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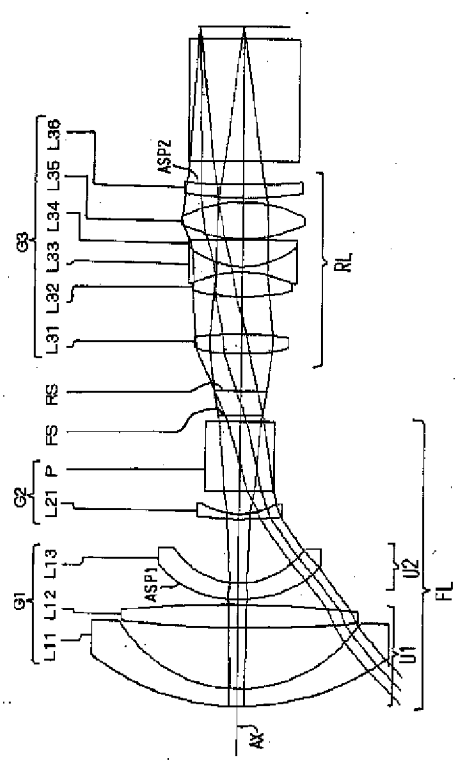
(54) [Title of invention] Projection lens and projector

(57) [Summary]
[Problem] To provide a projection lens having a large angle of view and a large aperture ratio and suitable for a three-plate type projector, and a projector equipped with this lens.
[Means for solving] The first lens group G1 having negative power, the second lens group G2 having negative power, and the third lens group G3 having positive power, in order from the screen side, wherein the negative power of the second lens group G2 is greater than the negative power of the first lens group G1.



[Scope of Patent Claims]

[Claim 1] A projection lens characterized by comprising, in order from the screen side, a first lens group having a negative power, a second lens group having a negative power, and a third lens group having a positive power, wherein the negative power of the second lens group is greater than the negative power of the first lens group.

[Claim 2] The projection lens according to Claim 1, characterized in that the lens furthest from the screen side of the first lens group and the lens furthest from the screen side of the third lens group each have an aspheric surface.

[Claim 3] The projection lens according to Claim 2, characterized in that the surface of the lens having the aspheric surface in the first lens group and the third lens group opposite to the aspheric surface is a surface that is not an aspheric surface.

[Claim 4] The projection lens according to Claim 2, characterized in that the aspheric surface of the first lens group has a shape that monotonically increases or monotonically decreases from the optical axis toward the lens periphery.

[Claim 5] The projection lens according to Claim 1, characterized in that the second lens group has a prism.

[Claim 6] The projection lens according to Claim 1, characterized in that the second lens group has a cemented lens.

[Claim 7] The projection lens according to Claim 1, characterized in that the third lens group has a cemented lens consisting of two or more lenses.

[Claim 8] The projection lens according to Claim 7, characterized in that an aperture is provided between the second lens group and the third lens group, and the refractive index of the lens of the third lens group closest to the aperture is greater than the refractive index of the negative lens constituting the cemented lens of the third lens group.

[Claim 9] The projection lens according to Claim 1, characterized in that the absolute value of the combined focal length between the first lens group and the second lens group is smaller than the absolute value of the combined focal length of the third lens group.

[Claim 10] The projection lens according to Claim 1, characterized in that at least some of the lenses comprising the second lens group are movable along the optical axis.

[Claim 11] The projection lens according to Claim 1, characterized in that the first lens group is composed of a first unit from the lens closest to the screen side to the lens adjacent to the screen side of the lens having the aspheric surface,
and a second unit from the lens having the aspheric surface to the lens furthest from the screen side, and the first unit is movable along the optical axis direction.

[Claim 12] The projection lens according to Claim 5, characterized in that it further has a fixing flange portion for securing the projection lens in the vicinity of the prism.

[Claim 13] A projection lens characterized by comprising, in order from the screen side, a front group having negative power and a rear group having positive power, wherein the convex surface in the front group and the rear group each have an aspheric surface.

[Claim 14] The projection lens according to Claim 13, characterized in that the opposite side of the aspheric surface of the lens having the aspheric surface of the front group is a surface that is not an aspheric surface.

[Claim 15] The projection lens according to Claim 13, characterized in that the aspheric surface of the front group has a shape that monotonically increases or monotonically decreases from the optical axis toward the lens periphery.

[Claim 16] The projection lens according to Claim 13, characterized in that an aperture is provided between the front group and the rear group, wherein the front group has a prism.

[Claim 17] The projection lens according to Claim 13, characterized in that the front group has a cemented lens.

[Claim 18] The projection lens according to Claim 13, characterized in that the rear group has a cemented lens composed of two or more lenses.

[Claim 19] The projection lens according to Claim 18, characterized in that an aperture is provided between the front group and the rear group, wherein the refractive index of the lens in the rear group closest to the aperture is greater than the refractive index of the negative lens constituting the cemented lens of the rear group.

[Claim 20] The projection lens according to Claim 13, characterized in that the absolute value of the composite focal length of the front group is smaller than the absolute value of the composite focal length of the rear group.

[Claim 21] The projection lens according to Claim 13, characterized in that at least some of the lenses in the front group are movable along the optical axis.

[Claim 22] The projection lens according to Claim 13, characterized in that the front group is composed of a first unit from the lens closest to the screen side to the lens adjacent to the screen side of the lens having the aspheric surface, and a second unit from the lens having the aspheric surface to the lens farthest from the screen side,
wherein the first unit is movable along the optical axis direction.

[Claim 23] The projection lens according to Claim 16, characterized by further having a fixing flange portion for fixing the projection lens in the vicinity of the prism.

[Claim 24] A projector comprising an illumination optical system that emits illumination light, a light modulation device that modulates the illumination light emitted from the illumination optical system in response to an image signal, and a projection lens for projecting an optical image formed on the light modulation device, the projection lens characterized in that it is a projection lens according to any one of Claims 1 to 23.

[Claim 25] The projector according to Claim 24, characterized in that the F-number of the projection lens is smaller than the F-number of the illumination optical system.

[Detailed Description of the Invention]

[0001]

[Technical field to which the invention belongs] The present invention relates to projection lenses and projectors using this lens.

[0002]

[Prior Art] Projectors have been used to obtain large images. The projector forms an optical image corresponding to the image signal in the light modulation device. The light is then projected into an optical image on the light modulation device, and the optical image is projected into a screen surface, etc. by means of a projection lens.

[0003] These projector are broadly classified into front projectors and a rear projectors. Front projectors have a configuration in which the projector body and the screen are separated. Rear projectors also have a configuration that mounts a transparent-type screen in the front of a cabinet and houses all optical components in the cabinet.

[0004] One effective means for making projectors thinner, especially rear projectors, is to broaden the projection lens to shorten the projection distance. Projection lenses are proposed in, for example, Japanese Unexamined Patent Application Publication No. H5-150158, Japanese Patent No. 3105805, and the like. The lens proposed in the Japanese Unexamined Patent Application Publication H5-150158 publication consists of three lens groups. Then, a mirror is disposed between the lens groups to bend the optical axis by 90 degrees. In addition, the lens proposed in Patent No. 3105805 is composed of four lens groups. Then, a fourth lens group for ensuring telecentricity is disposed immediately before the liquid crystal panel. In addition, a prism is provided between the lens groups to bend the optical axis by 90° or more.

[0005]

[Problem to be Solved by the Invention] However, although the lens proposed in Japanese Unexamined Patent Application Publication No. H5-150158 is applicable to a so-called three-plate type projector, the angle of view θ of the lens is small, at 30.5° to 31.2°. In addition, the F-number becomes large, about 4.0. Therefore, the problem is that the projector cannot be miniaturized because the projector cannot be sufficiently shortened.

[0006] Also, the lens proposed in Patent No. 3105805 is arranged immediately before the liquid crystal panel a fourth lens group having positive power to ensure telecentricity as described above. Therefore, in order to apply this projection lens to a three-plate projector, it is necessary to incident light collected by the fourth lens group into the color synthesis optical system. Here, the polarizing film of the color synthesis optical system has an angular characteristic with respect to the incident light beam. Therefore, if converging light according to the fourth lens group is incident on the color synthesis optical system, there is a problem that color volatility occurs due to the incident angle dependence of the polarizing film. As a result, it is difficult to apply the lens proposed in Patent No. 3105805 to a three-plate projector.

[0007] The first invention has been made in consideration of the above problems, and has an object to provide a projection lens having a large angle of view, a large aperture ratio, and good optical performance, particularly a projection lens suitable for a three-plate projector. Furthermore, the second invention is intended to provide a projector that uses the projection lens described above to obtain a bright projection image and is small and thin.

[0008]

[Means for solving the problem]To solve the above problem, the projection lens according to the first invention consists of a first lens group having negative power, a second lens group having negative power, and a third lens group having positive power, in order from the screen side, characterized in that the negative power of the second lens group is greater than the negative power of the first lens group. This makes it possible to provide a retrofocus type projection lens having a long back focus, a wide angle of view and a large aperture ratio.

