the shooting lens together constitute a central measurement chart-side optical system, while each peripheral collimator lens and the shooting lens together constitute a peripheral measurement chart-side optical system. Then, the central collimator lens forms an image of the central measurement chart on the imaging plane of the image sensor through the entrance pupil of the shooting lens. With the central measurement chart disposed inclined relative to a plane vertical to the optical axis of the central collimator lens, the heights of image forming planes of an image formed by the shooting lens which corresponds to an image formed on the imaging plane of the image sensor vary in accordance with the distance from the optical axis of the central collimator lens in a direction orthogonal to the optical axis. Similarly, the peripheral collimator lens forms an image of the peripheral measurement chart on the imaging plane of the image sensor through the entrance pupil of the shooting lens. With the peripheral measurement chart disposed inclined relative to a plane vertical to the optical axis of the peripheral collimator lens, the heights of image forming planes of an image formed by the shooting lens which corresponds to an image formed on the imaging plane of the image sensor vary in accordance with the distance from the optical axis of the peripheral collimator lens in a direction orthogonal to the optical axis. This makes it possible to accurately calculate a focus evaluation value, such as a spatial frequency response, with one image capturing operation. This enables adjustment of the lens unit and the sensor substrate in a short period of time, and thus can further improve productivity.

ADVANTAGEOUS EFFECTS OF INVENTION

[0012]

The camera module manufacturing device according to this disclosure can adjust the relative positions of the lens unit and the sensor substrate in a short period of time in order to improve productivity, and accommodate change of the type of a camera module to be produced with a simple method.

image sensor when the image forming plane of the shooting lens is adjusted to be substantially the same plane as the imaging plane of the image sensor.

FIG. 21 is a plan view of a pattern of a central measurement chart in another embodiment.

DESCRIPTION OF EMBODIMENTS

[0014]

With reference to the accompanying drawings, a camera module manufacturing device 100 according to an embodiment will now be described. Initially, referring to FIG. 1 to FIG. 10, the structure of the camera module manufacturing device 100 will be described.

[0015]

As illustrated in FIG. 1, the camera module manufacturing device 100 is a device for adhering a lens unit 40 having a built-in shooting lens 41, and a sensor substrate 51 having an image sensor 52 mounted thereon to manufacture a camera module 50. The camera module manufacturing device 100 includes an optical module 10, a robot arm 45 for holding the lens unit 40, a stage 55 having the sensor substrate 51 on its upper surface, a six-axis actuator 56 for moving the position of the stage 55 in six axial directions, and a controller 57 for controlling the six-axis actuator 56. Note that the robot arm 45 constitutes a lens-unit holding unit, and the stage 55 constitutes a sensor-substrate holding unit. The following description is made based on an assumption, as illustrated in FIG. 2, that the horizontal direction in which a central measurement chart 32 built in a central optical unit 30 extends is defined as the X direction, a direction orthogonal to the X direction on a horizontal plane is defined as the Y direction, a vertical direction is defined as the Z direction, the positive side in the Z direction is defined extending in the upper direction, and the negative side in the Z direction is defined extending in the lower direction.

[0016]

respectively, such that the optical axis 31a of the central collimator lens 31 built in the central optical unit 30 crosses the optical axis 33a of the peripheral collimator lens 33 built in each peripheral optical unit 35 at one point 29, and that the respective focal points 31f, 33f of the central collimator lens 31 and the peripheral collimator lens 33 fall on the one point 29. Here, each peripheral optical unit 35 is mounted on the guide plate 12 such that the optical axis 33a of each peripheral collimator lens 33 is changeable between the direction T4 and the direction T41, or between the direction T3 and the direction T31, and the angle of inclination defined by the optical axis 33a of the peripheral collimator lens 33 relative to the optical axis of the central collimator lens 31 is changeable, as indicated by arrows 101, 102 in FIG. 1, which is to be described later in detail.

[0019]

As illustrated in FIG. 4 and FIG. 5, the respective peripheral optical units 35 are disposed such that the angles defined by the optical axes 33a of the adjacent peripheral collimator lenses 33 on a plane vertical to the optical axis 31a of the central collimator lens 31 coincide with the respective angles θ1, θ2 defined by the two diagonals 52a, 52b of the rectangular image sensor. Note that the angle θ1 and the angle θ2 are a smaller angle and a larger angle, respectively, of the angles defined by the two diagonals 52a, 52b. Thus, assuming that the respective directions in which the respective optical axes 33a of the peripheral collimator lenses 33 of the four peripheral optical units 35 extend are defined as directions T1 to T4, when the image sensor 52 is disposed such that the optical axis 31a of the central collimator lens 31 passes through the center of the image sensor 52 and the longer edge and the shorter edge of the image sensor 52 extend in the X direction and the Y direction, respectively, the directions in which the two diagonals 52a, 52b of the image sensor 52 extend coincide with the respective directions T1 to T4 on a plane vertical to the optical axis 31a of the central collimator lens 31.

