

DESCRIPTION

Zoom Lens and Image Pick-up Apparatus Using Zoom Lens

Technical Field

The present invention relates to a zoom lens compact and adapted for performing realization of thin structure in a camera depth direction, which is suitable when used in image pick-up optical system of a digital input/output equipment such as digital still camera or video camera, etc., and an image pick-up apparatus using such a zoom lens.

This Application claims priority of Japanese Patent Application No. 2004-077213, filed on March 17, 2004, the entirety of which is incorporated by reference herein.

Background Art

In recent years, image pick-up apparatuses using solid-state image pick-up device such as digital still camera, etc. are being popularized. With popularization of such digital still camera, realization of higher picture quality is required. Particularly, in digital still camera having a large number of pixels, etc., photographing (imaging) lenses excellent in image formation performance, particularly zoom lenses, which comply with solid-state image pick-up device having a large number of pixels are required. Further, there

also exists demands for miniaturization, and particularly zoom lenses in which realization of thin structure in the camera depth direction is attained are required.

For example, as a zoom lens which is compact and is excellent in image formation performance, there conventionally exists a three group zoom lens consisting of a negative first lens group, a positive second lens group and a positive third lens group in order from the object side as described in the Japanese Patent Application Laid Open No. 2002-350726 publication. In the optical system disclosed in this publication, length of the optical system lens total thickness is limit as thickness in the camera depth direction at the time of sinking barrel so that it cannot be said that miniaturization in the camera depth direction is sufficient.

On the other hand, there is known a zoom lens in which prism is inserted between lenses to thereby bend or fold the optical system so that miniaturization in the optical axis direction has been further promoted. For example, as described in the Japanese Patent Application Laid Open No. 1996-248318 publication, the optical axis is bent or folded by using prism within four group zoom lens optical system consisting of a positive first lens group, a negative second lens group, a positive third lens group and a positive fourth lens group in order from the object side to thereby realize miniaturization in the optical axis direction. In the optical system described in

this publication, front (optical) gem (front lens element) and reflection member are large so that miniaturization is not sufficient.

Disclosure of the Invention

Problems to be solved by the invention

Example embodiments may provide a novel zoom lens which can solve problems that conventional zoom lenses have, and an image pick-up apparatus using such a zoom lens.

Example embodiments may provide a zoom lens compact and adapted for attaining realization of thin structure in camera depth direction which is used in video camera or digital still camera, etc., and an image pick-up apparatus using such a zoom lens.

In accordance with a first aspect of the present invention, there is provided a zoom lens at least including, in order from an object side, a first group of optical elements including a reflection member for bending or folding the optical axis and having negative refractive power and a first lens disposed on the object side of the reflection member, a second group of optical elements having negative refractive power, and a light quantity adjustment member fixed during magnification changing or adjustment operation and serving to adjust light quantity; wherein the following conditional formula (1) is satisfied. $0.1 < |f_1/f_2| < 1.2$ (1). In the

above formula, f_1 : focal length of the first group, f_2 : focal length of the second group and wherein the following conditional formula (2) is satisfied.

$$1.6 < D_{12w}/f_w < 5 \quad (2).$$

In the above formula, D_{12w} : a distance at wide-angle end state between the first lens of the first group of optical elements and a second lens of the second group of optical elements, the second lens being directly adjacent the reflection member and being disposed on an opposite side of the reflection member to the first lens, f_w : focal length of the entire system at wide-angle end state.

In accordance with a second aspect of the present invention, there is provided a zoom lens composed, in order from an object side, of a first group of optical elements including a reflection member for bending or folding the optical axis and having negative refractive power and a first lens disposed on the object side of the reflection member, a second group of optical elements having negative power, a third group of optical elements having positive refractive power, and a fourth group of optical elements having positive refractive power, wherein a light quantity adjustment member for adjusting light quantity is fixed during magnification changing or adjustment operation, wherein the following conditional formula (3) is satisfied.

$$0.1 < |f_1/f_2| < 1.2 \quad (3).$$

In the above formula, f_1 : focal length of the first group, f_2 : focal

length of the second group and wherein the following conditional formula (4) is satisfied. $1.6 < D12w/fw < 5$ (4).

In the above formula, D12w: a distance at wide-angle end state between the first lens of the first group of optical elements and a second lens of the second group of optical elements, the second lens being directly adjacent the reflection member and being disposed on an opposite side of the reflection member to the first lens, fw: focal length of the entire system at wide-angle end state

In the example embodiments, the zoom lens can comprise, in order from an object side, a first group including a reflection member for bending or folding the optical axis and having negative refractive power, a

second group having negative refractive power, a third group having positive refractive power, and a fourth group having positive refractive power, wherein a light quantity adjustment member for adjusting light quantity is fixed during magnification changing or adjustment operation.

The image pick-up apparatus in example embodiments is directed to an image pick-up apparatus comprising a zoom lens, and an image pick-up device for converting an optical image formed by the zoom lens into an electric signal, wherein there is used, as a zoom lens used in the image pick-up apparatus, a zoom lens comprising, in order from an object side, a first group including a reflection member for bending or folding the optical axis and having negative refractive power, a second group having negative refractive power, and a light quantity adjustment member fixed during magnification changing or adjustment operation and serving to adjust light quantity, or a zoom lens comprising, in order from an object side, a first group including a reflection member for bending or folding the optical axis and having negative refractive power, a second group having negative refractive power, a third group having positive refractive power, and a fourth group having positive refractive power, wherein a light quantity adjustment member for adjusting light quantity is fixed during magnification changing or adjustment operation.

In the zoom lens, the length in the

incident optical axis direction can be greatly shortened while maintaining high magnification changeable ratio and high picture quality, and there is employed the so-called minus lead configuration in which the first and second lens groups are caused to have negative refractive power. Thus, the front gem (front optical element) and the reflection member can be reduced. In addition, since the light quantity adjustment member for adjusting light quantity is fixed during zooming operation, mirror cylindrical configuration can become compact.

In the zoom lens , the length in the incident optical axis direction can be greatly reduced while maintaining high magnification changeable ratio and high picture quality, and the optical front gem and the reflection member can be reduced by the minus lead configuration. Moreover, since the light quantity adjustment member for adjusting light quantity is fixed during zooming operation, the mirror cylindrical configuration can become compact.

In the image pick-up apparatus , image formation performance is improved, and the length in the incident optical axis direction of the zoom lens system is reduced so that the front gem diameter and the reflection member can be reduced, and the mirror cylindrical configuration can become compact. Accordingly, compact configuration and thin structure of the image pick-up apparatus can be realized.

