LENS, PROJECTION DEVICE, VEHICLE LAMP DEVICE, AND VEHICLE

[0001] This application claims priority to Chinese Patent Application No. 202410487235.1, filed with the China National Intellectual Property Administration on April 22, 2024 and entitled "LENS, PROJECTION APPARATUS, VEHICLE LAMP APPARATUS, AND VEHICLE", which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

[0002] Embodiments of this application relate to the field of optical technologies, and in particular, to a lens, a projection apparatus, a vehicle lamp apparatus, and a vehicle.

BACKGROUND

[0003] With development of intelligent vehicle technologies, a vehicle-mounted headlight needs to have a conventional lighting function, and also needs to be capable of projecting a pattern, to meet increasing requirements in aspects such as welcoming, information exchange, and autonomous driving. Therefore, to meet the increasing requirements, optical specifications of a projectable vehicle lamp are increasingly strict. For example, the vehicle lamp is required to have a large projection field of view (field of view, FOV). The field of view may be used as one of important indicators for reflecting a projection information amount. A larger field of view indicates a larger projection information amount. However, a lens in the projectable vehicle lamp cannot have both a large aperture and a large field of view.

SUMMARY

[0004] Embodiments of this application provide a lens, a projection apparatus, a vehicle lamp apparatus, and a vehicle, so that the lens can have both a large aperture and a large field of view.

[0005] A first aspect of this application provides a lens, including at least six lens elements arranged from an image side to an object side. A lens element closest to the image side in the lens has positive focal power, there are at least three lens elements having positive focal power in the lens, and there is at least one lens element having negative focal power in the lens. The lens satisfies

a relation: 33 mm<EFL<38 mm, where EFL is a focal length of the lens.

[0006] The lens provided in this embodiment of this application includes the at least six lens elements. The at least three lens elements in the lens have the positive focal power, the at least one lens element in the lens has the negative focal power, and the lens element closest to the image side in the lens has the positive focal power. A large field of view can be implemented when Fno is less than or equal to 1.3, so that the lens can have features of both a large aperture and a large field of view. In addition, the focal length of the lens is greater than 33 mm and less than 38 mm, so that a field of view greater than 20°×10° can be implemented while a large aperture is implemented. 20° is a field of view of the lens in a horizontal direction, and 10° is a field of view of the lens in a vertical direction. Therefore, the lens provided in this embodiment of this application can implement a projection field of view greater than 20°×10° when Fno≤1.3, thereby meeting a projection requirement.

[0007] In a possible implementation, the lens satisfies a relation: BFL/EFL≥0.846, where BFL is a back focal length of the lens, and EFL is the focal length of the lens.

[0008] After the lens provided in this embodiment of this application satisfies the relation: BFL/EFL≥0.846, an excessively long or excessively short optical path of the lens can be avoided. This facilitates designing and setting of a back-end optical path. In addition, it can be further ensured that the lens has the features of both the large aperture and the large field of view.

[0009] In a possible implementation, the lens satisfies a relation: 6<R1/EFL<50, where R1 is a curvature radius of an image-side surface of the lens element closest to the image side in the lens, and EFL is the focal length of the lens.

[0010] In addition, the lens provided in this embodiment of this application satisfies the relation: 6<R1/EFL<50. This can reduce manufacturing difficulty of the lens element closest to the image side in the lens, increase a yield, and help improve cost-effectiveness while implementing both the large aperture and the large field of view, and can further facilitate aberration correction. In addition, this can further prevent the image-side surface of the lens element closest to the image side in the lens from being excessively protruding or excessively flat. An excessively protruding image-side surface of the lens element closest to the image side may cause interference between the lens element and another element, and an excessively flat image-side surface of the lens element closest to the image side may affect a shape of a vehicle lamp.

[0011] In a possible implementation, the lens satisfies a relation: 198 mm<R1<1500 mm, where R1 is the curvature radius of the image-side surface of the lens element closest to the image side in the lens.

[0012] The lens provided in this embodiment of this application satisfies the relation: 198 mm<R1<1500 mm. This can reduce the manufacturing difficulty of the lens element closest to the

image side in the lens, increase the yield, and help improve the cost-effectiveness while implementing both the large aperture and the large field of view, and can further facilitate aberration correction. In addition, this can further prevent the image-side surface of the lens element closest to the image side in the lens from being excessively protruding or excessively flat, to effectively balance optical performance of the lens and the shape of the vehicle lamp.

[0013] In a possible implementation, the lens satisfies a relation: 4<R2/EFL<16, where R2 is a curvature radius of an object-side surface of the lens element closest to the object side in the lens, and EFL is the focal length of the lens.

[0014] The lens provided in this embodiment of this application satisfies the relation: 4<R2/EFL<16. This can reduce manufacturing difficulty of the lens element closest to the object side in the lens, increase a yield, and help improve cost-effectiveness while implementing both the large aperture and the large field of view. In addition, this can further prevent the object-side surface of the lens element closest to the object side in the lens from being excessively protruding or excessively concave. An excessively protruding object-side surface of the lens element closest to the object side may interfere with another optical element, or compress optical space between the lens and a projection chip, or cause damage to the lens element closest to the object side. An excessively concave object-side surface of the lens element closest to the object side is unfavorable to aberration correction.

[0015] In a possible implementation, the lens satisfies a relation: 140 mm<R2<560 mm, where R2 is the curvature radius of the object-side surface of the lens element closest to the object side in the lens.

[0016] The lens provided in this embodiment of this application satisfies the relation: 140 mm<R2<560 mm. This can reduce the manufacturing difficulty of the lens element closest to the object side in the lens, increase the yield, and help improve the cost-effectiveness while implementing both the large aperture and the large field of view. In addition, this can further prevent the object-side surface of the lens element closest to the object side in the lens from being excessively protruding or excessively concave, to effectively balance optical performance of the lens and a shape of the vehicle lamp.

[0017] In a possible implementation, the lens element closest to the object side in the lens has positive focal power.