[0020]

As illustrated in FIG. 6, the two guide plates 12 are mounted on the lower surface of the rectangular base 11 so as to together define the angles θ1, θ2. Here, the rectangular base 11 is disposed such that its edges extend in the X direction and the Y direction,

respectively. Thus, when the image sensor 52 is set such that the directions in which the respective edges of the rectangular base 11 extend coincide with those in which the longer edge and the shorter edge of the image sensor 52 respectively extend, the directions in which the two guide plates 12 extend coincide with the directions in which the two diagonals 52a, 52b of the image sensor 52 extend; namely, the directions T1 to T4 on a plane vertical to the optical axis 31a of the central collimator lens 31.

[0021]

As illustrated in FIG. 7, each guide plate 12 is a flat plate whose lower surface is cut into an arc shape with the one point 29 as the center. Each guide plate 12 has a guide slit 13 formed thereon extending in an arc shape with the one point 29 as the center along the arc cut. On the outer circumferential side of the guide slit 13, pin holes 14 for fixture of the position of the bracket 15 carrying the peripheral optical unit 35 thereon are formed aligned in an arc shape. The bracket 15, on which the peripheral optical unit 35 is mounted, moves in an arc manner, while being guided along the guide slit 13 with a pin 16 inserted in the guide slit 13. With a fixing pin 17 inserted into a hole formed on the bracket 15 and the pin hole 14 of the guide plate 12, the bracket 15 is fixed at a predetermined angular position.

[0022]

The guide slit 13 is formed in an arc shape with the one point 29 as the center. The guide plates 12 extend in the respective directions in which the two diagonals 52a, 52b of the image sensor 52 extend. Hence, the respective peripheral optical units 35 move in an arc manner from the direction T1 to the direction T11, or from the direction T3 to the direction T31, as indicated by the arrows 101, 102, above the shooting lens 41 within respective vertical planes containing the two respective diagonals 52a, 52b of the image sensor 52 with the optical axes 33a of the peripheral collimator lenses 33 passing through the one point 29.

[0023]

portions of the four corners of the image sensor 52, as illustrated in FIG. 12. The light forms images 91 of the respective peripheral measurement charts 34 on the four respective peripheral portions of the imaging plane 53 of the image sensor 52, as illustrated in FIG. 12. Each image 91 contains white triangular images 92 caused by the light having passed through the respective light transmissive portions 34t of the peripheral measurement charts 34, black images 93 resulting from shielding the light by the light shielding portions 34s, and boundary images 94 to 96 between the white images 92 and the black images 93. The images 94 to 96 are images of the first edge 34e1 to the third edge 34e3, respectively, of the peripheral measurement chart 34.

[0043]

As illustrated in FIG. 11, in assembling a camera module 50 including a shooting lens 411 having an angle of view of α2, as the focal length of the shooting lens 411 is short, the image sensor 52 is set at a height P2 having a short distance from the shooting lens 41 in the Z direction. The peripheral optical units 35 are set such that the angle defined by the directions T11 and T31, or the directions of the optical axes 33a, coincides with the angle α2, or the angle of view of the shooting lens 41. With the above, also in assembling a camera module 50 including the shooting lens 411 having an angle of view wider than that of the shooting lens 41, it is possible to form the images of the respective peripheral measurement charts 34 of the peripheral optional units 35 on the respective peripheral portions of the four corners of the image sensor 52, similar to the case in which the shooting lens 41 having the angle of view of α1 is used.

[0044]

Details of the central optical unit 30 and the image 81 formed on the central portion of the imaging plane 53 by the central optical unit 30 will now be described.

[0045]

As illustrated in FIG. 13(a), the central collimator lens 31 has a focal point 31f on the side of the shooting lens 41. The lens unit 40 is held such that the focal point 31f of

plane 75 of the shooting lens 41 at different heights with one image capturing operation. Consequently, it is possible to generate a peripheral portion through-focus graph, such as that illustrated in FIG. 18, with one image capturing operation.