Example embodiments are applied, thereby making it possible to attain improvement in image formation performance and miniaturization of zoom lens used in video camera or digital still camera, etc.

Practical merits obtained by example embodiments will become more apparent from the embodiments which will be given below with reference to the attached drawings.

Brief Description of the Drawings

FIG. 1 is a lens configuration diagram of a first embodiment of a zoom lens to which the present invention is applied.

FIG. 2 is a lens configuration diagram of a second embodiment of a zoom lens to which the present invention is applied.

FIG. 3 is a lens configuration diagram of a third embodiment of a zoom lens to which the present invention is applied.

FIG. 4 is a lens configuration diagram of a fourth embodiment of a zoom lens to which the present invention is applied.

FIG. 5 is a view showing various aberrations at short focal length (distance) end of the embodiment 1 of the zoom lens to which the present invention is applied.

FIG. 6 is a view showing various aberrations at intermediate focal

length of the embodiment 1 of the zoom lens to which the present invention is applied.

FIG. 7 is a view showing various aberrations at long focal length end of the embodiment 1 of the zoom lens to which the present invention is applied.

FIG. 8 is a view showing various aberrations at short focal length end of the embodiment 2 of the zoom lens to which the present invention is applied.

FIG. 9 is a view showing various aberrations at intermediate focal length of the embodiment 2 of the zoom lens to which the present invention is applied.

FIG. 10 is a view showing various aberrations at long focal length end of the embodiment 2 of the zoom lens to which the present invention is applied.

FIG. 11 is a view showing various aberrations at short focal length end of the embodiment 3 of the zoom lens to which the present invention is applied.

FIG. 12 is a view showing various aberrations at intermediate focal length of the embodiment 3 of the zoom lens to which the present invention is applied.

FIG. 13 is a view showing various aberrations at long focal length end

of the embodiment 3 of the zoom lens to which the present invention is applied.

FIG. 14 is a view showing various aberrations at short focal length end of the embodiment 3 of the zoom lens to which the present invention is applied.

FIG. 15 is a view showing various aberrations at intermediate focal length of the embodiment 3 of the zoom lens to which the present invention is applied.

FIG. 16 is a view showing various aberrations at long focal length end of the embodiment 3 of the zoom lens to which the present invention is applied.

FIG. 17 is a view showing outline of the configuration of the present invention.

FIG. 18 is a block diagram of an image pick-up apparatus to which the present invention is applied.

Best Mode for Carrying Out the Invention

The first to fourth embodiments of a zoom lens of the present invention will now be explained with reference to FIGS. 1 to 4.

FIGS. 1 to 4 are lens configurations diagrams respectively corresponding to the zoom lens systems constituting these first to fourth

embodiments, and show lens arrangements at wide-angle end state (a) and telescopic end state (b) by optical cross section. Arrows m_j ($j = 1, 2, \dots$) in respective lens configuration diagrams show, in a model form, movements of the j -th lens group (GR $_j$), etc. at zooming operation from wide-angle end state (a) to telescopic end state (b). Moreover, in respective lens configuration diagrams, plane to which r_i ($i = 1, 2, \dots$) is attached is the i -th plane when counted from the object surface side. Further, in respective lens configuration diagrams, I indicates image surface of image pick-up device, CG indicates cover glass of the image pick-up device, and LPF indicates low pass filter.

As shown in the lens configuration diagram of FIG. 1, the zoom lens of the first embodiment is composed, in order from the object side, a negative first lens group GR1, a negative second lens group GR2, a positive third lens group GR3, a light quantity adjustment member ST1, and a positive fourth lens group GR4.

The first lens group GR1 is composed of a negative lens, and a rectangular prism for bending or folding the optical axis by 90° . The second lens group GR2 is composed of a negative lens having non-spherical surface at the image surface side thereof, and a positive lens. The third lens group GR3 is composed of a positive lens having non-spherical surfaces at both surface sides thereof, a connection lens of the positive lens and a negative lens,

and a positive lens. The fourth lens group GR4 is comprised of positive lens having non-spherical surface at the object side thereof. Between the third lens group GR3 and the fourth lens group GR4, there are fixed an iris for adjusting light quantity, a ND filter, and a light quantity adjustment member ST1 such as liquid crystal, etc. The positions of the first lens group GR1 and the low pass filter LPF are fixed at zooming operation. Moreover, the third lens group GR3 includes an aperture limiting member ST2 for limiting aperture diameter at the side closest to the object. The aperture limiting member ST2 is only required to limit aperture diameter. For example, light shielding plate, etc. is used for this purpose.

In performing magnification changing or adjustment operation from the wide-angle end state shown in (a) of FIG. 1 to the telescopic end state shown in (b) of FIG. 1, the second lens group GR2 moves toward the image surface side thereafter to take a U-turn toward the object side, and the third lens group GR3 moves towards the object side and the fourth lens group GR4 slightly moves toward the image surface side.

Moreover, actual arrangement in the shortest focal length state of the zoom lens system of the first embodiment is shown in FIG. 17. While the configuration of the reflection member is schematically indicated as parallel flat plate in the lens configuration diagram of FIG. 1, perpendicular prism PR is disposed as an actual configuration as shown in FIG. 17. Here, in FIG. 17,

TL indicates zoom lens system, RS indicates reflection surface of the perpendicular prism PR, and SR indicates image pick-up device. It is to be noted that such a configuration is similar also in the zoom lens systems of second and third embodiments which will be described later. Further, also in the zoom lens system of the fourth embodiment, a reflection mirror M having reflection surface RS is disposed at the position of the perpendicular prism PR in FIG. 17.

As shown in the lens configuration diagram of FIG. 2, the zoom lens of the second embodiment is composed, in order from the object side, of a negative first lens group GR1, a negative second lens group GR2, a positive third lens group GR3, a light quantity adjustment member ST1, and a positive fourth lens group GR4.

The first lens group GR1 is composed of a negative lens, and a perpendicular prism PR for bending or folding the optical axis by 90° . The second lens group GR2 is composed of a negative lens having non-spherical surface at the image side thereof, and a positive lens. The third lens group GR3 is composed of a positive lens having non-spherical surfaces at both surface sides thereof, and a connection lens of the positive lens and a negative lens. The fourth lens group GR4 is comprised of plastic positive lens having non-spherical surfaces at both surface sides thereof. Between the third lens group GR3 and the fourth lens group GR4, there are fixed an iris for adjusting

light quantity, a ND filter and a light quantity adjustment member ST1 such as liquid crystal, etc. The positions of the first lens group GR1 and the low pass filter LPF are fixed during zooming operation. Moreover, the third lens group GR3 includes an aperture limiting member ST2 for limiting aperture diameter at the side closest to the object. The aperture limiting member ST2 is only required to limit aperture diameter. For example, a light shielding plate, etc. is used for this purpose.