[0018] According to the lens provided in this embodiment of this application, the lens element closest to the object side is disposed as a lens element having positive focal power, so that an amount of light entering the lens can be increased, to improve optical performance, and further improve cost-effectiveness of the lens.

[0019] In a possible implementation, the at least six lens elements include a first lens element,

a second lens element, a third lens element, a fourth lens element, a fifth lens element, and a sixth lens element that are sequentially arranged from the image side to the object side, the first lens element is closest to the image side and has the positive focal power, and the sixth lens element is closest to the object side. Such disposition can reduce a quantity of lens elements while implementing both the large field of view and the large aperture, thereby helping improve the cost-effectiveness of the lens.

[0020] A second aspect of this application provides a projection apparatus, including a display unit and the lens in any one of the implementations of the first aspect. The display unit is configured to emit imaging light to the lens.

[0021] In a possible implementation, the display unit includes a light source unit and a modulation unit. The modulation unit is configured to: modulate a light beam emitted by the light source unit to generate the imaging light, and emit the imaging light to the lens.

[0022] In a possible implementation, the display unit further includes a reflection unit, and the reflection unit is configured to reflect the light beam emitted by the light source unit to the modulation unit.

[0023] A third aspect of this application provides a vehicle lamp apparatus, including a housing and the projection apparatus in any one of the implementations of the second aspect. At least a part of the projection apparatus is disposed inside the housing.

[0024] A fourth aspect of this application provides a vehicle, including the vehicle lamp apparatus in the third aspect.

BRIEF DESCRIPTION OF DRAWINGS

[0025] FIG. 1 is a diagram of a structure of a vehicle lamp apparatus according to an embodiment of this application;

[0026] FIG. 2 is a diagram of a structure of a lens according to an embodiment of this application;

[0027] FIG. 3 is a diagram of a structure of a first projection apparatus according to Embodiment 1 of this application;

[0028] FIG. 4 is a spherical and chromatic aberration diagram of a lens in FIG. 3;

[0029] FIG. 5 is an astigmatism and field curvature diagram of the lens in FIG. 3;

[0030] FIG. 6 is a distortion diagram of the lens in FIG. 3;

[0031] FIG. 7 is a diagram of a structure of a second projection apparatus according to Embodiment 2 of this application;

[0032] FIG. 8 is a spherical and chromatic aberration diagram of a lens in FIG. 7;

[0033] FIG. 9 is an astigmatism and field curvature diagram of the lens in FIG. 7; and

[0034] FIG. 10 is a distortion diagram of the lens in FIG. 7.

[0035] Descriptions of reference numerals:

100: vehicle lamp apparatus;

110: housing;

120: projection apparatus;

10: lens;

11: first lens element; 12: second lens element; 13: third lens element; 14: fourth lens element; 15: fifth lens element; 16: sixth lens element;

17: aperture stop;

18: cover glass;

20: display unit;

21: light source unit; 211: light source; 212: collimation unit;

22: modulation unit; and

23: reflection unit.

DESCRIPTION OF EMBODIMENTS

[0036] Terms used in implementations of this application are only used to explain specific embodiments of this application, but are not intended to limit this application.

[0037] For ease of understanding, related technical terms in embodiments of this application are first explained and described.

[0038] A focal length, also referred to as a focal length, is a measurement manner for measuring convergence or divergence of light in an optical system, and is a vertical distance from an optical center of a lens or a lens group to a focal plane when a clear image of an infinite scene is formed on the focal plane through the lens or the lens group.

[0039] An image side, bounded by a lens, is a side on which an image is located. A surface that is of a lens element and that faces the image side is an image-side surface of the lens element.

[0040] An object side is a side on which a modulation unit is located. A surface that is of a lens element and that faces the object side is an object-side surface.

[0041] A total track length (total track length, TTL for short) is a total length from a vertex of a first lens element that is disposed adjacent to an object side in a lens to an imaging plane of the lens, and is also referred to as an optical total length.

[0042] A back focal length (back focal length, BFL for short) is defined as a distance from a lens element closest to an imaging plane in a lens to a modulation unit.

[0043] Focal power represents a refraction capability of a lens element on an incident parallel light beam.

[0044] Positive focal power represents that a lens element has a positive focal length and has effect of converging light.

[0045] Negative focal power represents that a lens element has a negative focal length and has effect of diverging light.

[0046] An aperture is an apparatus configured to control an amount of light entering the interior of an electronic device through a lens, and is usually in the lens. A size of the aperture is represented by an F# (F-number) value.

[0047] An F-number F# is a relative value (a reciprocal of a relative aperture) obtained by dividing a focal length of a lens by a light transmission diameter of the lens. A smaller value of the F-number F# indicates a larger amount of light entering the lens within a same unit of time.

[0048] Cover glass (cover glass, CG) is configured to protect a projection chip.

[0049] A modulation unit is configured to modulate a light beam emitted by a light source, to generate imaging light that forms an image.

[0050] A digital micromirror device (digital micromirror device, DMD) is configured to reflect light to form an image.

[0051] A liquid crystal on silicon (liquid crystal on silicon, LCOS) is configured to reflect light.

[0052] An axial chromatic aberration, also referred to as a longitudinal chromatic aberration or a positional chromatic aberration. After passing through a lens, a beam of light parallel to an optical axis is converged at different positions. This aberration is referred to as the positional chromatic aberration or the axial chromatic aberration. This is because positions of images formed by the lens for light of different wavelengths are different. As a result, imaging planes for images of light of different colors cannot overlap during final imaging, and dispersion is formed by divergence of polychromatic light.

[0053] Distortion (distortion), also referred to as distortion, is a degree at which an image formed by an optical system for an object is distorted relative to the object. Distortion is caused because a height of a point at which chief light with different fields of view intersects a Gaussian image plane after the chief light passes through the optical system is not equal to a desirable image height due to impact of an aperture stop aberration, and a difference between the two heights is distortion. Therefore, distortion only changes an imaging position of an off-axis object point on a desirable plane, so that a shape of an image is distorted, but definition of the image is not affected.