[0061]

Utilizing the central portion through-focus graph illustrated in FIG. 15 and the relationship between the height of the image forming plane 65 and the distance in the X direction, illustrated in FIG. 13(b), the controller 57 converts the line a shown in FIG. 15 to a line c shown in FIG. 19(a). The line c here is a line indicative of a change in spatial frequency response relative to the height displacement ΔH between the image forming plane 65 of the shooting lens 41 and the imaging plane 53 of the image sensor 52, in the central portion. Similarly, the lines b1 to b4 shown in FIG. 18 are converted into the respective lines d1 to d4 shown in FIG. 19(a). The lines d1 to d4 here are lines indicative of a change in spatial frequency response relative to the height displacement ΔH between the image forming plane 75 of the shooting lens 41 and the imaging plane 53 of the image sensor 52 in the respective peripheral portions.

[0062]

Referring to FIG. 19(a), the line c indicates that the spatial frequency response takes a maximum value at the height displacement ΔH1. As the height displacement ΔH1 is negative, it can be determined that the central portion of the imaging plane 53 is positioned lower by an amount ΔH1 relative to the image forming plane 65 of the shooting lens 41, as illustrated in FIG. 19(b). Further, as the lines d1, d3 as well indicate that the spatial frequency response takes maximum values at the height displacement ΔH1, it can be determined that the imaging plane 53 is positioned lower by an amount ΔH1 relative to the image forming plane 75 of the shooting lens 41 in the respective peripheral portions in the directions R1, R3. Similarly, as the lines d2, d4 indicate that the spatial frequency response is maximum at the height displacements ΔH3, ΔH2, respectively, it can be determined that the imaging plane 53 is positioned lower by amounts ΔH3, ΔH2,

images of the peripheral measurement charts 34, respectively, on the central portion and the peripheral portions, respectively, of the image sensor 52 through the entrance pupil 42 of the shooting lens 41. With disposition of the central measurement chart 32 and the peripheral measurement charts 34 so as to be inclined relative to the respective planes vertical to the optical axis 31a of the central collimator lens 31 and to the respective optical axes 33a of the peripheral collimator lenses 33, an image 81 which has the image forming planes 65 of the shooting lens 41 at heights that vary in accordance with the distance from the optical axis 31a of the central collimator lens 31 in a direction orthogonal to the optical axis 31a is formed on the imaging plane of the image sensor 52, and an image 91 which has the image forming planes 75 of the shooting lens 41 at heights that vary in accordance with the distance from the optical axis 33a of each peripheral collimator lens 33 in the direction orthogonal to the optical axis 33a is formed on the imaging plane of the image sensor 52. This enables highly accurate calculation of a focus evaluation value, such as the spatial frequency response, with one image capturing operation. This enables adjustment of the lens unit and the sensor substrate in a short period, and thus further improvement in productivity.

[0071]

In this case, a scale 32m for absolute positions is marked on the central measurement chart 32, as illustrated in FIG. 21, and a similar scale is marked on each peripheral measurement chart 34 as well. Then, a spatial frequency response is calculated with reference to the scales 32m. This can achieve a similar level of accuracy as that which is achieved with a telecentric optical system.

[0072]

The ratio (A1/A2) of the difference A1 in height along the optical axis 31a of the central collimator lens 31 between the distal end 32f and the proximal end 32n of the central measurement chart 32 to the difference A2 in height between the upper image forming plane 65n and the lower image forming plane 65f, as illustrated in FIG. 13(a), and

the ratio of the focal length f1 of the central collimator lens 31 to the focal length f2 of the shooting lens 41 hold the relationship expressed by the expression (1) below.

$A1/A2 = (f1/f2)^2$ --- (1)

[0073]

Similarly, the ratio (B1/B2) of the difference B1 in distance along the optical axis 33a of the peripheral collimator lens 33 between the distal end 34f and the proximal end 34n of each peripheral measurement chart 34 to the height difference B2 between the upper image forming plane 75n and the lower image forming plane 75f, as illustrated in FIG. 16(a), and the ratio of the focal length g1 of the peripheral collimator lens 33 to the local focal length f3 of the shooting lens 41 hold the relationship expressed by the expression (2) below.

$B1/B2 = (g1/f3)^2$ --- (2)

wherein the local focal length f3 is, for example, a local focal length expressed as $f3=f2/\cos(\theta)$ with θ representing the view of angle relative to the optical axis 41a.

[0074]

Note that the differences A2, B2 in height between the respective upper image forming planes 65n, 75n and the respective lower image forming planes 65f, 75f are within a range for height adjustment of the sensor substrate 51. Thus, changing the respective angles and lengths of the central measurement chart 32 and the respective peripheral measurement charts 34 relative to the respective planes vertical to the optical axes 31a, 33a, based on the focal length f2 and the local focal length f3, respectively, of the shooting lens 41 enables adjustment of the respective height differences A2, B2, to thereby adjust the range for height adjustment of the sensor substrate 51 in accordance with the shooting lens 41.

[0075]