In performing magnification changing or adjustment operation from the wide-angle end state shown in (a) of FIG. 2 to the telescopic end state shown in (b) of FIG. 2, the second lens group GR2 moves toward the image surface side thereafter to take a U-turn toward the object side, and the third lens group GR3 moves towards the object side and the fourth lens group GR4 slightly moves towards the image surface side.

The zoom lens of the third embodiment is composed, in order from the object side, a negative first lens group GR1, a negative second lens group GR2, a positive third lens group GR3, a light quantity adjustment member ST1, and a positive fourth lens group GR4.

The first lens group GR1 is composed of a negative lens, and a perpendicular prism PR for bending or folding the optical axis by 90° . The second lens group GR2 is composed of a plastic negative lens having non-spherical surfaces at both surface sides thereof, and a positive lens. The

third lens group GR3 is composed of a positive lens, a connection lens of the positive lens and a negative lens, and a plastic positive lens having non-spherical surfaces at both surface sides thereof. The fourth lens group GR4 is comprised of plastic positive lens having non-spherical surfaces at both surface sides thereof. Between the third lens group GR3 and the fourth lens group GR4, there are fixed an iris for adjusting light quantity, a ND filter, and a light quantity adjustment member ST1 such as liquid crystal, etc. The positions of the first lens group GR1 and the low-pass filter LPF are fixed during zooming operation. Moreover, the third lens group GR3 includes an aperture limiting member ST2 for limiting aperture diameter at the side closest to the object. The aperture limiting member ST2 is only required to limit the aperture diameter. For example, light shielding plate, etc. is used for this purpose.

In performing magnification changing or adjustment operation from the wide-angle end state shown in (a) of FIG. 3 to the telescopic end state shown in (b) of FIG. 3, the second lens group GR2 moves toward the image surface side thereafter to take a U-turn toward the object side, and the third lens group GR3 moves toward the object side and the fourth lens group GR4 moves toward the image surface side thereafter to take a U-turn toward the object side.

The zoom lens of the fourth embodiment is composed, in order from

the object side, a negative first lens group GR1, a negative second lens group GR2, a positive third lens group GR3, a light quantity adjustment member ST1, and a positive fourth lens group GR4.

The first lens group GR1 is composed of a negative lens, and a reflection mirror M for bending or folding the optical axis by 90°. The second lens group GR2 is composed of a negative lens having non-spherical surfaces at both surface sides thereof, and a positive lens. The third lens group GR3 is composed of a positive lens having non-spherical surfaces at both surface sides thereof, a connection lens of the positive lens and a negative lens, and a positive lens. The fourth lens group GR4 is comprised of positive lens having non-spherical surfaces at both surface sides thereof. Between the third lens group GR3 and the fourth lens group GR4, there are fixed an iris for adjusting light quantity, a ND filter, and a light quantity adjustment member ST1 such as liquid crystal, etc. The positions of the first lens group GR1 and the low-pass filter LPF are fixed during zooming operation. Moreover, the third lens group GR3 includes an aperture limiting member ST2 for limiting aperture diameter at the side closest to the object. The aperture limiting member ST2 is only required to limit the aperture diameter. For example, light shielding plate, etc. is used for this purpose.

In performing magnification changing or adjustment operation from the wide-angle end state shown in (a) of FIG. 4 to the telescopic end state

shown in (b) of FIG. 4, the second lens group GR2 moves toward the image surface side thereafter to take a U-turn toward the object side, and the third lens group GR3 moves towards the object side and the fourth lens group GR4 slightly moves towards the image surface side.

At the above-described zoom lenses of the first to fourth embodiments, there is employed such a configuration to bend or fold the optical axis by substantially 90° by the reflection member to thereby have ability to greatly shorten the length in the incident optical axis direction, and to overlap optical path of object light in the vicinity of the reflection surface. Accordingly, space can be effectively used and miniaturization can be made. In the above-described zoom lens, the position of the reflection member is caused to be position of the first lens group disposed at the side closest to the object, thereby making it possible to attain miniaturization of the image pick-up apparatus using zoom lens.

Moreover, in the zoom lenses of the first to fourth embodiments, there is employed the so-called minus lead configuration for allowing the first lens group and the second lens group to have negative refractive power, thereby making it possible to reduce the front gem (front optical element) diameter and the reflection member.

Further, in the zoom lenses of the first to fourth embodiments, complicated mirror cylindrical configuration is not required, and realization of

compact configuration and thin structure can be performed. Further, since the light quantity adjustment member ST1 is disposed between the third lens group GR3 and the fourth lens group GR4, miniaturization can be most effectively attained.

In the zoom lenses of the first to third embodiments, since perpendicular prism PR is used as the reflection member, spacing in transmission through prism results in reduced spacing shorter than physical spacing of ordinary air spacing in accordance with refractive index of medium as compared to the time when the reflection mirror is used. For this reason, it is possible to attain optically equivalent configuration by more compact space.

Then, the condition desirable to be satisfactory in the zoom lens system of minus·minus·plus·plus, or the zoom lens system beginning with minus·minus as in the first to fourth embodiments will be explained.

It is to be noted that while if respective conditions explained below can be respectively satisfied by themselves, it is possible to attain actions/effects corresponding thereto, it is a matter of course that a method of satisfying plural conditions is more desirable from viewpoints of optical performance and/or miniaturization, etc.

It is desirable to satisfy the following conditional formula or expression.

$$0.1 < |f1/f2| < 1.2 \cdots (1)$$

In the above formula,

f_1 : focal length of the first lens group

f_2 : focal length of the second lens group

The conditional formula (1) is a conditional formula for prescribing focal length ratio between the first lens group and the second lens group. When the focal length ratio becomes equal to lower limit of the conditional formula (1) or less, focal length of the first lens group becomes short. As a result, correction of distortion aberration becomes difficult. When the focal length ratio exceeds the upper limit of the conditional formula (1), the focal length of the first group is elongated, leading to increase in the front gem diameter. Thus, miniaturization becomes difficult, and the focal length of the second lens group becomes short. As a result, eccentricity sensitivity of the second lens group is also increased.