[0009] This projection lens consists of a first lens group of negative power, a second lens group of negative power, and a third lens group of positive power between apertures. By increasing the negative power of the second lens group, it is possible to ensure sufficient space for disposing a color synthesis optical system behind the projection lens on the light modulation device side while maintaining sufficient optical performance and telecentricity.

[0010] According to a preferred aspect of the present invention, the lens furthest from the screen side of the first lens group and the lens furthest from the screen side of the third lens group are also characterized in that each has an aspheric surface. This allows the aspheric surface of the first lens group to achieve a smaller lens system. In addition, the aspheric surface of the third lens group can most effectively compensate for aberrations. More preferably, it is desirable to form a convex surface of the first lens group and a concave surface of the third lens group in an aspheric surface. If the aspheric lens is formed of a plastic lens, placing the aspheric surface in a concave and convex pair can compensate for the change in optical performance due to expansion or deflation of the plastic member due to changes in ambient temperature.

[0011] Looking at the first invention from another point of view, it is characterized in that it consists of a front group having negative power and a rear group having positive power from the screen side, and that the convex surface within the front group and the rear group each have an aspheric surface. This makes it possible to provide a retrofocus type projection lens having a long back focus, a wide angle of view and a large aperture ratio. Also, the aspheric surface of the front group has the same effect as the aspheric surface of the first lens group, and the aspheric surface of the rear group has the same effect as the aspheric surface of the third lens group.

[0012] According to a preferred aspect of the present invention, it is also characterized in that the face opposite the aspheric surface of a lens having the aspheric surface of the first lens group or the front group and the third lens group or the rear group is a surface that is not an aspheric surface. This makes it easier to build a mold for making lenses. This makes lens molding easier and increases lens productivity.

[0013] In addition, according to a preferred aspect of the present invention, the aspheric surface of the first lens group or the front group is characterized by having a shape that monotonically increases or monotonically decreases from the optical axis toward the lens periphery. This can bring the distortion aberration closer to the monotonic change. Thus, this projection lens is particularly suitable for rear projectors having a screen frame.

[0014] Also, according to a preferred aspect of the present invention, the second lens group or the rear group is characterized by having a prism. This allows for good correction of the spherical aberration due to insufficient correction due to large aperture ratio. Moreover, by bending the optical path with a prism, the rear projector can be made thinner.

[0015] Furthermore, according to a preferred aspect of the present invention, the second lens group or the front lens group is characterized by having a cemented lens. This allows the path length to be secured for positioning the prisms, while correcting for chromatic aberrations and reducing the size of the lens system on the screen side from the prisms.

[0016] In addition, according to a preferred aspect of the present invention, the third lens group or the rear group is characterized by having a cemented lens constituted by two or more lenses. In this way, the cost of the lens can be reduced while effectively reducing chromatic aberrations for the two cemented lenses. In addition, for a three-piece cemented lens, color aberration can be further effectively reduced.

[0017] Also, according to a preferred aspect of the present invention is characterized in that a aperture is provided between the second lens group or the front group and the third lens group or the rear group, and the refractive index of the lens closest to the aperture of the third lens group or the rear group is greater than the refractive index of the negative lens constituting the cemented lens of the third lens group or the rear group. This allows the imaging lens to be removed from the aperture. Thus, the impact of manufacturing errors on the imaging lens can be reduced.

[0018] According to a preferred aspect of the present invention, it is also characterized that the absolute value of the combined focal length of the first lens group and the second lens group, or the absolute value of the combined focal length of the front group, is less than the absolute value of the combined focal length of the third lens group or the rear group. This allows for sufficient ambient light.

[0019] According to a preferred aspect of the present invention, it is also characterized in that at least some of the lenses constituting the second lens group or the front group are movable along the optical axis. This allows the focus to be adjusted without affecting optical performance.

[0020] Also, according to a preferred aspect of the present invention, the first lens group or the front group is characterized in that it comprises a first unit from a lens closest to the screen side to a lens adjacent the screen side of the lens having the aspheric surface, and a second unit from a lens having the aspheric surface to a lens furthest from the screen side, the first unit being movable along the optical axis direction. This allows for good correction of the plane curvature.

[0021] According to a preferred aspect of the present invention, it is also characterized in that there it further has a fixing flange section for securing the projection lens in the vicinity of the prism. This allows the projection lens, in particular the L-shaped projection lens, to be held stably.

[0022] According to the second invention, a projector can be provided that includes an lighting optical system that emits illumination light, a light modulation device that modulates illumination light emitted from the lighting optical system in response to an image signal, and a projection lens for projecting an optical image formed in the light modulation device to a predetermined surface, and that is characterized by using the projection lens according to the first invention as the projection lens. This results in a small, thin projector with a large angle of view and bright projections. The color synthesis optical system can also be positioned on the light modulator side of the projection lens while having sufficient optical performance and telecentricity. Therefore, a projector can be provided that can reduce the color shaking caused by the angular properties of the color synthesis optical system.

[0023] According to a preferred aspect of the present invention, the F-number of said projection lens is also characterized in that it is smaller than the F-number of the lighting optical system. This can improve the peripheral illumination ratio of the projection image.

[0024]

[Embodiments of the invention] The following describes the embodiments of the present invention based on the accompanying drawings.

(First embodiment) FIG. 1 is a diagram illustrating lens configuration of a projection lens according to the first embodiment of the present invention. From the screen side, in order, it is comprised of the first lens group G1 having negative power, the second lens group G2 having negative power, and the third lens group G3 having positive power. Here, the negative power of the second lens group G2 is greater than the negative power of the first lens group G1. In addition, between the second lens group G2 and the third lens group G3, a front aperture FS and a rear aperture RS are provided.

[0025] Here, we will briefly explain the functions of each lens group to correct for various aberrations. The positive power third lens group G3 has an aberration that cancels the aberrations when the negative power first lens group G1 and the negative power second lens group G2 are combined. As a result, all systems of the projection lens can have good aberration characteristics. In addition, the combed aberrations that have a major impact on image imaging performance are corrected in the lens group synthesized with the first lens group G1 and the second lens group G2, and in the third lens group G3, respectively. Table 1 below shows the correction function that each lens group has for each aberration. Below, [over] indicates the state of overcorrection and [under] indicates the state of undercorrection.

Table 1

	First lens group G1 Second lens group G2	Third lens group G3
Spherical aberration	Over	Under
Comatic aberration	Correction	Correction
Distortion aberration	Under	Over
Astigmatism (Meridional)	Under	Over
Astigmatism (Sagittal)	Over	Under
Axial chromatic aberration	Over	Under
Magnification color aberration	Over	Under

[0027] It should be noted that the correction functions of each lens group described above are the same in the second and third embodiments described below. Next, the description of the lens configuration of the projection lens according to this embodiment continues. First, the first lens group G1 consists of a meniscus-shaped negative lens L11 with a convex surface facing the screen side, a bi-convex-shaped positive lens L12, and a meniscus-shaped negative lens L13 with a convex surface facing the screen side, in order from the screen side. The screen side face of the meniscus-shaped negative lens L13, ASP 1, is an aspheric surface.

[0028] Also, the first unit U1 is configured with a meniscus-shaped negative lens L11 of the first lens group G1 and a biconvex-shaped positive lens L12. Further, the second unit U2 is configured with a meniscus-shaped negative lens L13. Thus, the first unit U1 is movable along the optical axis AX.

[0029] In the first lens group G1, a large negative distortion aberration occurs in the meniscus-shaped negative lens L11. Then, since the biconvex-shaped positive lens L12 has positive distortion aberration, this negative distortion aberration is reduced. However, with the positive lens L12 only, the distortion aberration of the curved shape remains. Therefore, the residual distortion aberrations of the meniscus-shaped negative lens L13 with aspheric surface ASP1 are further corrected.

[0030]The second lens group G2 consists of a meniscus-shaped negative lens L21 with a convex surface facing the screen side and prism P for folding the optical path. The meniscus-shaped negative lens L21 is movable along the optical axis AX. The meniscus-shaped negative lens L21, when combined with the first lens group G1, has a stronger negative power at the screen side portion than the front aperture FS. As a result, a long back focus can be obtained in all systems of the projection lens.

[0031] Prism P also produces a positive spherical aberration. Therefore, negative spherical aberrations that are prone to occur with large aperture ratios can be reduced. In addition, prism P produces a positive distortion aberration. As such, the negative distortion aberrations that occur with the meniscus-shaped negative lens L21 can be reduced.

[0032] In addition, the synthesis system of the first lens group G1 and the second lens group G2 has a strong negative power. In this composite system, over-image curvature and negative distortion aberration occur between the meniscus-shaped negative lens L11 of the first lens group G1 and the meniscus-shaped negative lens L21 of the second lens group G2. The aspheric surface ASP1 of the first lens group G1 has the function of correcting for this over-image curvature and negative distortion aberration.