[0054] With development of intelligent vehicle technologies, a vehicle-mounted headlight needs to have a conventional lighting function, and also needs to be capable of projecting a pattern, to meet increasing requirements in aspects such as welcoming, information exchange, and

autonomous driving. Therefore, to meet the increasing requirements, optical requirements on a projectable vehicle lamp are increasingly strict. For example, the vehicle lamp is required to have a large projection field of view (field of view, FOV). The field of view may be used as one of important indicators for reflecting a projection information amount. A larger field of view indicates a larger projection information amount.

[0055] However, a lens in the projectable vehicle lamp cannot have both a large aperture and a large field of view, and cannot meet diversified projection requirements. Therefore, how to enable the lens to have both the large aperture and the large field of view becomes an urgent problem to be solved.

[0056] In view of this, embodiments of this application provide a lens 10, a projection apparatus 120, a vehicle lamp apparatus 100, and a vehicle. The lens 10 can have features of both a large aperture and a large field of view, and can expand a projection range and improve brightness, to meet use requirements.

[0057] The vehicle may include but is not limited to a car, a truck, a motorcycle, a bus, a ship, an airplane, a helicopter, a lawn mower, a recreational vehicle, a playground vehicle, a construction device, a tram, a golf cart, a train, or a handcart. In embodiments of this application, an example in which the vehicle is a car is used for description.

[0058] The vehicle includes a vehicle body and the vehicle lamp apparatus 100, and the vehicle lamp apparatus 100 is mounted on the vehicle body. The vehicle lamp apparatus 100 may include but is not limited to a pixel display vehicle lamp, a near-field greeting vehicle lamp, a pedestrian or interaction vehicle lamp, and a vehicle headlight. For example, in embodiments of this application, an example in which the vehicle lamp apparatus 100 is a vehicle headlight is used for description. The vehicle lamp apparatus 100 may emit illumination light for lighting, to improve driving safety of a vehicle. In addition, the vehicle lamp apparatus 100 may emit imaging light for projection imaging, to meet a display requirement.

[0059] FIG. 1 is a diagram of a structure of a vehicle lamp apparatus 100 according to an embodiment of this application.

[0060] As shown in FIG. 1, the vehicle lamp apparatus 100 may include a housing 110 and a projection apparatus 120. At least a part of the projection apparatus 120 is disposed in the housing 110. For example, as shown in FIG. 1, the projection apparatus 120 is disposed inside the housing 110. Certainly, alternatively, at least a part of the projection apparatus 120 may be disposed inside the housing 110, and the other part of the projection apparatus may be disposed outside the housing 110. The projection apparatus 120 is configured to implement projection imaging and display lighting functions.

[0061] As shown in FIG. 1, the projection apparatus 120 may include a display unit 20 and a

lens 10. The display unit 20 is configured to emit imaging light to the lens 10, and the lens 10 may emit the imaging light to the outside of the housing 110, to form an image outside the housing 110 or implement a lighting function.

[0062] For example, as shown in FIG. 1, the display unit 20 may include a light source unit 21 and a modulation unit 22. The modulation unit 22 is configured to: modulate a light beam emitted by the light source unit 21 to generate the imaging light, and emit the imaging light to the lens 10.

[0063] A specific structure of the modulation unit 22 is not limited herein. For example, the modulation unit 22 may include a projection chip. The projection chip may modulate the light beam emitted by the light source unit 21 and generate the imaging light emitted to the lens 10.

[0064] The projection chip may include but is not limited to a DMD, an LCOS, an MEMS, or an LCD.

[0065] In some possible implementations, still as shown in FIG. 1, the light source unit 21 may include a light source 211 and a collimation unit 212. The collimation unit 212 is configured to collimate light emitted by the light source 211, and the modulation unit 22 is configured to modulate the collimated light to generate the imaging light emitted to the lens 10.

[0066] In some possible implementations, still as shown in FIG. 1, the display unit 20 may further include a reflection unit 23. The reflection unit 23 is configured to reflect the light beam emitted by the light source unit 21 to the modulation unit 22. Specifically, as shown in FIG. 1, the collimation unit 212 emits a collimated light beam to the reflection unit 23, and the reflection unit 23 reflects the collimated light beam to the modulation unit 22, to ensure that the modulation unit 22 modulates the collimated light beam.

[0067] A specific structure of the reflection unit 23 is not limited herein. For example, still as shown in FIG. 1, the reflection unit 23 may be a curved mirror, and a curved surface of the curved mirror reflects the light emitted by the light source unit 21 to the modulation unit 22.

[0068] It should be noted that an optical path direction in FIG. 1 is merely a diagram, and another optical path solution may also be used. Details are not described herein.

[0069] It should be further noted that, in addition to being used in the vehicle lamp apparatus 100 for implementing projection imaging and display lighting functions, the projection apparatus 120 provided in embodiments of this application may further be used in devices such as a projector, a head-up display apparatus, and augmented reality (augmented reality, AR) glasses, to implement the projection imaging function.

[0070] The following describes the lens 10 provided in embodiments of this application with reference to accompanying drawings.

[0071] FIG. 2 is a diagram of a structure of a lens 10 according to an embodiment of this application.

[0072] The lens 10 provided in this embodiment of this application includes at least six lens elements arranged from an image side to an object side. For example, as shown in FIG. 2, the lens 10 may include six lens elements sequentially arranged from an image side to an object side. Certainly, there may alternatively be more than six lens elements. The six lens elements are respectively a first lens element 11, a second lens element 12, a third lens element 13, a fourth lens element 14, a fifth lens element 15, and a sixth lens element 16 that are sequentially arranged from the image side to the object side. The first lens element 11 is closest to the image side, and the sixth lens element 16 is closest to the object side. Such disposition can reduce a quantity of lens elements while implementing both a large field of view and a large aperture, thereby helping improve cost-effectiveness of the lens 10.