Moreover, it is desirable to satisfy the following conditional formula (2).

$$1.6 < D_{12w}/f_w < 5 \cdots (2)$$

In the above formula,

D_{12w} : spacing from the plane at the side closest to the image of the lens group of the object side from the reflection member at wide-angle end state up to plane at the side closest to the object of the second lens group,

f_w : focal length of the entire system at wide-angle end state.

The conditional formula (2) is a conditional formula for prescribing spacing from the plane at the side closest to the image of the lens group of the object side from the reflection member up to the plane at the side closest to the object of the second lens group. When the spacing from the plane at the side closest to the image of the lens group of the object side from the reflection member to the plane at the side closest to the object of the second lens group becomes equal to lower limit of the conditional formula (2) or less, negative power of the group before the reflection member becomes too strong. Thus, correction of distortion aberration becomes difficult. In addition, space of the reflection member is small, and it also becomes difficult to arrange the reflection member. On the other hand, when the above mentioned spacing is above the upper limit of the conditional formula (2), negative power of the group before the reflection member becomes weak, leading to increase of the front gem diameter and the reflection member. Thus, miniaturization becomes difficult.

Moreover, in connection with the configuration of the first group of the first to third embodiments, in the case where prism is used as reflection member for bending or folding the optical axis within the zoom lens system, it is desirable to use nitric material having high refractive index. It is desirable that the refractive index is 1.7 or more. It is more desirable that the refractive index is 1.8 or more.

When the refractive index of the prism is 1.7 or less, contribution to compact configuration would become small. Moreover, when the refractive index of the prism is 1.7 or more, the reflection condition becomes close to the total reflection condition so that light quantity loss is reduced. This is preferable. Further, when the refractive index of the prism is 1.8 or more, it is possible to further reduce light quantity loss.

The configuration of the zoom lens system used in the image pick-up lens apparatus to which the present invention is applied will be explained in more concrete terms by taking examples of numeric data and aberration diagrams, etc.

The embodiments 1 to 4 mentioned as an example here respectively correspond to the previously described first to fourth embodiments, and lens configuration diagrams representing the first to fourth embodiments (see FIGS. 1 to 4) respectively show lens configurations of corresponding embodiments 1 to 4.

In numeric data of respective embodiments, r_i ($i = 1, 2, \dots$) indicates curvature of radius (mm) of the i -th plane when counted from the object side, d_i ($i = 1, 2, \dots$) indicates the i -th axial spacing (mm) when counted from the object side, n_{di} ($i = 1, 2, \dots$) indicates refractive index with respect to d line of the i -th optical element when counted from the object side, and v_{di} ($i = 1, 2, \dots$) indicates Abbe number with respect to the d line of the i -th optical element

when counted from the object side.

Moreover, in the numeric data, axial spacing (d_i) to which (variable) is attached indicates variable spacing at wide-angle end state (short focal length end, W) ~ middle (intermediate focal length end, M) ~ telescopic end state (long focal length end, T) in zooming operation. Moreover, in numeric data, FNo. indicates F number, f indicates focal length (mm), and ω indicates half picture angle ($^\circ$), wherein these values indicate values at the entire system corresponding to respective focal length states (W), (M), (T).

Moreover, in the numeric data, the plane indicated at (ASP) is non-spherical surface, and the shape of non-spherical surface is shape represented by the following formula.

[Formula 1]

$$x = \frac{y^2 \cdot c^2}{1 + (1 - \varepsilon \cdot y^2 \cdot c^2)^{1/2}} + \sum A^i \cdot Y^i$$

In the above formula, x , y , c , ε and A_i are defined as below.

x : distance in the optical axis direction from lens surface summit point

y : height in a direction perpendicular to the optical axis

c : paraxial curvature at lens summit point

ε : cone constant

A_i : i -th non-spherical coefficient

Respective numeric values and respective conditional formulas for determining the conditional formula (1) and the conditional formula (2) of the zoom lenses shown in the above-described embodiments 1 to 4 are shown in the following Table 1.

FIGS. 5 and 16 show various aberrations (spherical aberration, astigmatism and distortion aberration in order from the left) of the embodiments 1 to 4. In the case of the spherical aberration, ratio with respect to aperture F value is taken on the ordinate, and defocus is taken on the abscissa, wherein the solid line (d) indicates spherical aberration at the d line, the broken lines (c) indicate spherical aberration at the line c , and single dotted lines (g) indicate spherical aberration at g line. In the case of the astigmatism, the ordinate indicates image height (mm), the abscissa indicates focus, the solid line (DS) indicates image surface of sagittal, and broken lines (DM) indicate the image surface of meridional. In the case of the distortion aberration, the ordinate indicates image height (mm), and the abscissa indicates distortion %. Here, IMG HT indicates image height (mm).

Also apparent from the Table 1, the zoom lenses of the embodiments 1 to 4 satisfy the conditional formula (1) and the conditional formula (2). Moreover, as shown in the respective aberration diagrams, respective aberrations are corrected in well-balanced manner at wide-angle end state (W),

intermediate focal length (M) between the wide-angle end state and the telescopic end state, and the telescopic end state (T).

<Embodiment 1>

(W) ~ (M) ~ (T)

FNo. = 2.86 ~ 4.15 ~ 5.17

f = 3.69 ~ 7.02 ~ 10.70

ω = 38.56 ~ 21.79 ~ 14.41

d4 = 0.880 ~ 3.827 ~ 0.880

d8 = 12.829 ~ 3.737 ~ 1.724

d16 = 1.405 ~ 7.550 ~ 12.510

d17 = 1.519 ~ 2.630 ~ 2.830

d19 = 2.151 ~ 1.040 ~ 0.840

[Curvature of radius] [Axial spacing] [Refractive index] [Abbe number]

r1 = 22.595 d1 = 0.650 nd1 = 1.88300 vd1 = 40.805

r2 = 8.409 d2 = 2.300

r3 = ∞ d3 = 8.900 nd2 = 1.84666 vd2 = 23.785

r4 = ∞ d4 = (variable)

r5 = 81.924 d5 = 0.900 nd3 = 1.73077 vd3 = 40.501

r6 = 4.612 (ASP) d6 = 1.410

r7 = 9.874 d7 = 2.100 nd4 = 1.84666 vd4 = 23.785

r8 = 882.961 d8 = (variable)