[0033]The third lens group G3 is composed of a three-piece cemented lens consisting of a biconvex-shaped positive lens L31, a biconvex-shaped positive lens L32, and a biconcave-shaped negative lens L33, a convex flat-shaped positive lens L34, a biconvex-shaped positive lens L35, and a meniscus-shaped positive lens L36 with its convex surface facing the screen side. ASP2 is an aspheric surface on the side far from the screen of the meniscus-shaped positive lens L36.

[0034] To make the object side telecentric, the front focal position of the third lens group G3 is configured to be near the position of the rear aperture RS. The aberration correction function is performed by the biconvex-shaped positive lens L31 on the screen side for under-correction, the three piece negative lens for over-correction, and the biconvex-shaped positive lens L35 on the liquid crystal panel side, which is the imaging surface, for under-correction. This allows for well-balanced correction of all aberrations.

[0035] The three-piece cemented lens cemented lens in the third lens group G3 mainly has the function of correcting chromatic aberration. Also, the meniscus-shaped positive lens L36 with aspheric surface A SP2 compensates for image plane curvature and distortion aberration. This makes possible well-balanced correction of all aberrations. Also, in this embodiment, the first lens group G1 and the second lens group G2 constitute the front group FL, and the third lens group constitutes the rear group RL.

[0036] Table 2 shows the various values of this embodiment. In the lens data, No. indicates the order of the lens surface counted from the screen side, R indicates the radius of curvature, D indicates the surface spacing, Nd indicates the refractive index for the d line (λ=587.6 nm), and νd indicates the Abbe number. It should be noted that, in the lens data, the radius of curvature R = 0. 0 represents the plane.

[0037] Furthermore, the refractive index of air is Nd=1.00000, and the description thereof is omitted. FNO is F-number, θ is the angle of view, f is the focal length of the entire projection lens system, fG1 is the focal length of the first lens group G1, fG2 is the focal length of the second lens group G2, fG3 is the focal length of the third lens group G3, and fG12 is the combined focal length of the first lens group G1 and the second lens group G2, respectively.

[0038] The aspheric surface is also shown by the following equation when the height in the direction perpendicular to the optical axis is H, the optical axial shift at the height H (distance along the optical axis from the tangent plane of the apex of each aspheric surface: sag amount) is X, the radius of curvature is R, the cone coefficient is K, and the aspherical coefficient in the nth order (n=4, 6, 8, 10) is An. In addition, [E-n] in the aspheric coefficient column indicates [x10 $^{-n}$]. The symbols and aspheric expressions in the above-mentioned specifications are the same in all the following examples.

[0039] $X= CH^2 /[1+ \{1-(1+k)C^2 □ ^2 □ ^{1/2}] □ A4 H^4 +A6H^6 +A8H^8 +A10H^{10}$

However, C = 1/R.

[0040] Table 2

FNO=2. □

θ=43. 7 degrees

f=16. 023

fG1=-89. 280

fG2=-36. 619

fG3= 45. 369

fG12=-20. 880

No.	R	D	Nd	ν d	Remarks
0	0	600.00			Screen surface
1	87.39	6.00	1.65844	50.9	
2	50.28	21.50			
3	421.70	8.00	1.48749	70.4	
4	-421.70	2.00			
5	48.35	5.50	1.52540	56.3	Aspheric surface
6	27.54	22.57			
7	162.29	1.80	1.83400	37.3	
8	25.71	8.00			
9	0.00	25.00	1.48749	70.4	
10	0.00	2.00			
11	0.00	9.00			Front aperture
12	0.00	12.97			Rear aperture
13	63.09	7.00	1.92286	20.9	
14	-147.62	13.46			
15	70.38	8.80	1.48749	70.4	
16	-39.00	2.00	1.84666	23.8	
17	29.19	9.70	1.49700	81.6	
18	0.00	0.20			
19	48.31	13.00	1.49700	81.6	
20	-48.31	1.50			
21	118.98	5.00	1.52540	56.3	
22	-919.83	8.00			Aspheric surface
23	0.00	43.50	1.51680	64.2	
24	0.00				

Aspheric surface (No. 5)				
K	A4	A6	A8	A10
1.210E+00	1.333E-06	-1.346E-11	-6.174E-13	6.444E-16

Aspheric surface (No.)				
K	A4	A6	A8	A10
0.000E+00	6.128E-06	4.302E-10	1.289E-12	1.679E-15

[0041] FIG. 2 is a diagram illustrating the aberrations of the projection lens according to this embodiment. In the spherical aberration diagram and the comatic aberration diagram, the dotted line shows the aberration at 610 nm, the solid line at 546 nm, and the dashed line at 46 0 nm, respectively. In addition, in the astigmatism diagram, solid lines indicate the sagittal direction and dotted lines indicate the meridional direction. It should be noted that the same symbols as in this embodiment are used in the various aberration diagrams of all the following embodiments. As is clear from the various aberration diagrams, it can be seen that the present embodiment has good aberration correction and excellent optical performance, despite its wide angle of view and large aperture ratio.

[0042] (Second embodiment) FIG. 3 is a diagram illustrating lens configuration of a projection lens according to the second embodiment of the present invention. From the screen side to the screen side, it consists of a first lens group G1 having negative power, a second lens group G2 having negative power, and a third lens group G3 having positive power. Here, the negative power of the second lens group G2 is greater than the negative power of the first lens group G1. In addition, between the second lens group G 2 and the third lens group G 3, a front aperture FS and a rear aperture RS are provided.

[0043] The first lens group G1 consists of a meniscus-shaped negative lens L11 with a convex surface facing the screen side in order from the screen side, and a meniscus-shaped negative lens L12 with a convex surface facing the screen side. The screen side face of the meniscus-shaped negative lens L12, ASP 1, is an aspheric surface.

[0044] Also, the first unit U1 is configured with a meniscus-shaped negative lens L11 of the first lens group G1. Further, the second unit U2 is configured with a meniscus-shaped negative lens L12. Thus, the first unit U1 is movable along the optical axis AX.

[0045] In the first lens group G1, a large negative distortion aberration occurs in the meniscus-shaped negative lens L11. Therefore, a positive distortion aberration is generated and corrected with a meniscus-shaped negative lens L12 having aspheric surface ASP1. The second lens group G2 consists of a two-piece negative lens consisting of a biconvex-shaped positive lens L21 and a biconcave-shaped negative lens L22, in sequence from the screen side, and prism P for bending the optical path. The two-piece cemented negative lens is movable along the optical axis AX.

[0046] By combining the two-piece cemented negative lens with the first lens group G1, it has a strong negative power in a portion closer to the screen than the front aperture FS. As a result, a long back focus can be obtained for the entire projection lens system, and chromatic aberration can be corrected and the lens system located on the screen side of the prism can be made compact. Prism P also produces a positive spherical aberration. Therefore, negative spherical aberrations that are prone to occur with large aperture ratios can be reduced. In addition, prism P produces a positive distortion aberration. As such, the negative distortion aberrations that occur with the two-piece cemented negative lens can be reduced.

[0047] In addition, the synthesis system of the first lens group G1 and the second lens group G2 has a strong negative power. When considered in the composite system, over-image plane curvature and negative distortion aberration occur with the meniscus-shaped negative lens L 11 of the first lens group G1 and the cemented negative lens of the second lens group G2. The aspheric surface ASP 1 of the meniscus-shaped negative lens L12 of the first lens group G1 has the function of correcting for this over-image curvature and negative distortion aberration. Furthermore, the cemented negative lens of the second lens group G2 balances the color aberration of the composite system.

[0048] The third lens group G3 is composed of, in order from the screen side, a biconvex-shaped positive lens L31, a three-piece cemented negative lens consisting of a biconvex-shaped positive lens L32, a biconcave-shaped negative lens L33, a biconvex-shaped positive lens L34, a biconvex-shaped positive lens L35, and a meniscus-shaped positive lens L36 with its convex surface facing the screen side. ASP2 is an aspheric surface on the side far from the screen of the meniscus-shaped positive lens L36.

[0049] The biconvex-shaped positive lens L31 on the screen side provides under-correction, the three-piece cemented lens provides over-correction, and the biconvex-shaped positive lens L35 on the liquid crystal panel side, which is the image formation surface, provides under-correction. This allows for good overall correction of aberrations. The three-piece cemented lens primarily has the function of correcting chromatic aberrations. Also, the meniscus-shaped positive lens L36 with aspheric surface A SP2 compensates for image plane curvature and distortion aberration. This makes possible well-balanced correction of all aberrations.

[0050] Also, in this embodiment, the first lens group G1 and the second lens group G2 constitute the front group FL, and the third lens group constitutes the rear group RL. Table 3 shows the various values of this embodiment.