[0073] A lens element closest to the image side in the lens 10 has positive focal power. For example, as shown in FIG. 2, the first lens element 11 has positive focal power. There are at least three lens elements having positive focal power in the lens 10, and there is at least one lens element having negative focal power in the lens 10. For example, as shown in FIG. 2, four of the six lens elements have positive focal power, and the other two lens elements have negative focal power; or five of the six lens elements have positive focal power, and the other lens element has negative focal power. The lens 10 satisfies a relation: 33 mm<EFL<38 mm, where EFL is a focal length of the lens 10.

[0074] The lens 10 uses the following architecture: At least six lens elements are included, at least three lens elements have positive focal power, at least one lens element has negative focal power, a lens element closest to the image side has positive focal power, and the focal length of the lens 10 is greater than 33 mm and less than 38 mm. A large field of view greater than 20°×10° can be implemented when Fno is less than or equal to 1.3, so that the lens 10 has features of both a large aperture and a large field of view, thereby meeting a projection requirement. 20° is a field of view of the lens 10 in a horizontal direction, and 10° is a field of view of the lens 10 in a vertical direction. In addition, the lens element closest to the image side has the positive focal power. This helps improve cost-effectiveness of the lens 10 while implementing both the large aperture and the large field of view.

[0075] In this embodiment of this application, a specific value of the focal length of the lens 10 is not limited herein, for example, may include but is not limited to 33.1 mm, 33.5 mm, 33.88 mm, 33.9 mm, 34 mm, 34.5 mm, 35 mm, 35.3 mm, 36 mm, 37 mm, or 37.5 mm.

[0076] All lens elements in the lens 10 may be made of a same material. For example, all the lens elements may be made of optical glass or plastic.

[0077] In some possible implementations, the lens 10 may further satisfy a relation: BFL/EFL≥0.846, where BFL is a back focal length of the lens 10, and EFL is the focal length of

the lens 10.

[0078] Correspondingly, after the lens 10 satisfies the relation: BFL/EFL≥0.846, an excessively long or excessively short optical path of the lens 10 can be avoided. This facilitates designing and setting of a back-end optical path. In addition, it can be further ensured that the lens 10 has the features of both the large aperture and the large field of view.

[0079] A specific ratio of BFL/EFL is not limited herein, for example, may include but is not limited to 0.846, 0.847, 0.848, 0.849, 0.85, 0.8591, 0.86, 0.87, 0.88, or 0.89.

[0080] In some possible implementations, the lens 10 may further satisfy a relation: 6<R1/EFL<50, where R1 is a curvature radius of an image-side surface of the lens element closest to the image side in the lens 10, and EFL is the focal length of the lens 10.

[0081] Correspondingly, the lens 10 satisfies the relation: 6<R1/EFL<50. This can reduce manufacturing difficulty of the lens element closest to the image side in the lens 10, increase a yield, and help improve cost-effectiveness while implementing both the large aperture and the large field of view, and can further facilitate aberration correction. In addition, this can further prevent the image-side surface of the lens element closest to the image side in the lens 10 from being excessively protruding or excessively flat. An excessively protruding image-side surface of the lens element closest to the image side may cause interference between the lens element and another element, and an excessively flat image-side surface of the lens element closest to the image side may affect a shape of a vehicle lamp.

[0082] A specific ratio of R1/EFL is not limited herein, for example, may include but is not limited to 6.5, 7, 7.5, 8, 8.5, 8.9, 9, 9.5, 9.9, 10, 10.5, 11, 12, 13, 14.5, 20, 25, 30, 35, 40, 45, 48, or 49.5.

[0083] In some possible implementations, the lens 10 may further satisfy a relation: 198 mm<R1<1500 mm, where R1 is the curvature radius of the image-side surface of the lens element closest to the image side in the lens 10.

[0084] Correspondingly, the lens 10 may further satisfy the relation: 198 mm<R1<1500 mm. This can reduce the manufacturing difficulty of the lens element closest to the image side in the lens 10, increase the yield, and help improve the cost-effectiveness while implementing both the large aperture and the large field of view, and can further facilitate aberration correction. In addition, this can further prevent the image-side surface of the lens element closest to the image side in the lens 10 from being excessively protruding or excessively flat, to effectively balance optical performance of the lens 10 and the shape of the vehicle lamp.

[0085] A specific value of R1 is not limited herein, for example, may include but is not limited to 199 mm, 200 mm, 250 mm, 300 mm, 350 mm, 390.5 mm, 400 mm, 480.95 mm, 500 mm, 600 mm, 670 mm, 700 mm, 790 mm, 800 mm, 900 mm, 1000 mm, 1100 mm, 1200 mm, 1300 mm,

1450 mm, or 1499.5 mm.

[0086] In some possible implementations, the lens 10 may further satisfy a relation: 4<R2/EFL<16, where R2 is a curvature radius of an object-side surface of the lens element closest to the object side in the lens 10, and EFL is the focal length of the lens 10.

[0087] Correspondingly, the lens 10 satisfies the relation: 4<R2/EFL<16. This can reduce manufacturing difficulty of the lens element closest to the object side in the lens 10, increase a yield, and help improve cost-effectiveness while implementing both the large aperture and the large field of view. In addition, this can further prevent the object-side surface of the lens element closest to the object side in the lens 10 from being excessively protruding or excessively concave. An excessively protruding object-side surface of the lens element closest to the object side may interfere with another optical element, or compress optical space between the lens 10 and a projection chip, or cause damage to the lens element closest to the object side. An excessively concave object-side surface of the lens element closest to the object side is unfavorable to aberration correction.

[0088] A specific ratio of R2/EFL is not limited herein, for example, may include but is not limited to 4.3, 4.5, 5, 5.1, 5.159, 5.19, 5.195, 6, 7, 8, 9, 9.1, 9.22, 10, 10.5, 11, 11.654, 12, 12.5, 13, 13.5, 14, 14.5, 15, or 15.5.