r9 = Aperture d9 = 0.100

limiting

member

r10 = 5.520 (ASP) d10 = 2.200 nd5 = 1.58313 vd5 = 59.461

r11 = -12.931 (ASP) d11 = 0.320

r12 = 24.065 d12 = 2.220 nd6 = 1.48749 vd6 = 70.441

r13 = -5.047 d13 = 0.600 nd7 = 1.64769 vd7 = 33.841

r14 = 4.327 d14 = 1.145

r15 = 12.000 d15 = 1.411 nd8 = 1.48749 vd8 = 70.441

r16 = -14.666 d16 = (variable)

r17 = Light quantity d17 = (variable)

adjustment

member

r18 = -18.906 (ASP) d18 = 2.000 nd9 = 1.77377 vd9 = 47.200

r19 = -9.058 d19 = (variable)

r20 = ∞ d20 = 1.530 nd10 = 1.51680 vd10 = 64.198

r21 = ∞ d21 = 0.500

r22 = ∞ d22 = 0.600 nd11 = 1.51680 vd11 = 64.198

r23 = ∞

[non-spherical data of the 6-th plane (r6)]

$\varepsilon = 1$, $A_4 = -0.154426 \times 10^{-2}$, $A_6 = -0.967007 \times 10^{-5}$,

$$A8 = -0.441264 \times 10^{-5}, A10 = 0.125661 \times 10^{-6}$$

[non-spherical data of the 10-th plane (r10)]

$$\varepsilon_1, A4 = -0.111861 \times 10^{-2}, A6 = -0.460219 \times 10^{-4}$$

$$A8 = 0.192625 \times 10^{-5}, A10 = -0.101161 \times 10^{-5}$$

[non-spherical data of the 11-th plane (r11)]

$$\varepsilon_1 = 1, A4 = -0.540695 \times 10^{-3}, A6 = 0.292235 \times 10^{-5},$$

$$A8 = -0.817608 \times 10^{-5}, A10 = -0.224752 \times 10^{-6}$$

[non-spherical data of the 18-th plane (r18)]

$$\varepsilon_1 = 1, A4 = -0.479030 \times 10^{-3}, A6 = -0.679555 \times 10^{-4},$$

$$A8 = 0.872286 \times 10^{-5}, A10 = -0.361221 \times 10^{-6}$$

<Embodiment 2>

(W) ~ (M) ~ (T)

$$FNo. = 2.86 \sim 4.15 \sim 5.21$$

$$f = 5.71 \sim 10.84 \sim 16.54$$

$$\omega = 32.24 \sim 17.45 \sim 11.52$$

$$d4 = 1.100 \sim 4.350 \sim 0.839$$

$$d8 = 15.058 \sim 4.456 \sim 1.651$$

$$d14 = 2.614 \sim 9.973 \sim 16.282$$

$$d15 = 3.236 \sim 4.582 \sim 4.629$$

$$d17 = 2.594 \sim 1.240 \sim 1.200$$

[Curvature of radius] [Axial spacing] [Refractive index] [Abbe number]

$r1 = 24.631$	$d1 = 0.700$	$nd1 = 1.88300$	$vd1 = 40.805$
$r2 = 11.994$	$d2 = 2.400$		
$r3 = \infty$	$d3 = 10.800$	$nd2 = 1.84666$	$vd2 = 23.785$
$r4 = \infty$	$d4 = (\text{variable})$		
$r5 = -92.234$	$d5 = 1.200$	$nd3 = 1.80611$	$vd3 = 40.734$
$r6 = 8.121 (\text{ASP})$	$d6 = 1.471$		
$r7 = 13.080$	$d7 = 2.550$	$nd4 = 1.84666$	$vd4 = 23.785$
$r8 = 264.232$	$d8 = (\text{variable})$		
$r9 = \text{Aperture}$	$d9 = 1.071$		

limiting

member

$r10 = 8.616 (\text{ASP})$	$d10 = 2.840$	$nd5 = 1.48749$	$vd5 = 70.441$
$r11 = -11.801 (\text{ASP})$	$d11 = 0.340$		
$r12 = 15.092$	$d12 = 2.907$	$nd6 = 1.72916$	$vd6 = 54.674$
$r13 = -7.318$	$d13 = 0.800$	$nd7 = 1.59270$	$vd7 = 35.446$
$r14 = 4.864$	$d14 = (\text{variable})$		
$r15 = \text{Light}$	$d15 = (\text{variable})$		

quantity

adjustment

member

$r16 = -31.547 (\text{ASP})$	$d16 = 2.100$	$nd8 = 1.52470$	$vd8 = 56.236$
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$r_{17} = -10.101$ (ASP) $d_{17} = (\text{variable})$

$r_{18} = \infty$ $d_{18} = 1.900$ $nd_9 = 1.51680$ $vd_9 = 64.198$

$r_{19} = \infty$ $d_{19} = 0.600$

$r_{20} = \infty$ $d_{20} = 0.700$ $nd_{10} = 1.51680$ $vd_{10} = 64.198$

$r_{21} = \infty$

[non-spherical data of the 6-th plane (r_6)]

$\varepsilon_1 = 1$, $A_4 = -0.236090 \times 10^{-3}$, $A_6 = 0.195539 \times 10^{-5}$,

$A_8 = -0.240030 \times 10^{-6}$, $A_{10} = 0.568074 \times 10^{-8}$

[non-spherical data of the 10-th plane (r_{10})]

$\varepsilon_1 = 1$, $A_4 = -0.810299 \times 10^{-3}$, $A_6 = -0.309901 \times 10^{-6}$,

$A_8 = -0.164625 \times 10^{-5}$, $A_{10} = -0.132742 \times 10^{-8}$

[non-spherical data of the 11-th plane (r_{11})]

$\varepsilon_1 = 1$, $A_4 = -0.150065 \times 10^{-3}$, $A_6 = 0.743678 \times 10^{-5}$,

$A_8 = -0.226961 \times 10^{-5}$, $A_{10} = 0.404500 \times 10^{-7}$

[non-spherical data of the 16-th plane (r_{16})]

$\varepsilon = 1$, $A_4 = -0.209875 \times 10^{-3}$, $A_6 = -0.202921 \times 10^{-4}$,

$A_8 = 0.765438 \times 10^{-6}$, $A_{10} = 0.226804 \times 10^{-7}$

[non-spherical data of the 17-th plane (r_{17})]

$\varepsilon = 1$, $A_4 = 0.271556 \times 10^{-3}$, $A_6 = -0.317324 \times 10^{-4}$,