[0051] Table 3

FNO=2. □

θ=43. 8 degrees

f=16. 030

fG1=-84. 071

fG2=-38. 744

fG3= 46. 874

fG12=-21. 125

No.	R	D	Nd	νd	Remarks
0	0	600.00			Screen surface
1	79.85	7.00	1.65844	50.9	
2	47.72	15.00			
3	74.55	5.50	1.52540	56.3	Aspheric surface
4	38.47	18.25			
5	86.92	10.00	1.56883	56.0	
6	-38.11	3.00	1.75700	47.7	
7	26.31	9.15			
8	0.00	25.00	1.48749	70.4	
9	0.00	1.00			
10	0.00	9.00			Front aperture
11	0.00	14.48			Rear aperture
12	64.05	15.00	1.92286	20.9	
13	-171.90	10.37			
14	66.14	9.50	1.48749	70.4	
15	-42.95	2.00	1.84666	23.8	
16	31.59	11.50	1.49700	81.6	
17	-812.81	0.20			
18	52.89	13.50	1.49700	81.6	
19	-54.33	1.50			
20	104.91	5.00	1.52540	56.3	
21	17767.43	8.00			Aspheric surface
22	0.00	43.50	1.51680	64.2	
23	0.00				

Aspheric surface (No. 3)				
K	A4	A6	A8	A10
3.889E+00	2.295E-06	-5.981E-10	3.193E-13	1.134E-16

Aspheric surface (No. 21)				
K	A4	A6	A8	A10
0.000E+00	5.382E-06	-5.950E-12	1.305E-12	7.938E-16

[0052] FIG. 4 is a diagram illustrating the aberrations of the projection lens according to this embodiment. As is clear from the various aberration diagrams, it can be seen that the present embodiment has good aberration correction and excellent optical performance, despite having a wide angle of view and large aperture ratio.

[0053] (Third embodiment) FIG. 5 is a diagram illustrating lens configuration of a projection lens according to the third embodiment. From the screen side to the screen side, it consists of a first lens group G1 having negative power, a second lens group G2 having negative power, and a third lens group G3 having positive power. Here, the negative power of the second lens group G2 is greater than the negative power of the first lens group G1. In addition, between the second lens group G 2 and the third lens group G 3, a front aperture FS and a rear aperture RS are provided.

[0054] The first lens group G1 consists of a meniscus-shaped negative lens L11 with a convex surface facing the screen side in order from the screen side, a meniscus-shaped positive lens L12 with a convex surface facing the screen side and a meniscus-shaped negative lens L13 with its convex surface facing the screen side. The screen side face of the meniscus-shaped negative lens L13, ASP 1, is an aspheric surface.

[0055] Also, the first unit U1 is configured with a meniscus-shaped negative lens L11 of the first lens group G1 and a meniscus-shaped positive lens L12. Further, the second unit U2 is configured with a meniscus-shaped negative lens L13. Thus, the first unit U1 is movable along the optical axis AX.

[0056] In the first lens group G1, a large negative distortion aberration occurs in the meniscus-shaped negative lens L11. Then, since the meniscus-shaped positive lens L12 has positive distortion aberration, this distortion aberration is reduced. However, with the meniscus-shaped positive lens L12 only, the distortion aberration of the curved shape remains. Therefore, the residual distortion aberrations of the meniscus-shaped negative lens L13 with aspheric surface ASP1 are further corrected.

[0057] The second lens group G2 consists of a two-piece negative lens consisting of a biconvex-shaped positive lens L21 and a biconcave-shaped negative lens L22, in sequence from the screen side, and prism P for bending the optical path. The two-piece cemented negative lens is movable along the optical axis AX.

[0058] By combining the two-piece cemented negative lens with the first lens group G1, it has a strong negative power in a portion closer to the screen than the front aperture FS. As a result, a long back focus can be obtained for the entire projection lens system, and chromatic aberration can be corrected and the lens system located on the screen side of the prism can be made compact.

[0059] Prism P also produces a positive spherical aberration. Therefore, negative spherical aberrations that are prone to occur with large aperture ratios can be reduced. In addition, prism P produces a positive distortion aberration. As such, the negative distortion aberrations that occur with the two-piece cemented negative lens can be reduced.

[0060] In addition, the synthesis system of the first lens group G1 and the second lens group G2 has a strong negative power. When considered in the composite system, over-image plane curvature and negative distortion aberration occur with the meniscus-shaped negative lens L 11 of the first lens group G1 and the cemented negative lens of the second lens group G2. First lens group the aspheric surface ASP 1 of the meniscus-shaped negative lens L13 of G1 has the function of correcting for this over-image curvature and negative distortion aberration. Furthermore, the cemented negative lens of the second lens group G2 balances the color aberration of the composite system.

[0061] The third lens group G3 is composed of a two-piece cemented negative lens consisting of a biconvex-shaped positive lens L31, a biconvex-shaped positive lens L32, a cemented negative lens consisting of a biconcave-shaped negative lens L33 and a biconvex-shaped positive lens L34, a biconvex-shaped positive lens L35, and a meniscus-shaped positive lens L36 with its convex surface facing the screen side. ASP2 is an aspheric surface on the side far from the screen of the meniscus-shaped positive lens L36.

[0062] To make the object side telecentric, the front focal position of the third lens group G3 is configured to be near the position of the rear aperture RS. In terms of aberration correction, the biconvex-shaped positive lens L31 provides under-correction, the biconvex-shaped positive lens L32 and the cemented negative lens provide over-correction, and the biconvex-shaped positive lens L35 on the liquid crystal panel side, which is the imaging surface, provides under-correction. This allows for good overall correction of various aberrations.

[0063] The two-piece cemented negative lens primarily has the function of correcting chromatic aberrations. Also, the meniscus-shaped positive lens L36 with aspheric surface A SP2 compensates for image plane curvature and distortion aberration. This makes possible well-balanced correction of all aberrations.

[0064] Also, in this embodiment, the first lens group G1 and the second lens group G2 constitute the front group FL, and the third lens group constitutes the rear group RL. Table 4 shows the various values of this embodiment.

[0065] Table

4 FNO=2. □

θ=43. 8 degrees

f=16. 011

fG1=-83. 629

fG2=-35. 370

fG3= 47. 152

fG12=-19. 928

No.	R	D	Nd	νd	Remarks
0	0	600.00			Screen surface
1	95.08	6.00	1.63854	55.5	
2	47.38	15.00			
3	113.01	10.00	1.51680	64.2	
4	313.00	1.00			
5	59.05	5.50	1.52540	56.3	Aspheric
6	30.59	14.21			surface
7	123.76	11.00	1.65160	58.4	
8	−29.23	3.00	1.80420	46.5	
9	27.38	8.00			
10	0.00	25.00	1.48749	70.4	
11	0.00	1.00			
12	0.00	12.00			Front aperture
13	0.00	3.64			Rear aperture
14	64.78	15.00	1.92286	20.9	
15	−499.11	17.51			
16	48.88	7.00	1.48749	70.4	
17	−969.56	1.86			
18	−148.19	2.00	1.84666	23.8	
19	30.85	11.00	1.49700	81.6	
20	−173.12	0.20			
21	43.29	12.00	1.49700	81.6	
22	−86.19	1.50			
23	82.59	5.00	1.52540	56.3	
24	372.03	8.00			Aspheric
25	0.00	43.50	1.51680	64.2	surface
26	0.00				

Aspheric surface (No. 5)

K	A4	A6	A8	A10
3.060E+00	2.150E−06	−4.381E−10	−4.645E−14	5.202E−16

Aspheric surface (No. 24)

K	A4	A6	A8	A10
0.000E+00	5.577E−06	−4.045E−10	2.051E−12	−8.623E−17

[0066] FIG. 6 is a diagram illustrating the aberrations of the projection lens according to this embodiment. As is clear from the various aberration diagrams, it can be seen that the present embodiment has good aberration correction and excellent optical performance, and has a wide angle of view and large aperture ratio.

[0067] (Fourth embodiment) FIG. 7 is a diagram illustrating a schematic of an internal configuration of a rear projector according to the fourth embodiment. The rear projector 101 according to this embodiment includes projection lenses according to the first through third embodiments described above. In FIG. 7, only the main components are shown for ease of description.

[0068] Light from the projection light generating section 102 is emitted via the projection optical system 16. Reflective mirror 103 folds and reflects the optical axis AX of the projection light emitted by projection optical system 16. The projection optical system 16 has projection lenses according to the first through third embodiments described above. The transparent screen portion 104 displays a projected image of the projected light reflected by the reflective mirror 103.

[0069] The projection light generating section 102 has a light source device, image forming optics, etc. that is not shown in the drawings. Light from the projection light generating section 102 enters the reflective mirror 103 as it spreads through the projection optical system 16. Reflective mirror 103 then reflects the projection light to the screen section 104 side. The reflected projection light is incident on the screen section 104 such that the optical axis AX is generally perpendicular to the screen surface. The screen section 104 transmits the projection light and displays it as an image.