[0089] In some possible implementations, the lens 10 may further satisfy a relation: 140 mm<R2<560 mm, where R2 is the curvature radius of the object-side surface of the lens element closest to the object side in the lens 10.

[0090] Correspondingly, the lens 10 satisfies the relation: 140 mm<R2<560 mm. This can reduce the manufacturing difficulty of the lens element closest to the object side in the lens 10, increase the yield, and help improve the cost-effectiveness while implementing both the large aperture and the large field of view. In addition, this can further prevent the object-side surface of the lens element closest to the object side in the lens 10 from being excessively protruding or excessively concave, to effectively balance the optical performance of the lens 10 and the shape of the vehicle lamp.

[0091] A specific value of R2 is not limited herein, for example, may include but is not limited to 141 mm, 145 mm, 150 mm, 160 mm, 170 mm, 180 mm, 181 mm, 182 mm, 183 mm, 184 mm, 184.954 mm, 200 mm, 250 mm, 300 mm, 310 mm, 340 mm, 350 mm, 355 mm, 359 mm, 360 mm, 370 mm, 400 mm, 450 mm, 500 mm, 550 mm, 555 mm, or 559 mm.

[0092] In some possible implementations, the lens element closest to the object side in the lens 10 may have positive focal power. For example, as shown in FIG. 2, the sixth lens element 16 closest to the object side has positive focal power.

[0093] Correspondingly, the lens element closest to the object side is disposed as a lens

element having positive focal power, so that an amount of light entering the lens 10 can be increased, to improve the optical performance, and further improve the cost-effectiveness of the lens 10.

[0094] It should be noted that, in addition to having the positive focal power, the lens element closest to the object side in the lens 10 may also have negative focal power.

[0095] In some possible implementations, at least one lens element may be a spherical lens element. For example, as shown in FIG. 2, all the six lens elements in the lens 10 may be spherical lens elements. Certainly, there may alternatively be fewer than six spherical lens elements.

[0096] Correspondingly, a larger quantity of spherical lens elements in the lens 10 indicates a larger extent to which processing difficulty of the lens 10 is reduced. This helps increase the yield, and can further improve imaging quality.

[0097] In some possible implementations, as shown in FIG. 2, the lens 10 may further include an aperture stop 17. The aperture stop 17 may be disposed between two adjacent lens elements in the lens 10. For example, as shown in FIG. 2, the aperture stop 17 may be disposed between the fourth lens element 14 and the fifth lens element 15. Certainly, the aperture stop 17 may alternatively be disposed at another position.

[0098] In some possible implementations, the lens 10 may further include cover glass 18 (not shown in the figure). The cover glass 18 is configured to be disposed between the lens element closest to the object side in the lens 10 and the modulation unit 22, and the cover glass 18 is configured to protect the modulation unit 22.

[0099] In some possible implementations, the lens 10 may further include a light filter (not shown in the figure) configured to correct a color deviation. The light filter is configured to be disposed between the lens element closest to the object side in the lens 10 and the modulation unit 22.

[00100] It should be noted that one of the cover glass 18 and the light filter may be disposed in the lens 10, or both the cover glass and the light filter may be disposed in the lens.

[00101] The following describes a structure and performance of the projection apparatus 120 provided in embodiments of this application with reference to specific embodiments.

[00102] FIG. 3 is a diagram of a structure of a first projection apparatus 120 according to Embodiment 1 of this application.

[00103] As shown in FIG. 3, the projection apparatus 120 may include a lens 10 and a modulation unit 22. The lens 10 includes a first lens element 11, a second lens element 12, a third lens element 13, a fourth lens element 14, an aperture stop 17, a fifth lens element 15, a sixth lens element 16, and cover glass 18 that are sequentially arranged from an image side to an object side. The first lens element 11 is closest to the image side, the sixth lens element 16 is closest to the

object side, and the cover glass 18 is disposed between the sixth lens element 16 and the modulation unit 22. The modulation unit 22 may include a projection chip, and the projection chip may be a DMD or an LCOS.

[00104] The first lens element 11 has positive focal power, and a ratio of a focal length f1 of the first lens element 11 to a focal length EFL of the lens 10 is |f1/EFL|=10.8.

[00105] The second lens element 12 has negative focal power, and a ratio of a focal length f2 of the second lens element 12 to the focal length EFL of the lens 10 is |f2/EFL|=–4.

[00106] The third lens element 13 has positive focal power, and a ratio of a focal length f3 of the third lens element 13 to the focal length EFL of the lens 10 is |f3/EFL|=2.44.

[00107] The fourth lens element 14 has negative focal power, and a ratio of a focal length f4 of the fourth lens element 14 to the focal length EFL of the lens 10 is |f4/EFL|=–0.65.

[00108] The fifth lens element 15 has positive focal power, and a ratio of a focal length f5 of the fifth lens element 15 to the focal length EFL of the lens 10 is |f5/EFL|=1.0.

[00109] The sixth lens element 16 has positive focal power, and a ratio of a focal length f6 of the sixth lens element 16 to the focal length EFL of the lens 10 is |f6/EFL|=1.82.

[00110] All the first lens element 11, the second lens element 12, the third lens element 13, the fourth lens element 14, the fifth lens element 15, and the sixth lens element 16 may be made of optical glass or plastic. In addition, a surface profile of each lens element may be modeled as spherical.

[00111] The focal length EFL of the lens 10 is 35.34 mm, which is greater than 33 mm and less than 38 mm, and meets a requirement.

[00112] A lens element closest to the image side in the lens 10 is the first lens element 11, and a curvature radius R1 of an image-side surface of the first lens element 11 is 557.2 mm, which is greater than 198 mm and less than 1500 mm, and meets a requirement. A ratio R1/EFL of the curvature radius R1 of the image-side surface of the first lens element 11 to the focal length EFL of the lens 10 is 15.77, which is greater than 6 and less than 50, and meets a requirement.