$A_8 = 0.132533 \times 10^{-5}$, $A_{10} = 0.000000 \times 1000$

<Embodiment 3>

	(W)	~	(M)	~	(T)
FNo.	= 2.86	~	4.09	~	5.05
f	= 5.70	~	10.83	~	16.53
ω	= 32.26	~	17.56	~	11.55
d4	= 1.210	~	4.570	~	1.091
d8	= 14.658	~	4.102	~	1.239
d16	= 1.639	~	8.834	~	15.177
d17	= 1.600	~	4.137	~	3.761
d19	= 3.777	~	1.240	~	1.615

[Curvature of radius] [Axial spacing] [Refractive index] [Abbe number]

r1 = 24.599	d1 = 0.700	nd1 = 1.88300	vd1 = 40.805
r2 = 11.190	d2 = 2.400		
r3 = ∞	d3 = 10.450	nd2 = 1.84666	vd2 = 23.785
r4 = ∞	d4 = (variable)		
r5 = -14.092 (ASP)	d5 = 1.360	nd3 = 1.52470	vd3 = 56.236
r6 = 12.422 (ASP)	d6 = 1.400		
r7 = 10.136	d7 = 1.880	nd4 = 1.84666	vd4 = 23.785
r8 = 19.634	d8 = (variable)		
r9 = Aperture	d9 = 1.200		

limiting

member

$r_{10} = 11.100$ $d_{10} = 2.359$ $nd_5 = 1.58913$ $vd_5 = 61.253$
 $r_{11} = -99.119$ $d_{11} = 0.100$
 $r_{12} = 7.694$ $d_{12} = 2.947$ $nd_6 = 1.65844$ $vd_6 = 50.855$
 $r_{13} = -11.867$ $d_{13} = 0.700$ $nd_7 = 1.71736$ $vd_7 = 29.501$
 $r_{14} = 7.244$ $d_{14} = 1.300$
 $r_{15} = -43.564$ (ASP) $d_{15} = 1.700$ $nd_8 = 1.52470$ $vd_8 = 56.236$
 $r_{16} = -18.354$ (ASP) $d_{16} = (\text{variable})$
 $r_{17} = \text{Light}$ $d_{17} = (\text{variable})$

quantity

adjustment

member

$r_{18} = -22.956$ (ASP) $d_{18} = 2.550$ $nd_9 = 1.52470$ $vd_9 = 56.236$
 $r_{19} = -10.989$ (ASP) $d_{19} = (\text{variable})$
 $r_{20} = \infty$ $d_{20} = 1.870$ $nd_{10} = 1.51680$ $vd_{10} = 64.198$
 $r_{21} = \infty$ $d_{21} = 0.600$
 $r_{22} = \infty$ $d_{22} = 0.720$ $nd_{11} = 1.51680$ $vd_{11} = 64.198$
 $r_{23} = \infty$

[non-spherical data of the fifth plane (r_5)]

$\varepsilon = 1$, $A_4 = 0.189079 \times 10^{-2}$, $A_6 = -0.703670 \times 10^{-4}$

$A_8 = 0.186108 \times 10^{-5}$, $A_{10} = -0.226657 \times 10^{-7}$

[non-spherical data of the sixth plane (r_6)]

$$\varepsilon = 1, \quad A4 = 0.193344 \times 10^{-2}, \quad A6 = -0.666082 \times 10^{-4},$$

$$A8 = 0.187470 \times 10^{-5}, \quad A10 = -0.262350 \times 10^{-7}$$

[non-spherical data of the 15-th plane (r15)]

$$\varepsilon = 1, \quad A4 = -0.574999 \times 10^{-3}, \quad A6 = 0.386315 \times 10^{-4},$$

$$A8 = 0.964146 \times 10^{-6}, \quad A10 = 0.000000 \times 1000$$

[non-spherical data of the 16-th plane (r16)]

$$\varepsilon = 1, \quad A4 = 0.195080 \times 10^{-3}, \quad A6 = 0.465132 \times 10^{-4},$$

$$A8 = 0.148996 \times 10^{-5}, \quad A10 = 0.000000 \times 1000$$

[non-spherical data of the 18-th plane (r18)]

$$\varepsilon = 1, \quad A4 = -0.212753 \times 10^{-3}, \quad A6 = 0.457906 \times 10^{-4},$$

$$A8 = -0.413322 \times 10^{-6}, \quad A10 = 0.000000 \times 1000$$

[non-spherical data of the 19-th plane (r19)]

$$\varepsilon = 1, \quad A4 = 0.133306 \times 10^{-3}, \quad A6 = 0.284156 \times 10^{-4},$$

$$A8 = 0.230880 \times 10^{-6}, \quad A10 = 0.000000 \times 1000$$

<Embodiment 4>

	(W)	~	(M)	~	(T)
FNo. =	2.87	~	4.34	~	5.53
f =	4.85	~	9.22	~	14.07
ω =	38.29	~	21.60	~	14.30
d4 =	0.780	~	4.152	~	0.780
d8 =	16.722	~	5.627	~	2.323

$$d16 = 2.243 \quad \sim \quad 9.966 \quad \sim \quad 16.642$$

$$d17 = 1.349 \quad \sim \quad 3.787 \quad \sim \quad 3.969$$

$$d19 = 3.640 \quad \sim \quad 1.202 \quad \sim \quad 1.020$$

[Curvature of radius] [Axial spacing] [Refractive index] [Abbe number]

$$r1 = 29.54 \quad d1 = 0.850 \quad nd1 = 1.88300 \quad vd1 = 40.805$$

$$r2 = 11.27 \quad d2 = 3.800$$

$$r3 = \infty \quad d3 = 12.220$$

$$r4 = \infty \quad d4 = (\text{variable})$$

$$r5 = 26.237 \text{ (ASP)} \quad d5 = 1.200 \quad nd2 = 1.73077 \quad vd2 = 40.501$$

$$r6 = 5.980 \text{ (ASP)} \quad d6 = 2.320$$

$$r7 = 12.918 \quad d7 = 2.740 \quad nd3 = 1.84666 \quad vd3 = 23.785$$

$$r8 = 72.468 \quad d8 = (\text{variable})$$

$$r9 = \text{Aperture} \quad d9 = 0.130$$

limiting

member

$$r10 = 7.857 \text{ (ASP)} \quad d10 = 3.420 \quad nd4 = 1.58313 \quad vd4 = 59.461$$