[0070] FIG. 8 is a diagram illustrating a schematic configuration and optical path from the light modulation device 14R in the projection light generating section 102 to the projection lens L when red image light is used as a representative example. Light from the light modulation device 14R is incident on the projection lens L via the retardation plate 141R and the color synthesis optical system 15. The projection lens L is a projection lens according to the first through third embodiments above. Prism P in projection lens L bends the optical axis AX. This causes the projection light from the projection lens L to be injected into the reflective mirror 103 (FIG. 7) side.

[0071] Next, the rear projector according to this embodiment will be described in detail. FIG. 9 is a diagram illustrating the configuration from the light source to the projection lens. First, the polarized lighting device 11 will be described. The polarized lighting device 11 comprises a light source 111 and a uniform uniform lighting optical system 112. The light emitted from the light source 11 1 is incident on the uniform lighting optical system 112. Uniform lighting optical system 112 include a first lens array 113, a second lens array 114, a polarization conversion element array 115, and a superimposing lens 116. The first lens array 113 divides light from the light source 111 into a plurality of partial luminous bundles. Second lens array 114 converts each partial luminous flux divided by first lens array 113 into parallel light. The polarization conversion element array 115 then converts parallel light into light in one type of polarization direction with aligned vibration direction and firing it out.

[0072] In this embodiment, polarization conversion element array 115 converts the light into S-polarized light for wavelength selective films 152 and 153 of a cross dichroic prism 151, which will be described later. Here, S-polarized light refers to light in a polarized state that vibrates within a plane perpendicular to a plane that includes the normal to the incident position on a specific reflecting surface and the central axis of the incident light beam. In addition, P-polarized light refers to light in a polarized state that vibrates within a plane parallel to a plane that includes the normal at the incident position on a specific reflecting surface and the central axis of the incident light beam. Furthermore, the polarization conversion element array 115 can be configured to convert incident light into light that is P-polarized relative to the wavelength selective films 152, 153 and emit it.

[0073] Then, the light that has been polarized and converted by the polarization conversion element array 115 enters the superimposing lens 116 . The superimposing lens 116 overlays and illuminates light converted to one polarization direction in polarization conversion element array 115 on the light modulator 14R, 14G, 14B, which is the illuminated area. It should be noted that the uniform lighting optical system 112 is not limited to the configuration using a lens array, and may be composed of a rod integrator, etc.

[0074] The light emitted from the polarized lighting device 11 is incident on the color separation optical system 12. The color separation optical system 12 separate the light source light emitted from the light source 11 into three colors of light, e.g., red (hereinafter abbreviated as [R]), green (hereinafter abbreviated as [G]), and blue (hereinafter abbreviated as [G]. Color separation optical system 12 include dichroic mirrors 121, 122, reflective mirrors 123, and parallelized lenses 124, 125.

[0075] First, the configuration in which the color separation optical system 12 separates R light from the light source light is described. Light emitted from the polarized lighting device 11 is incident on the first dichroic mirror 121. The first dichroic mirror 121 has a dichroic film, such as a dielectric multilayer film. The first dichroic mirror 121 reflects R light and transmits G light and B light. The reflected R light is further reflected by the reflective mirror 123 to bend the optical path. The R light whose optical path has been bent enters the first parallelized lens 124. The R light passing through the first parallelized lens 124 enters light modulation device 14R for R light.

[0076] Next, the configuration in which the color separation optical system 12 separates G light from the light source light is described. The combined light of G and B light transmitted through the first dichroic mirror 121 is incident on the second dichroic mirror 122. Second dichroic mirror 122 reflects G light and transmits B light. The reflected G light enters light modulation device 14G for the G light via second parallelized lens 125.

[0077] Next, the configuration in which the color separation optical system 12 separates B light from the light source light is described. B light transmitted through the first dichroic mirror 121 and the second dichroic mirror 122 is incident on relay optical system 13.

[0078] Relay optical system 13 includes an incident side lens 13 1, an incident side mirror 132, an intermediate lens 133, an exit side mirror 134, and exit side lens lens 135. The B light emerging from the color separation optical system 12 passes through an incident side lens 131 and has its optical path bent by an incident side mirror 132. The B light, whose optical path has been bent, passes through an intermediate lens 133 and has its optical path further bent by an exit side mirror 134 . Then, the B light passes through the exit side lens 135 and enters the B light modulation device 14B.

[0079] The light modulation devices 14R, 14G, 14B are composed of, for example, transparent liquid crystal devices. As described above, light converted to S-polarization for wavelength selective reflective films 152 and 153 of cross-dichroic prism 151 described below by polarization conversion element array 115 is incident on each light modulator 14R, 14G, 14B.

[0080] The incident side polarizing plate is disposed between the parallelizing lenses 124, 125, the injection side lens 135, and each light modulation device 14R, 14G, and 14B, respectively. The incident side polarizing plate has the function of increasing the polarization of light aligned in the polarization direction by polarization conversion element array 115. Light incident on each light modulation device 14R, 14G, 14B via the incident polarizing plate undergoes modulation in the polarization direction according to image information of each color.

[0081] An exit side polarizing plate is provided on the exit side of each of the light modulation devices 14R, 14G, and 14B. Of the modulated light, only light that becomes P-polarized with respect to the wavelength-selective reflective films 152 and 153 is emitted by the exit side polarizing plate. In addition, retardation plates 141R and 141B for converting P-polarized light into S-polarized light are disposed between the exit side polarizing plates disposed on the exit side of the light modulation devices 14R and 14B and the cross dichroic prism 151, respectively.

[0082] Therefore, R image light and B image light modulated by light modulation devices 14R, 141B by retardation plates 141R, 141B are S polarized to wavelength selective films 152, 153 and incident on cross-dichroic prism 151. In contrast, G-image light modulated by light modulation device 14G is P-polarized relative to wavelength selective films 152, 153 and incident on cross-dichroic prism 151. It should be noted that the position of the retardation plates 141R, 141B is not limited to those of this embodiment, and can be changed

accordingly depending on the polarization direction of light incident on each light modulation device 14R, 14G, 14B, and the characteristics of each light modulation device 14R, 14G, 14B itself.

[0083] Color synthesis optical system 15 is composed of cross dichroic prism 151. Cross dichroic prism 151 is an X-shaped arrangement of two types of wavelength selective films 152, 153 having different wavelength selection characteristics along the interface of the four prisms. G-image light transmits through these two wavelength selective films 152, 153. The R image light and the B image light are reflected by wavelength selective films 152, 153. This synthesizes three colors of image light.

[0084] In this embodiment, R and B image light using wavelength selective films 152 and 153 as reflective films are incident as S-polarized light. Also, G image light using wavelength selective films 152, 153 as transmission films is incident as P-polarized light. Thus, the wavelength range selected by the wavelength selective films 152, 153 is widened, thus increasing the efficiency of light utilization.

[0085] In addition, a wavelength selective retardation plate 2G is provided on the injection surface of the projection optical system 16 side of cross dichroic prism 151. The wavelength selective retardation plate 2G is composed of a wavelength selective 1/2 wave plate having a profile in which the retarder is λ/2 near a particular wavelength λo (550 nm in the present embodiment). By this, the wavelength selective retardation plate 2G converts only the polarization direction of light around a wavelength of 550 nm, that is, G image light, by 90 degrees. Therefore, the G image light emitted from the cross dichroic prism 151 as P-polarized light is converted by the wavelength selective retardation plate 2G into S-polarized light, the same as the R and B image lights.

[0086] The projection optical system 16 has projection lens L according to the first through third embodiments described above. Prism P in projection lens L causes the optical axis AX to be bent in a direction perpendicular to the paper surface. The light emitted from the projection optical system 16 is reflected by the reflecting mirror 103, as shown in FIG. 7, and is incident on the screen 104 from its back side to transmit through the screen 104 to form an image.

[0087] The reflective mirror 103 here comprises a light transmissive stretch resin, for example a film made of polyester, and a reflective film deposited on one side thereof. In addition, the screen 104 is equipped with a lenticular lens (not shown in the drawings). As described above, in this embodiment, the wavelength selective retardation plate 2G transforms the polarization direction of the G image light into the same direction as the polarization direction of the R image light and the B image light. Thus, the R image light, G image light, and B image light combined by the color synthesis optical system 15 are all aligned in the polarization direction. As a result, the polarization direction of the R, G and B image light emitted from the projection optical system 16 is incident on the reflective mirror 3 and screen 4 with the polarization direction aligned. Thus, the polarization-dependent effects of the reflective mirror 103 and the screen 104 can be reduced as much as possible, and the incident angle-dependent effects can also be reduced.

[0088] In addition, the projection optical system 16 of the rear projector of the present embodiment comprise the projection lens L according to the first through third embodiments described above. Thus, a brighter projection image is obtained with a wider angle of view and a larger aperture ratio. Furthermore, the short projection distance allows the rear projector to be thinner and smaller.