[00113] A lens element closest to the object side in the lens 10 is the sixth lens element 16, and a curvature radius R2 of an object-side surface of the sixth lens element 16 is 214.88 mm, which is greater than 140 mm and less than 560 mm, and meets a requirement. A ratio R2/EFL of the curvature radius R2 of the object-side surface of the sixth lens element 16 to the focal length EFL of the lens 10 is 6.08, which is greater than 4 and less than 16, and meets a requirement.

[00114] A back focal length BFL of the lens 10 is 29.88 mm, and a ratio of the back focal length BFL of the lens 10 to the focal length EFL of the lens 10 is BFL/EFL=0.846, which meets a requirement.

[00115] Table 1 shows optical parameters of optical elements in the projection apparatus 120

provided in Embodiment 1.

Surface number	Surface profile	R (mm)	TH (mm)	Nd	Vd
OBJ	Spherical	Infinity	10000		
S1	Spherical	557.195	10.725	1.91	35.2
S2	Spherical	–25.185	4.467	1.88	40.8
S3	Spherical	–150.850	0.021		
S4	Spherical	77.417	4.020	2.02	29.1
S5	Spherical	571.510	4.967		
S6	Spherical	–33.082	10.500	1.81	22.7
S7	Spherical	49.932	2.821		
S8	Spherical	Infinity	0.000	1.73	54.7
S9	Spherical	78.957	17.810		
S10	Spherical	–35.384	0.254	1.82	46.5
S11	Spherical	43.023	6.767		
S12	Spherical	214.877	28.579	1.523	58.6
S13	Spherical	Infinity	1.265		
S14	Spherical	Infinity	0		
ImgH	Spherical	Infinity	0		

[00116] S1 represents the image-side surface of the first lens element 11. S2 represents an equivalent surface formed by attaching the image-side surface of the first lens element 11 to an image-side surface of the second lens element 12. S3 represents the image-side surface of the second lens element 12. S4 represents an image-side surface of the third lens element 13. S5 represents an object-side surface of the third lens element 13. S6 represents an image-side surface of the fourth lens element 14. S7 represents an object-side surface of the fourth lens element 14. S8 represents the aperture stop 17. S9 represents an image-side surface of the fifth lens element 15. S10 represents an object-side surface of the fifth lens element 15. S11 represents an image-side surface of the sixth lens element 16. S12 represents the object-side surface of the sixth lens element 16. S13 represents an image-side surface of the cover glass 18. S14 represents an object-side surface of the cover glass 18. OBJ represents a projection surface (an object surface). ImgH represents an imaging plane.

[00117] R represents a curvature radius of an optical element (for example, a lens element or the cover glass) at a position corresponding to an optical axis. Th represents a surface thickness of the optical element in a direction of the optical axis. Nd represents a refractive index of each optical element irradiated by a line d. Vd represents an Abbe number of the optical element.

[00118] Table 2 shows optical parameters of the lens 10 provided in Embodiment 1.

f1 (mm)	355.877	EFL (mm)	35.34
f2 (mm)	–141.636	TTL (mm)	92.25
f3 (mm)	86.124	Fno	1.0
f4 (mm)	–22.910	BFL (mm)	29.88
f5 (mm)	35.628	R1 (mm)	557.2
f6 (mm)	64.245	R2 (mm)	214.88

[00119] EFL represents the focal length of the lens 10. Fno represents an aperture of the lens 10. BFL represents the back focal length of the lens 10. TTL represents an optical total length of the lens 10. R1 represents the curvature radius of the image-side surface of the lens element closest to the image side in the lens 10. R2 represents the curvature radius of the object-side surface of the lens element closest to the object side in the lens 10. f1 represents the focal length of the first lens element 11. f2 represents the focal length of the second lens element 12. f3 represents the focal length of the third lens element 13. f4 represents the focal length of the fourth lens element 14. f5 represents the focal length of the fifth lens element 15. f6 represents the focal length of the sixth lens element 16.

[00120] FIG. 4 is a spherical and chromatic aberration diagram of the lens 10 in FIG. 3.

[00121] In FIG. 4, a vertical coordinate represents a normalized pupil coordinate, and a horizontal coordinate represents an aberration in an axial direction, in millimeters. In FIG. 4, three curves respectively correspond to axial aberration curves of light with a wavelength of 625 nm, light with a wavelength of 550 nm, and light with a wavelength of 455 nm that pass through the lens 10 in this embodiment. It can be seen from FIG. 4 that, in this embodiment, axial aberrations are controlled within an excessively small range, and are well corrected.

[00122] FIG. 5 is an astigmatism and field curvature diagram of the lens 10 in FIG. 3, and FIG. 6 is a distortion diagram of the lens 10 in FIG. 3.

[00123] In FIG. 5, S represents field curvature values of light with a wavelength of 525 nm on a meridian image surface, and T represents field curvature values of the light with the wavelength of 525 nm on a sagittal image surface. In FIG. 6, a solid line represents distortion values of the light with a central wavelength of 525 nm that passes through the lens 10 in this embodiment. In this embodiment, with reference to FIG. 5 and FIG. 6, it can be seen that the lens 10 provided in this embodiment controls the field curvature and the distortion within corresponding ranges, so that a use requirement can be met.

[00124] FIG. 7 is a diagram of a structure of a second projection apparatus 120 according to Embodiment 2 of this application.

[00125] As shown in FIG. 7, the projection apparatus 120 may include a lens 10 and a modulation unit 22. The lens 10 includes a first lens element 11, a second lens element 12, a third lens element 13, a fourth lens element 14, an aperture stop 17, a fifth lens element 15, a sixth lens element 16, and cover glass 18 that are sequentially arranged from an image side to an object side. The first lens element 11 is closest to the image side, the sixth lens element 16 is closest to the object side, and the cover glass 18 is disposed between the sixth lens element 16 and the modulation unit 22. The modulation unit 22 may include a projection chip, and the projection chip may be a DMD or an LCOS.