$$r11 = -26.882 \text{ (ASP)} \quad d11 = 1.200$$

$$r12 = 11.250 \quad d12 = 2.938 \quad nd5 = 1.48749 \quad vd5 = 70.441$$

$$r13 = -6.313 \quad d13 = 0.800 \quad nd6 = 1.67270 \quad vd6 = 32.171$$

$$r14 = 5.285 \quad d14 = 0.913$$

$$r15 = 16.649 \quad d15 = 1.525 \quad nd7 = 1.48749 \quad vd7 = 70.441$$

$$r16 = -32.796 \quad d16 = (\text{variable})$$

$$r17 = \text{Light} \quad d17 = (\text{variable})$$

quantity

adjustment

member

$$r18 = -47.622 \text{ (ASP)} \quad d18 = 1.900 \quad nd8 = 1.77377 \quad vd8 = 47.200$$

$$r19 = -14.003 \text{ (ASP)} \quad d19 = (\text{variable})$$

$$r20 = \infty \quad d20 = 1.200 \quad nd9 = 1.51680 \quad vd9 = 64.198$$

$$r21 = \infty \quad d21 = 0.600$$

$$r22 = \infty \quad d22 = 0.500 \quad nd10 = 1.51680 \quad vd10 = 64.198$$

$$r23 = \infty$$

[non-spherical data of the fifth plane (r5)]

$$\varepsilon = 1, \quad A4 = -0.199102 \times 10^{-4}, \quad A6 = 0.120020 \times 10^{-4},$$

$$A8 = -0.410454 \times 10^{-6}, \quad A10 = 0.617981 \times 10^{-8}$$

[non-spherical data of the sixth plane (r6)]

$$\varepsilon = 1, \quad A4 = -0.633623 \times 10^{-3}, \quad A6 = 0.841957 \times 10^{-5},$$

$$A8 = -0.719036 \times 10^{-6}, \quad A10 = 0.414281 \times 10^{-8}$$

[non-spherical data of the 10-th plane (r10)]

$$\varepsilon = 1, \quad A4 = -0.387456 \times 10^{-3}, \quad A6 = 0.265755 \times 10^{-5},$$

$$A8 = -0.858779 \times 10^{-6}, \quad A10 = 0.215789 \times 10^{-9}$$

[non-spherical data of the 11-th plane (r11)]

$$\varepsilon = 1, \quad A4 = -0.309607 \times 10^{-3}, \quad A6 = 0.973513 \times 10^{-5},$$

$$A8 = -0.183569 \times 10^{-5}, \quad A10 = 0.398642 \times 10^{-7}$$

[non-spherical data of the 18-th plane (r18)]

$$\varepsilon = 1, \quad A4 = -0.338236 \times 10^{-3}, \quad A6 = -0.260827 \times 10^{-4},$$

$$A8 = 0.334152 \times 10^{-5}, \quad A10 = -0.688027 \times 10^{-7}$$

[non-spherical data of the 19-th plane (r19)]

$$\varepsilon = 1, \quad A4 = -0.183178 \times 10^{-3}, \quad A6 = -0.185327 \times 10^{-5},$$

$$A8 = 0.954236 \times 10^{-6}, \quad A10 = 0.000000 \times 1000$$

[Table 1]

Conditional Formula	Embodiment 1	Embodiment 2	Embodiment 3	Embodiment 4
(1) $ f1/f2 $	0.716	0.997	0.799	0.582
(2) $D12w/fw$	3.273	2.504	2.467	3.464

Meanwhile, the zoom lens system of the present invention as described above can be used in image pick-up apparatuses adapted for forming object image by the above-mentioned zoom lens to allow image pick-up device or element such as CCD or silver salt film to receive image of that object to perform photographic processing, especially digital still camera or video camera (personal computer as information processing equipment, telephone and/or mobile telephone, etc.)

The image pick-up apparatus to which the present invention is applied will be explained below with reference to FIG. 18.

FIG. 18 is a block diagram for explaining the image pick-up apparatus

to which the present invention is applied. This image pick-up apparatus comprises, as shown in FIG. 18, when roughly classified, a camera unit 1, a camera DSP (Digital Signal Processor) 2, a SDRAM (Synchronous Dynamic Random Access Memory) 3, a medium interface (hereinafter referred to as medium I/F) 4, a control unit 5, an operation unit 6, a LCD (Liquid Crystal Display) controller 7, a LCD 8, and an external interface (hereinafter referred to as I/F) 9, wherein a recording medium 10 is detachably attached.

While it is conceivable that various recording media such as so-called memory card using semiconductor memory, optical recording medium such as recordable DVD (Digital Versatile Disk) or recordable CD (Compact Disc), etc., and/or magnetic disc, etc. may be used as the recording medium 10, explanation will be given in this embodiment on the premise that, e.g., memory card is used as the recording medium 10.

Further, the camera unit 1 comprises, as shown in FIG. 18, an optical block 11, a CCD (Charge Coupled Device) 12 as image pick-up device, a pre-processing circuit 13, a driver 14 for optical block, a driver 15 for CCD, and a timing generating circuit 16. Here, the optical block 11 comprises lens, focus mechanism, shutter mechanism, and iris mechanism, etc.

In addition, the control unit 5 is a microcomputer caused to be of the configuration in which a CPU (Central Processing Unit) 51, a RAM (Random Access Memory) 52, a flash ROM (Read Only Memory) 53, and a clock

circuit 54 are connected through a system bus 55, and is adapted to have ability to control respective components of the image pick-up apparatus of this embodiment.

Here, the RAM 52 is used mainly as work area such as temporary storage of intermediate result of processing, etc. Moreover, the flash ROM 53 is adapted so that various programs executed at the CPU 51, and/or data required for processing, etc. are stored. Moreover, the clock circuit 54 is capable of providing current date, current day and current time, and is capable of providing photographing date and hour, etc.

Further, at the time of photographing image, the optical block driver 14 forms, in accordance with control from the control unit 5, such a drive signal to operate the optical block 11 to deliver the drive signal thus formed to the optical block 11 to allow the optical block 11 to be operative. At the optical block 11, focus mechanism, shutter mechanism and iris mechanism are controlled in accordance with drive signals from the optical block driver 14 to take thereinto image of object to offer the image thus taken in to the CCD 12.

The CCD 12 serves to perform photoelectric conversion of image from the optical block 11 to output the image thus obtained, and becomes operative in accordance with a drive signal from the CCD driver 15 to take thereinto image of object from the optical block 11, and to allow image of object which has been taken in (image information) to be an electric signal on

the basis of timing signal from the timing generating circuit 16 controlled by the control unit 5 to deliver the electric signal thus obtained to the pre-processing circuit 13.