[0089] Next, the mounting portion of projection optical system 16 is described. FIGS. 10(a), (b), (c) are diagrams showing the state in which the projection lens L according to the first through third embodiments described above is held in the lens barrel 200. Lens barrel 200 has a fixing flange 201 in the vicinity of prism P. The fixing flange 201 has a hole in which the screws 202 (FIG. 11) engage. FIG. 11(a) is an upper perspective view of a configuration securing the projection optical system 16 and the optical engine section 203. In addition, FIG. 11(b) is a downward perspective view of a configuration securing the projection optical system 16 and the optical engine section 203. Here, the optical engine section 203 includes light modulation devices 14R, 14G, 14B, and color synthesis optical system 15.

[0090] A fixing section 204 is provided in the portion corresponding to the fixing flange 201 of the optical engine section 203. The screw 202 can then be threaded to secure the projection optical system 16 and the optical engine section 203.

[0091] (Fifth embodiment) FIG. 12 is a diagram illustrating the configuration from the light source to the projection optical system of the projector according to the fifth embodiment. In this embodiment, projection lenses according to the first through third embodiments above are used as the projection optical system. In addition, a micromirror type light modulation device such as a Digital Micromirror Device (a registered trademark of Texas Instruments, hereinafter referred to as "DMD") is used as the light modulation device.

[0092] The DMD has a plurality of micromirrors corresponding to the plurality of pixels constituting the image. Each of the plurality of micromirrors changes its tilt depending on the image information. Each micromirror reflects light according to its tilt. Of the light reflected in each micromirror, light reflected in a predetermined direction is utilized as image light. Thus, DMD is an electro-optic device of the type that controls the direction of reflection of light to form image light.

[0093] The projector according to this embodiment includes lighting optical system 300, a micromirror-type light modulation device 306 such as DMD, and projection optical system 307. Lighting optical system 300 is composed of a light source unit 301, a first condenser lens 302, a color wheel 303, a transparent rod 304, and a second condenser lens 305.

[0094] Light emitted from light source section 301 passes through first condenser lens 302, color wheel 303, transparent rod 304 and second condenser lens 305, and enters micromirror-type light modulation device 306. The light incident on micromirror-type light modulation device 306 is modulated in response to the image signal. Light modulated by micromirror-type light modulation device 306 is incident on projection optical system 307 as image light.

[0095] Projection optical system 307 have projection lens L according to the first through third embodiments described above. Then, projection optical system 307 projects the modulated light by micromirror-type light modulation device 306 onto a screen (not shown in the drawings). The rear projector of this embodiment is equipped with the projection lens L according to the first to third embodiments. Thus, a bright projection image with a large aperture ratio can be obtained at a wide angle of view. Furthermore, the short projection distance allows the projector to be thinner and smaller. The projection lens L described above is not limited to a projector comprising a micromirror-type light modulation device 306, but can also be applied to a projector comprising, for example, a reflective liquid crystal panel. It should be noted that the present invention is not limited to the above embodiments, and it can be implemented in various aspects to the extent that it does not deviate from its summary.

[0096]

[Effects of the invention] As explained above, according to the first invention, a projection lens having a large angle of view and a large aperture ratio and having good optical performance can be provided, in particular, a projection lens suitable for a three-plate projector. In addition, according to the second invention, the projection lens described above can be used to obtain a bright projection image and provide a projector that is small and thin.

[Brief Description of the Drawings]

[FIG. 1] A diagram showing the lens configuration of a projection lens according to the first embodiment of the present invention.

[FIG. 2] A diagram showing the aberrations of the first embodiment above.

[FIG. 3] A diagram showing the lens configuration of a projection lens according to the second embodiment of the present invention.

[FIG. 4] A diagram showing the aberrations of the above-mentioned second embodiment.

[FIG. 5] A diagram showing the lens configuration of a projection lens according to the third embodiment of the present invention.

[FIG. 6] A diagram showing the aberrations of the above third embodiment.

[FIG. 7] A diagram showing a schematic configuration of a rear projector according to the fourth embodiment of the present invention.

[FIG. 8] A diagram showing the configuration of the projection lens in the above-mentioned fourth embodiment.

[FIG. 9] A diagram showing the configuration from the light source to the projection optical system in the above-mentioned fourth embodiment.

[FIG. 10] (a),(b),(c) are diagrams illustrating an appearance configuration of a projection lens held in a tube in the fourth embodiment above.

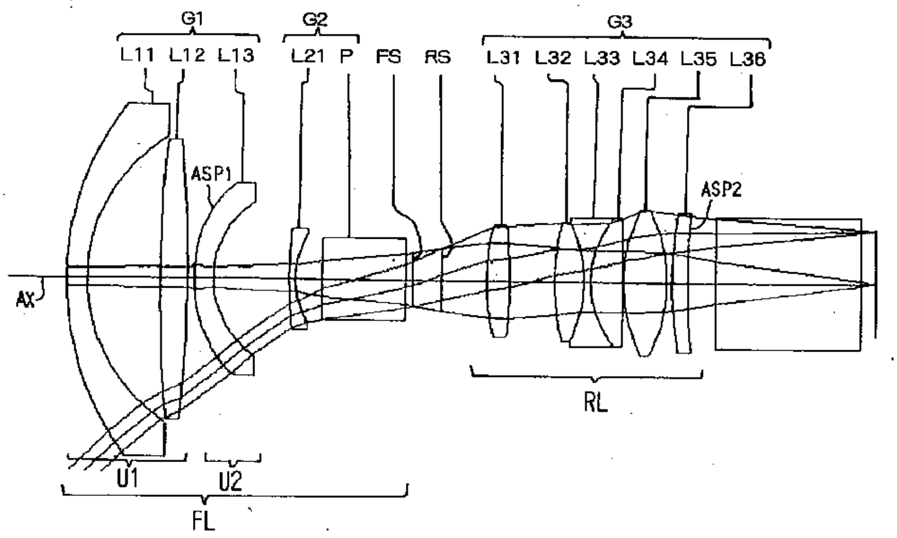
[FIGS. 11] (a) and (b) are diagrams illustrating the configuration in the vicinity of the projection optical system in the above-described fourth embodiment.

[FIG. 12] A diagram showing a schematic configuration of a projector according to the fifth embodiment of the present invention.

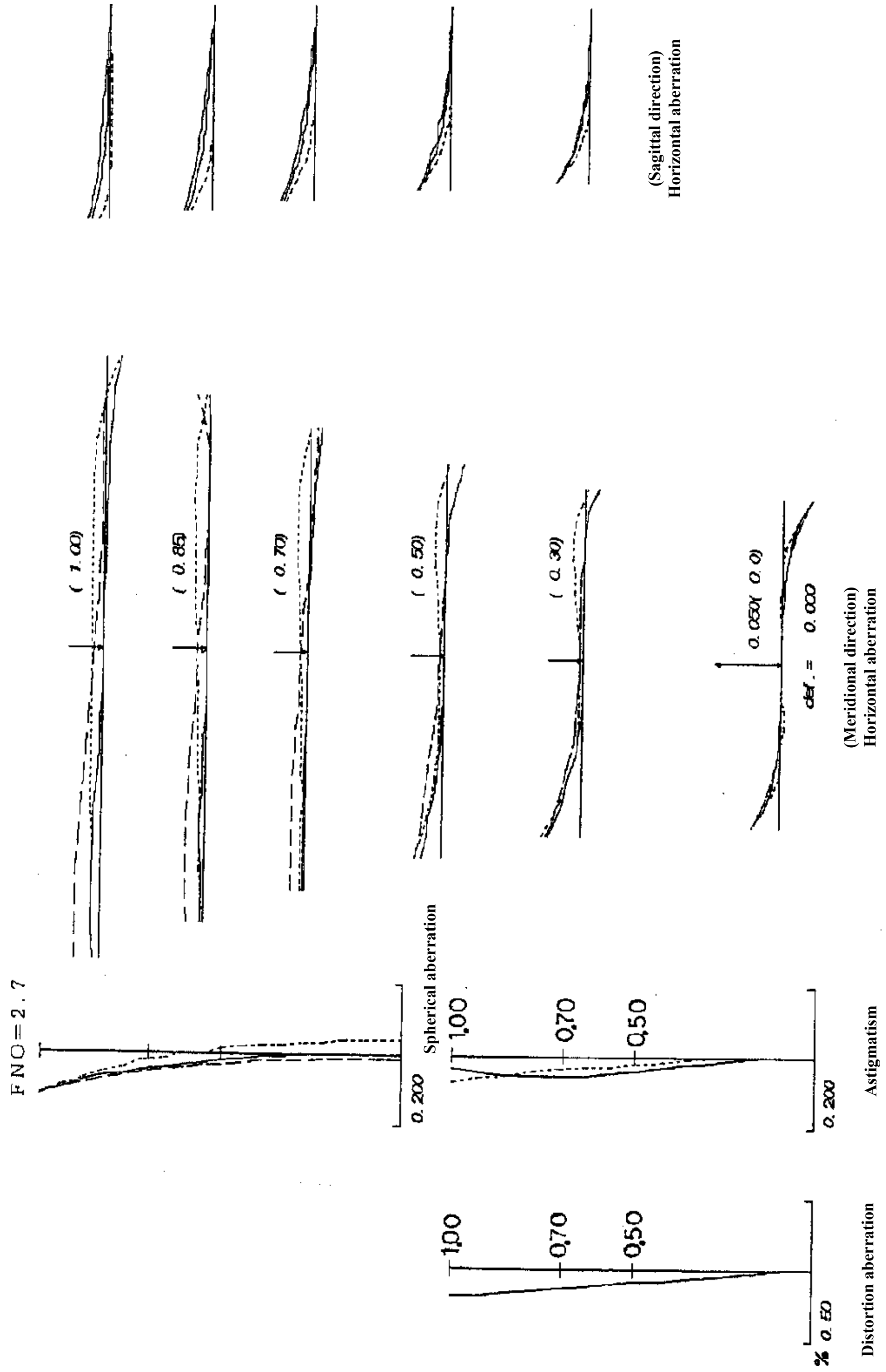
[Explanation of References]