[00126] All the first lens element 11, the second lens element 12, the third lens element 13, the fourth lens element 14, the fifth lens element 15, and the sixth lens element 16 may be made of optical glass or plastic. In addition, a surface profile of each lens element may be modeled as spherical.

[00127] The first lens element 11 has positive focal power, and a ratio of a focal length f1 of the first lens element 11 to a focal length EFL of the lens 10 is |f1/EFL|=9.654.

[00128] The second lens element 12 has negative focal power, and a ratio of a focal length f2 of the second lens element 12 to the focal length EFL of the lens 10 is |f2/EFL|=–3.912.

[00129] The third lens element 13 has positive focal power, and a ratio of a focal length f3 of the third lens element 13 to the focal length EFL of the lens 10 is |f3/EFL|=2.43.

[00130] The fourth lens element 14 has negative focal power, and a ratio of a focal length f4 of the fourth lens element 14 to the focal length EFL of the lens 10 is |f4/EFL|=–0.646.

[00131] The fifth lens element 15 has positive focal power, and a ratio of a focal length f5 of the fifth lens element 15 to the focal length EFL of the lens 10 is |f5/EFL|=1.0.

[00132] The sixth lens element 16 has positive focal power, and a ratio of a focal length f6 of the sixth lens element 16 to the focal length EFL of the lens 10 is |f6/EFL|=1.82.

[00133] The focal length EFL of the lens 10 is 35.34 mm, which is greater than 33 mm and less than 38 mm, and meets a requirement.

[00134] A lens element closest to the image side in the lens 10 is the first lens element 11, and a curvature radius R1 of an image-side surface of the first lens element 11 is 519.11 mm, which is greater than 198 mm and less than 1500 mm, and meets a requirement. A ratio R1/EFL of the curvature radius R1 of the image-side surface of the first lens element 11 to the focal length EFL of the lens 10 is 14.69, which is greater than 6 and less than 50, and meets a requirement.

[00135] A lens element closest to the object side in the lens 10 is the sixth lens element 16, and a curvature radius R2 of an object-side surface of the sixth lens element 16 is 255.52 mm, which is greater than 140 mm and less than 560 mm, and meets a requirement. A ratio R2/EFL of the curvature radius R2 of the object-side surface of the sixth lens element 16 to the focal length EFL

of the lens 10 is 7.23, which is greater than 4 and less than 16, and meets a requirement.

[00136] A back focal length BFL of the lens 10 is 29.88 mm, and a ratio of the back focal length BFL of the lens 10 to the focal length EFL of the lens 10 is BFL/EFL=0.846, which meets a requirement.

[00137] Table 3 shows optical parameters of optical elements in the projection apparatus 120 provided in Embodiment 2.

Surface number	Surface profile	R (mm)	TH (mm)	Nd	Vd
OBJ	Spherical	Infinity	10000.000		
S1	Spherical	519.116	10.880	1.91	35.2
S2	Spherical	–25.161	6.066	1.88	40.8
S3	Spherical	–146.395	0.023		
S4	Spherical	74.648	3.888	2.02	29.1
S5	Spherical	453.819	4.861		
S6	Spherical	–32.633	10.500	1.81	22.7
S7	Spherical	50.620	2.837		
S8	Spherical	Infinity	0.000		
S9	Spherical	81.334	17.002	1.73	54.7
S10	Spherical	–34.917	0.020		
S11	Spherical	44.444	6.647	1.82	46.5
S12	Spherical	255.515	28.583		
S13	Spherical	Infinity	1.265	1.523	58.6
S14	Spherical	Infinity	0.052		
ImgH	Spherical				

[00138] S1 represents the image-side surface of the first lens element 11. S2 represents an equivalent surface formed by attaching the image-side surface of the first lens element 11 to an image-side surface of the second lens element 12. S3 represents the image-side surface of the second lens element 12. S4 represents an image-side surface of the third lens element 13. S5 represents an object-side surface of the third lens element 13. S6 represents an image-side surface of the fourth lens element 14. S7 represents an object-side surface of the fourth lens element 14. S8 represents the aperture stop 17. S9 represents an image-side surface of the fifth lens element 15. S10 represents an object-side surface of the fifth lens element 15. S11 represents an image-side surface of the sixth lens element 16. S12 represents the object-side surface of the sixth lens element 16. S13 represents an image-side surface of the cover glass 18. S14 represents an object-side surface of the cover glass 18. OBJ represents a projection surface (an object surface). ImgH

represents an imaging plane.

[00139] R represents a curvature radius of an optical element (for example, a lens element or the cover glass) at a position corresponding to an optical axis. Th represents a surface thickness of the optical element in a direction of the optical axis. Nd represents a refractive index of each optical element irradiated by a line d. Vd represents an Abbe number of the optical element.

[00140] Table 4 shows optical parameters of the lens 10 provided in Embodiment 2.

f1 (mm)	341.143	EFL (mm)	35.34
f2 (mm)	–138.223	TTL (mm)	92.62
f3 (mm)	85.836	Fno	1.0
f4 (mm)	–22.849	BFL (mm)	29.88
f5 (mm)	35.468	R1 (mm)	519.11
f6 (mm)	64.481	R2 (mm)	255.52

[00141] EFL represents the focal length of the lens 10. Fno represents an aperture of the lens 10. BFL represents the back focal length of the lens 10. TTL represents an optical total length of the lens 10. R1 represents the curvature radius of the image-side surface of the lens element closest to the image side in the lens 10. R2 represents the curvature radius of the object-side surface of the lens element closest to the object side in the lens 10. f1 represents the focal length of the first lens element 11. f2 represents the focal length of the second lens element 12. f3 represents the focal length of the third lens element 13. f4 represents the focal length of the fourth lens element 14. f5 represents the focal length of the fifth lens element 15. f6 represents the focal length of the sixth lens element 16.

[00142] FIG. 8 is a spherical and chromatic aberration diagram of the lens 10 in FIG. 7.

