to make the first image **101** clearer and makes the user more suitable for viewing the second image **102**. In the embodiment, the imaging medium **120** is, for example, a diffuser, a hologram, a nonlinear crystal, or other suitable imaging medium.
(33) FIG. **7** is a schematic three-dimensional view of a floating image display device according to another embodiment of the disclosure. Referring to FIG. **7**, a floating image display device **100***e* of the embodiment is similar to the floating image display device **100** of FIG. **1**A. In the floating image display device **100***e* of the embodiment, a first reflective surface **201***e* and a second reflective surface **202***e* may be Fresnel surfaces or metasurfaces, where the Fresnel surfaces are, for example, surfaces of Fresnel reflectors, which may effectively reduce thicknesses of the first reflector **210***e* and the second reflector **220***e*, thereby reducing a volume of the floating image display device **100***e*. In the embodiment, the first reflective surface **201***e* and the second reflective surface **202***e* are, for example, transflective surfaces. However, in other embodiments, the first reflective surface **201***e* may also be a reflective surface suitable for reflecting light but is not suitable for being penetrated by light.
(34) In the floating image display device of the embodiment of the disclosure, the first reflective surface and the second reflective surface are used to reflect the rays from the first image by multiple times inside the transflective optical element, so as to form the second image (i.e. the floating image) outside the transflective optical element. A floating distance of the second image may be larger, and the integrity of the second image is maintained. In addition, the second reflective surface may be a transflective surface, and the first reflective surface and the second

reflective surface have no openings on optical axes thereof. When the user's eyes are on or near the optical axis (i.e., at the central viewing angle), the user may still view the floating image, so that the applicability of the floating image display device may be improved.
(35) It will be apparent to those skilled in the art that various modifications and variations can be made to the disclosed embodiments without departing from the scope or spirit of the disclosure. In view of the foregoing, it is intended that the disclosure covers modifications and variations provided they fall within the scope of the following claims and their equivalents.

Claims

1. A floating image display device, configured to generate a floating image, the floating image display device comprising: an image module, configured to provide a first image; and at least one transflective optical element, comprising a first reflective surface and a second reflective surface, wherein the first image is located between the first reflective surface and the second reflective surface, each of the first reflective surface and the second reflective surface comprises a curved surface and has no opening on an optical axis thereof, the second reflective surface is a transflective surface, the first reflective surface and the second reflective surface are configured to re-converge rays from the first image to form a second image, the second image is a floating image, an effective focal length of the first reflective surface is greater than an effective focal length of the second reflective surface, the second image is larger than the first image and is inverted relative to the first image, the first image is located between the first reflective surface and a midpoint between the first reflective surface and the second reflective surface, the second reflective surface is between the first reflective surface and the second image, the first reflective surface is disposed between the image module and the second reflective surface, the first reflective surface is a transflective surface, the image module is configured to provide an image beam, and the image beam forms the first image between the first reflective surface and the second reflective surface after passing through the first reflective surface.
2. The floating image display device as claimed in claim 1, further comprising an imaging medium disposed between the first reflective surface and the second reflective surface, wherein the image beam is projected on the imaging medium to form the first image after passing through the first reflective surface.
3. The floating image display device as claimed in claim 2, wherein the imaging medium is a diffuser, a hologram, or a nonlinear crystal.
4. The floating image display device as claimed in claim 1, wherein the first reflective surface and the second reflective surface are continuous curved surfaces without an opening.
5. The floating image display device as claimed in claim 1, wherein the transflective optical element comprises a first reflector and a second reflector, and the first reflective surface and the second reflective surface are respectively located on two surfaces of the first reflector and the second reflector facing each other.
6. The floating image display device as claimed in claim 5, wherein the second reflective surface is formed by a continuous transflective film without an opening, and the first reflective surface is formed by a continuous reflective film without an opening or a continuous transflective film without an opening.
7. The floating image display device as claimed in claim 6, wherein a concave surface of the reflective film or the transflective film forming the first reflective surface and a concave surface of the transflective film forming the second reflective surface face each other.
8. The floating image display device as claimed in claim 5, wherein the first reflector and the second reflector have straight trimming edges.
9. The floating image display device as claimed in claim 5, wherein side surfaces of the first reflector and the second reflector have a planar surface, a curved surface, or a tenon structure.

10. The floating image display device as claimed in claim 5, wherein anti-reflective films are provided on two surfaces of the first reflector and the second reflector facing away from each other.
11. The floating image display device as claimed in claim 1, wherein the second reflective surface is located between the first image and the second image.
12. The floating image display device as claimed in claim 1, wherein the at least one transflective optical element is a plurality of transflective optical elements arranged in a one-dimensional array or a two-dimensional array.
13. The floating image display device as claimed in claim 1, wherein the image module is a real object, a flat panel display, an integrated imaging display, a projector, a holographic display, or a volumetric display.
14. The floating image display device as claimed in claim 1, wherein the first reflective surface and the second reflective surface are paraboloids or paraboloid-like surfaces.
15. The floating image display device as claimed in claim 1, wherein the first reflective surface and the second reflective surface are Fresnel surfaces or metasurfaces.
16. The floating image display device as claimed in claim 1, wherein at least part of the first reflective surface and at least part of the second reflective surface are circularly symmetrical or elliptically symmetrical.
17. The floating image display device as claimed in claim 1, wherein an interval is between the transflective optical element and the second image, and the interval is along an optical axis of the transflective optical element and greater than zero.