G1 first lens group
G2 second lens group
G3 third lens group
L11 to L36 components of each lens
P prism
ASP1, ASP2 aspheric surface
FL front group
RL rear group
FS front aperture
RS rear aperture
U1 first unit
U2 second unit
AX optical axis
101 rear projector
102 projection light generating section
103 reflective mirror
104 screen
L projection lens
11 polarized lighting device
12 color separation optical system
13 relay optical system
14R, 14G, 14B light modulation device
15- color synthesis optical system
16 projection optical system
111 light source
112 uniform lighting optical system
113 first lens array
114 second lens array
115 polarization conversion element array
116 superimposing lens
121 first dichroic mirror
122 second dichroic mirror
123 reflective mirror
124 first parallelized lens
125 second parallelized lens
131 incident side lens
132 incident side mirror
133 intermediate lens
134 exit side mirror
135 exit side lens
141R, 141B retardation plate
151 cross dichroic prism
152, 153 wavelength selective film
2G wavelength selective retardation plate
200 lens barrel
201 fixing flange
202 screw
203 optical engine section
204 fixing section
300 lighting optical system
301 light source section
302 first condenser lens
303 color wheel
304 transparent rod
305 second condenser lens
306 micromirror-type light modulation device
307 projection optical system

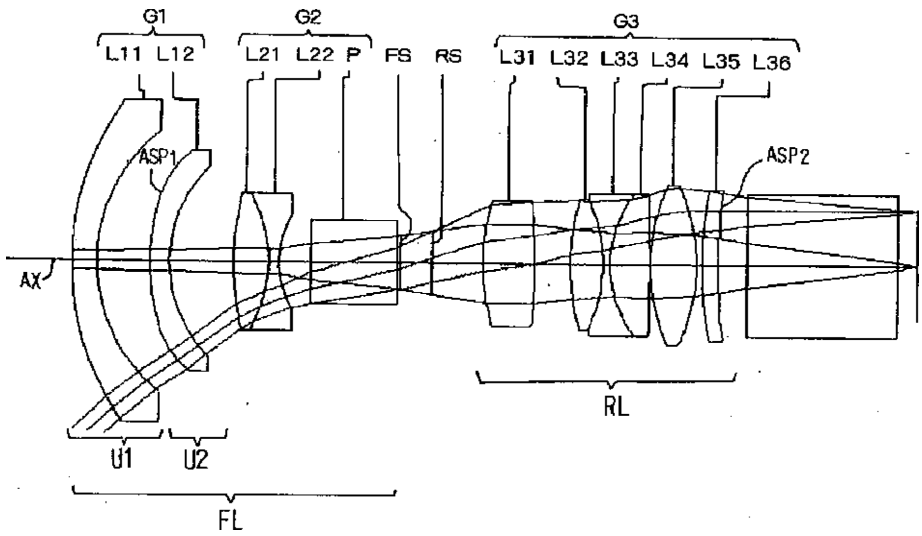
[Figure 1]


G1
L11 L12 L13
G2
L21 P FS RS
G3
L31 L32 L33 L34 L35 L36
ASP1
ASP2
AX
RL
U1
U2
FL

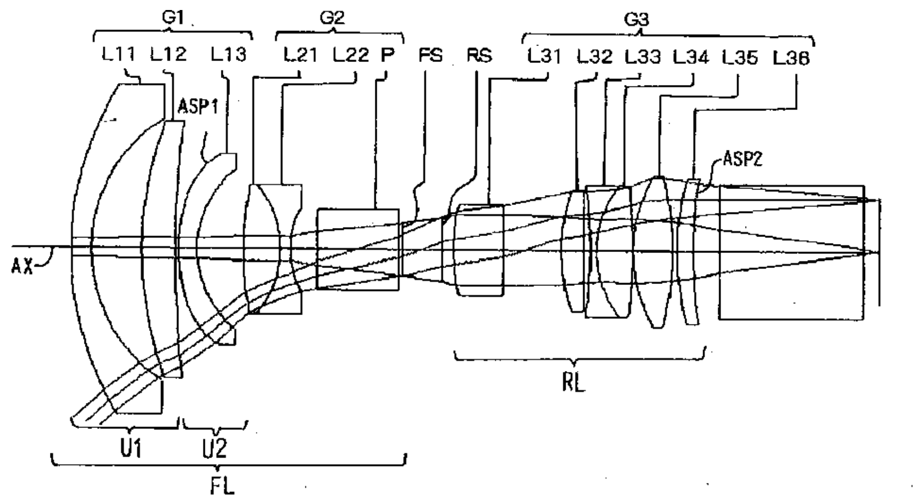
[FIG. 2]


(Sagittal direction)
Horizontal aberration
(1.00)
(0.85)
(0.70)
(0.50)
(0.30)
0.050(0.0)
def. = 0.000
(Meridional direction)
Horizontal aberration
FNO = 2.7
0.200
Spherical aberration
1.00
0.70
0.50
0.200
Astigmatism
1.00
0.70
0.50
% 0.50
Distortion aberration

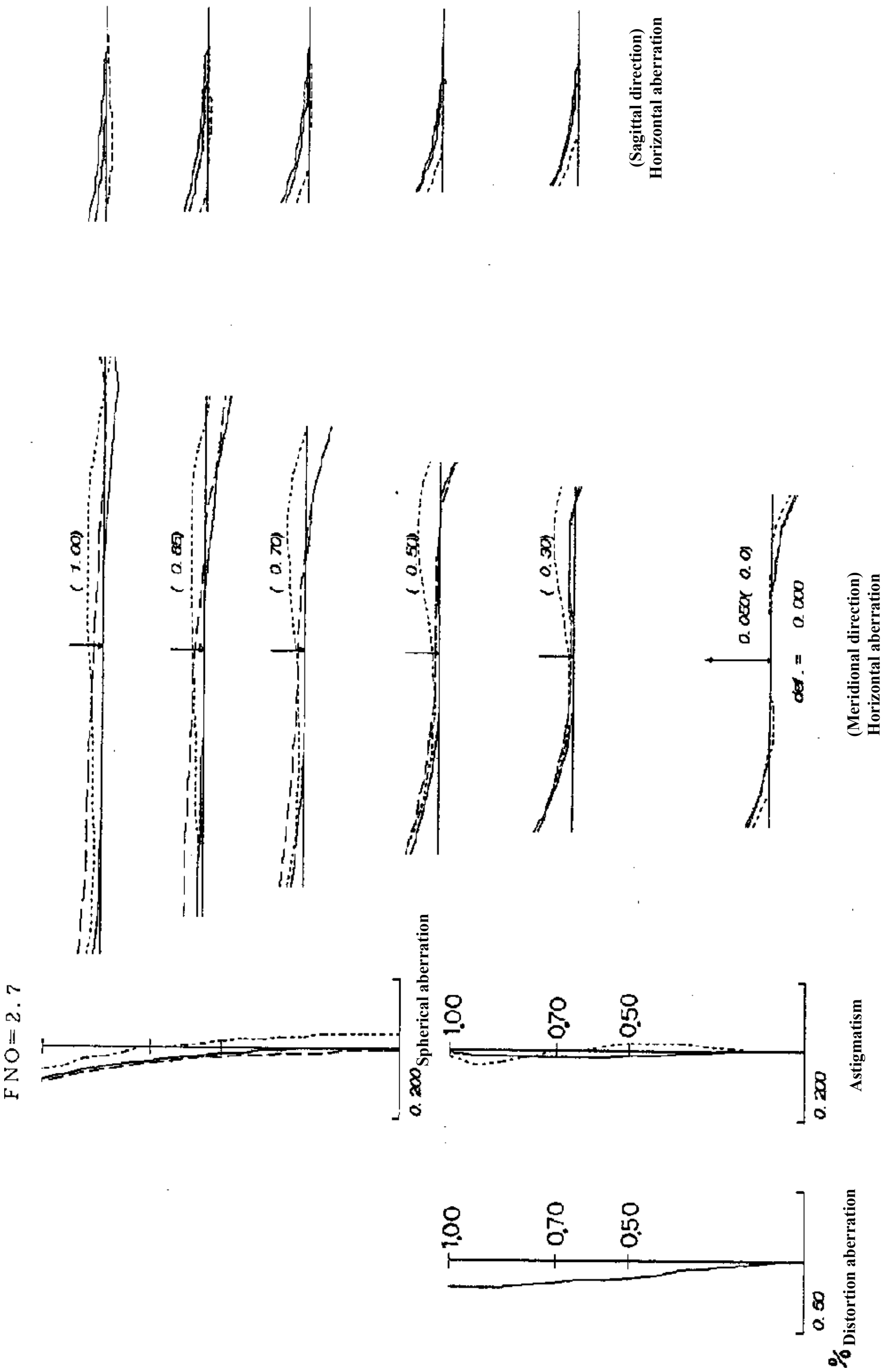
[FIG. 3]