In this example, in a manner as described above, the timing generating circuit 16 serves to form a timing signal which provides a predetermined timing in accordance with control from the control unit 5. Moreover, the CCD driver 15 serves to form a drive signal to be delivered to the CCD 12 on the basis of the timing signal from the timing generating circuit 16.

The pre-processing circuit 13 serves to perform CDS (Correlated Double Sampling) processing with respect to image information of the electric signal delivered thereto to maintain S/N ratio to be satisfactory, and to perform AGC (Automatic Gain Control) processing to control gain to further perform A/D (Analog/Digital) conversion to form image data caused to be a digital signal.

The image data caused to be digital signal from the pre-processing circuit 13 is delivered to the DSP 2. The DSP 2 implements camera signal processing such as AF (Auto Focus), AE (Auto Exposure) and AWB (Auto White Balance), etc. to the image data delivered thereto. The image data in which various adjustments have been performed in this way is caused to undergo data compression by a predetermined compression system. The image data thus processed is delivered to the recording medium 10 loaded into

the image pick-up apparatus of this embodiment through system bus 55 and medium I/F 4, and is recorded onto the recording medium 10 as file in a manner described below.

Further, with respect to the image data which have been recorded on the recording medium 10, target image data is read out from the recording medium 10 through the medium I/F 4 in accordance with operation input from user which has been accepted through the operation unit 6 composed of touch panel and/or control key, etc. The image data which has been read out in this way is delivered to the DSP2.

The DSP2 performs, with respect to compressed image data which has been read out from the recording medium 10 and has been delivered through the medium I/F 4, decompression processing (expansion processing) of that data compression to deliver the decompressed image data to the LCD controller 7 through the system bus 55. The LCD controller 7 forms, from the image data delivered thereto, an image signal to be delivered to the LCD 8 to deliver the image signal thus formed to the LCD8. Thus, image corresponding to image data recorded on the recording medium 10 is displayed on the display screen of the LCD 8.

In this case, form of display of image is in accordance with display processing program recorded in the ROM. Namely, this display processing program is a program indicating mechanism in which file system which will

be described later is recorded, and how to reproduce image.

Moreover, in the image pick-up apparatus of this embodiment, there is provided an external I/F 9. The image pick-up apparatus may be connected to, e.g., external personal computer through the external I/F 9 to receive supply of image data from the personal computer to record the data thus delivered onto recording medium loaded therewithin, or image data recorded at recording medium loaded therewithin may be delivered to external personal computer, etc.

Further, communication module may be connected to the external I/F 9 to thereby connect the image pick-up apparatus to network, e.g., Internet, etc. to acquire various image data and/or other information through the network to record such image data or information with respect to recording medium loaded therewithin, or data recorded at recording medium loaded therewithin may be transmitted to the other side serving as target through network.

Further, also with respect to information such as image data, etc. which is acquired through external personal computer or network and is recorded at the recording medium, it is a matter of course to read out, in a manner as described above, such image data or information at the image pick-up apparatus of this embodiment to reproduce it to display such information on the LCD 8 so that user can utilize such information.

It is to be noted that external I/F 9 may be also provided as interface

for wire such as IEEE (Institute of Electrical and Electronics Engineers) 1394, USB (Universal Serial Bus), etc., and may be provided as wireless interface by light or electric wave. Namely, the external I/F 9 may be either wire or wireless interface.

As stated above, the image pick-up apparatus of this embodiment can photograph image of object to have ability to record the image thus photographed onto recording medium loaded within the image pick-up apparatus, and to have ability to read out image data recorded on the recording medium to reproduce such image data to utilize it. In addition, the image pick-up apparatus can receive offer of image data through external personal computer or network to record the image data thus obtained onto recording medium loaded therewithin, or to read out such image data to reproduce it.

It should be noted that while CCD is used as the image pick-up device, CMOS sensor (Complementary Metal-oxide Semiconductor) may be used.

It is to be noted that while the present invention has been described in accordance with certain preferred embodiments thereof illustrated in the accompanying drawings and described in detail, it should be understood by those ordinarily skilled in the art that the invention is not limited to embodiments, but various modifications, alternative construction or equivalents can be implemented without departing from the scope and spirit of the present invention as set forth by appended claims.

Industrial Applicability

The zoom lens to which the present invention has been applied not only can be used at digital still camera or video camera, but also can be used at silver salt camera by disposing silver salt film in place of CCD. Further, the zoom lens to which the present invention has been applied can be used at camera included or externally attached at personal computer, telephone and/or mobile telephone, etc.

CLAIMS

1 A zoom lens at least including, in order from an object side, a first group of optical elements including a reflection member for bending or folding the optical axis and having negative refractive power and a first lens disposed on the object side of the reflection member, a second group of optical elements having negative refractive power, and a light quantity adjustment member fixed during magnification changing or adjustment operation and serving to adjust light quantity;

wherein the following conditional formula (1) is satisfied.

$$0.1 < |f1/f2| < 1.2 \quad \cdots (1)$$

In the above formula,

f1 : focal length of the first group

f2: focal length of the second group

and wherein the following conditional formula (2) is satisfied.

$$1.6 < D12w/fw < 5 \quad \cdots (2)$$

In the above formula,

D12w: a distance at wide-angle end state between the first lens of the first group of optical elements and a second lens of the second group of optical elements, the second lens being directly adjacent the reflection

member and being disposed on an opposite side of the reflection member to the first lens

fw : focal length of the entire system at wide-angle end state

2 A zoom lens composed, in order from an object side, of a first group of optical elements including a reflection member for bending or folding the optical axis and having negative refractive power and a first lens disposed on the object side of the reflection member, a second group of optical elements having negative power, a third group of optical elements having positive refractive power, and a fourth group of optical elements

having positive refractive power,

wherein a light quantity adjustment member for adjusting light quantity is fixed during magnification changing or adjustment operation,

wherein the following conditional formula (3) is satisfied.

$$0.1 < |f1/f2| < 1.2 \quad (3)$$

In the above formula,

f1: focal length of the first group

f2: focal length of the second group

and wherein the following conditional formula (4) is satisfied.

$$1.6 < D12w/fw < 5 \quad (4)$$

In the above formula,

D12w: a distance at wide-angle end state between the first lens of the first group of optical elements and a second lens of the second group of optical elements, the second lens being directly adjacent the reflection member and being disposed on an opposite side of the reflection member to the first lens

fw: focal length of the entire system at wide-angle end state