[00143] In FIG. 8, a vertical coordinate represents a normalized pupil coordinate, and a horizontal coordinate represents an aberration in an axial direction, in millimeters. In FIG. 8, three curves respectively correspond to axial aberration curves of light with a wavelength of 625 nm, light with a wavelength of 550 nm, and light with a wavelength of 455 nm that pass through the lens 10 in this embodiment. It can be seen from FIG. 8 that, in this embodiment, axial aberrations are controlled within an excessively small range, and are well corrected.

[00144] FIG. 9 is an astigmatism and field curvature diagram of the lens 10 in FIG. 7, and FIG. 10 is a distortion diagram of the lens 10 in FIG. 7.

[00145] In FIG. 9, S represents field curvature values of light with a wavelength of 525 nm on a meridian image surface, and T represents field curvature values of the light with the wavelength of 525 nm on a sagittal image surface. In FIG. 10, a solid line represents distortion values of the light with a central wavelength of 525 nm that passes through the lens 10 in this embodiment. In

this embodiment, with reference to FIG. 9 and FIG. 10, it can be seen that the lens 10 provided in this embodiment controls the field curvature and the distortion within corresponding ranges, so that a use requirement can be met.

[00146] In the descriptions of embodiments of this application, it should be noted that, unless otherwise clearly specified and limited, the term "mounting", "connection to", or "connection" should be understood in a broad sense, for example, may be fastening, or may be an indirect connection through an intermediate medium, or may be internal communication between two elements or an interaction relationship between two elements. A person of ordinary skill in the art may understand specific meanings of the foregoing terms in embodiments of this application based on specific cases.

[00147] In embodiments of this application, it is implied that an apparatus or element needs to have a particular orientation, or needs to be constructed and operated in a particular orientation, and therefore cannot be construed as a limitation on embodiments of this application. In the description of embodiments of this application, unless otherwise exactly and specifically ruled, "a plurality of" means two or more than two.

[00148] In the specification, claims, and accompanying drawings of embodiments of this application, the terms "first", "second", "third", "fourth", and the like (if existent) are intended to distinguish between similar objects but do not necessarily indicate a specific order or sequence. It should be understood that the data used in such a way is interchangeable in proper circumstances, so that embodiments of this application described herein can be implemented in other sequences than the sequence illustrated or described herein. In addition, the terms "include" and "have" and any other variants are intended to cover the non-exclusive inclusion. For example, a process, method, system, product, or device that includes a list of steps or units is not necessarily limited to those expressly listed steps or units, but may include other steps or units not expressly listed or inherent to such a process, method, product, or device.

[00149] The term "a plurality of" in this specification means two or more than two. The term "and/or" in this specification describes only an association relationship between associated objects and indicates that three relationships may exist. For example, A and/or B may indicate the following three cases: Only A exists, both A and B exist, and only B exists. In addition, a character "/" in this specification usually indicates an "or" relationship between associated objects, and a character "/" in a formula usually indicates a "division" relationship between associated objects.

[00150] It may be understood that various numbers in embodiments of this application are merely used for differentiation for ease of description, and are not used to limit the scope of embodiments of this application.

[00151] It may be understood that sequence numbers of the foregoing processes do not mean

execution sequences in embodiments of this application. The execution sequences of the processes should be determined based on functions and internal logic of the processes, and should not be construed as any limitation on the implementation processes of embodiments of this application.

CLAIMS

1. A lens, comprising at least six lens elements arranged from an image side to an object side, wherein

a lens element closest to the image side in the lens has positive focal power, there are at least three lens elements having positive focal power in the lens, and there is at least one lens element having negative focal power in the lens; and

the lens satisfies a relation: 33 mm<EFL<38 mm, wherein EFL is a focal length of the lens.

2. The lens according to claim 1, wherein the lens satisfies a relation: BFL/EFL≥0.846, wherein BFL is a back focal length of the lens, and EFL is the focal length of the lens.

3. The lens according to claim 1 or 2, wherein the lens satisfies a relation: 6<R1/EFL<50, wherein R1 is a curvature radius of an image-side surface of the lens element closest to the image side in the lens, and EFL is the focal length of the lens.

4. The lens according to any one of claims 1 to 3, wherein the lens satisfies a relation: 198 mm<R1<1500 mm, wherein R1 is a curvature radius of an image-side surface of the lens element closest to the image side in the lens.

5. The lens according to any one of claims 1 to 4, wherein the lens satisfies a relation: 4<R2/EFL<16, wherein R2 is a curvature radius of an object-side surface of the lens element closest to the object side in the lens, and EFL is the focal length of the lens.

6. The lens according to any one of claims 1 to 5, wherein the lens satisfies a relation: 140 mm<R2<560 mm, wherein R2 is a curvature radius of an object-side surface of the lens element closest to the object side in the lens.

7. The lens according to any one of claims 1 to 6, wherein the lens element closest to the object side in the lens has positive focal power.

8. The lens according to any one of claims 1 to 7, wherein the at least six lens elements comprise a first lens element, a second lens element, a third lens element, a fourth lens element, a fifth lens element, and a sixth lens element that are sequentially arranged from the image side to the object side, the first lens element is closest to the image side and has the positive focal power, and the sixth lens element is closest to the object side.

9. A projection apparatus, comprising a display unit and the lens according to any one of claims 1 to 8, wherein the display unit is configured to emit imaging light to the lens.

10. The projection apparatus according to claim 9, wherein the display unit comprises a light source unit and a modulation unit; and

the modulation unit is configured to: modulate a light beam emitted by the light source unit to generate the imaging light, and emit the imaging light to the lens.

11. The projection apparatus according to claim 10, wherein the display unit further comprises a reflection unit, and the reflection unit is configured to reflect the light beam emitted by the light source unit to the modulation unit.

12. A vehicle lamp apparatus, comprising a housing and the projection apparatus according to any one of claims 9 to 11, wherein at least a part of the projection apparatus is disposed inside the housing.

13. A vehicle, comprising the vehicle lamp apparatus according to claim 12.