G1
L11 L12
G2
L21 L22 P
FS
RS
G3
L31 L32 L33 L34 L35 L36
ASP1
ASP2
AX
RL
U1
U2
FL

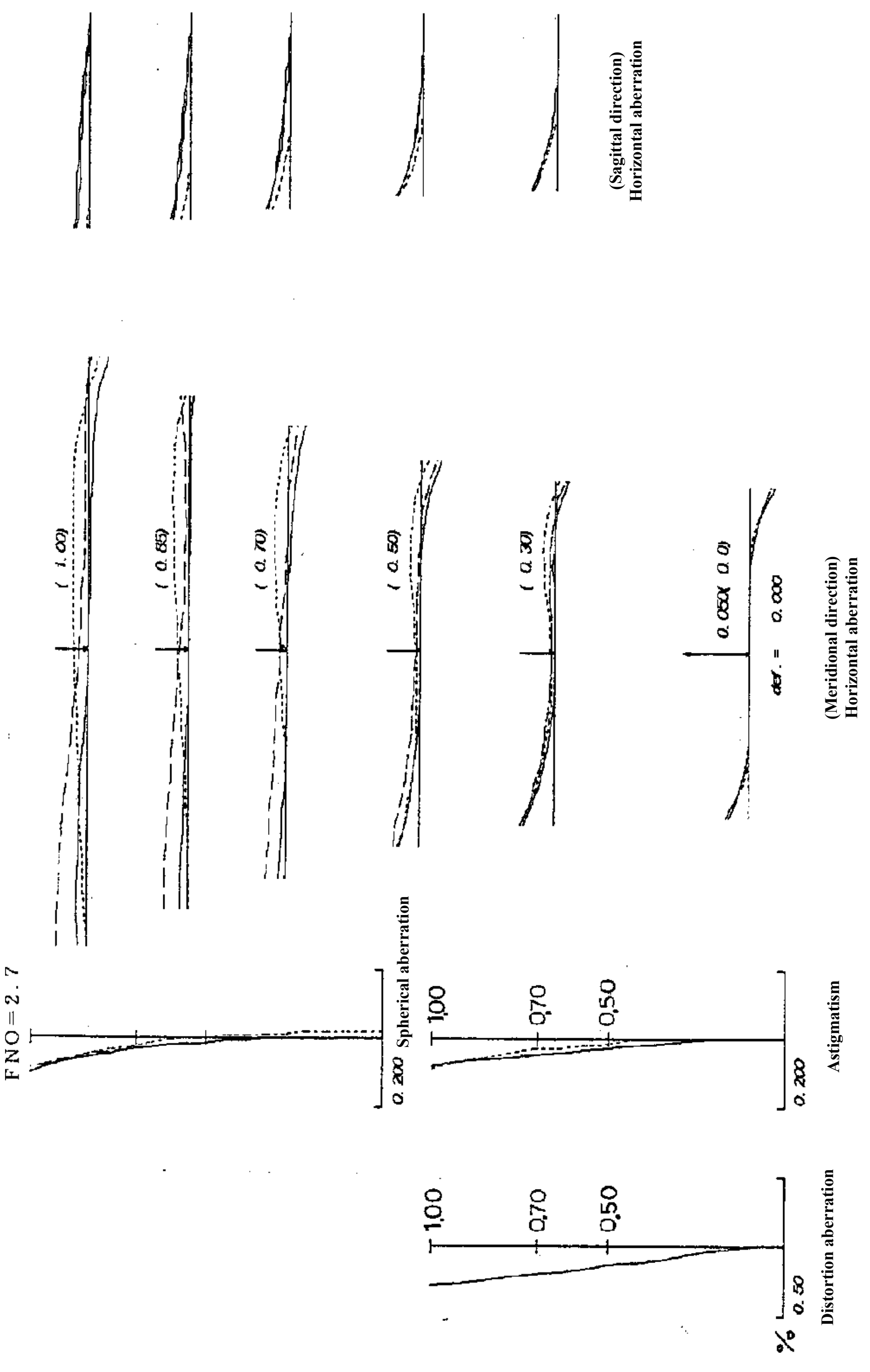
[FIG. 5]


G1
L11 L12 L13
G2
L21 L22 P
FS
RS
G3
L31 L32 L33 L34 L35 L36
ASP1
ASP2
AX
RL
U1
U2
FL

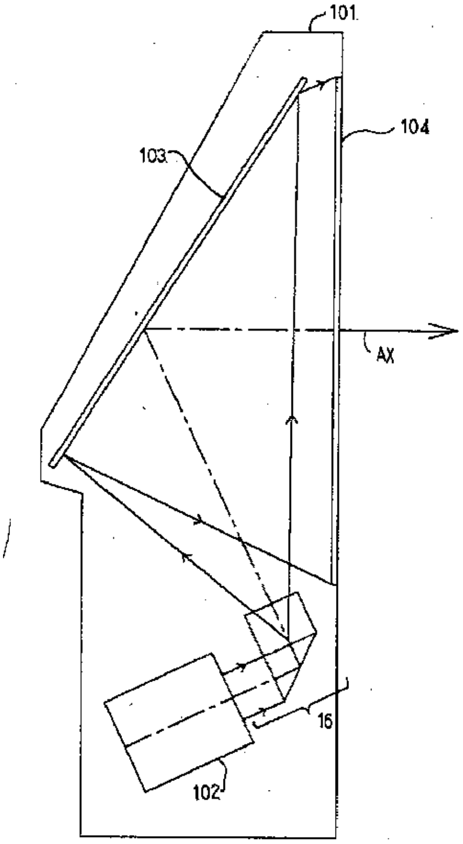
[FIG. 4]


(Sagittal direction)
Horizontal aberration
(1.00)
(0.85)
(0.70)
(0.50)
(0.30)
(Meridional direction)
Horizontal aberration
FNO= 2.7
0.200
Spherical aberration
1.00
0.70
0.50
0.200
Astigmatism
1.00
0.70
0.50
0.50
%
Distortion aberration

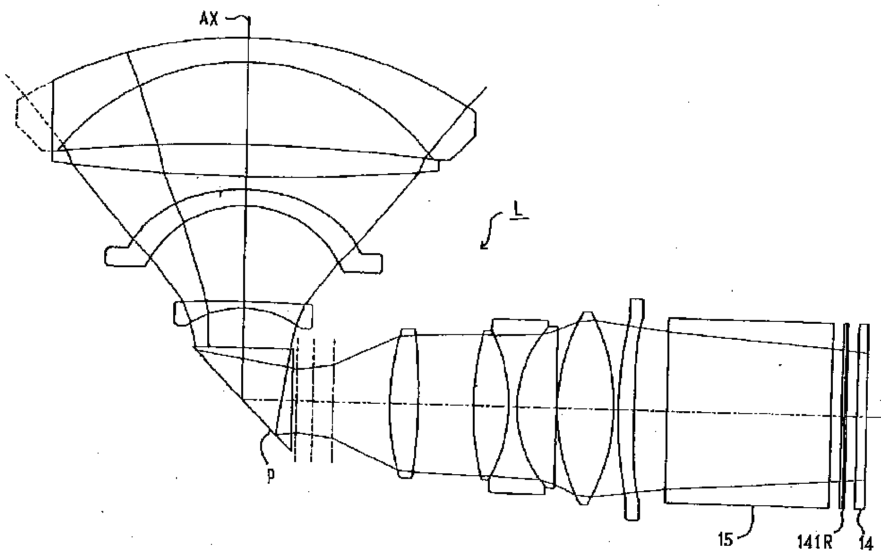
[FIG. 6]


(Sagittal direction)
Horizontal aberration
(1.00)
(0.85)
(0.70)
(0.50)
(0.30)
0.050(0.0)
def. = 0.000
(Meridional direction)
Horizontal aberration
FNO = 2.7
0.200
Spherical aberration
1.00
0.70
0.50
0.200
Astigmatism
1.00
0.70
0.50
% 0.50
Distortion aberration

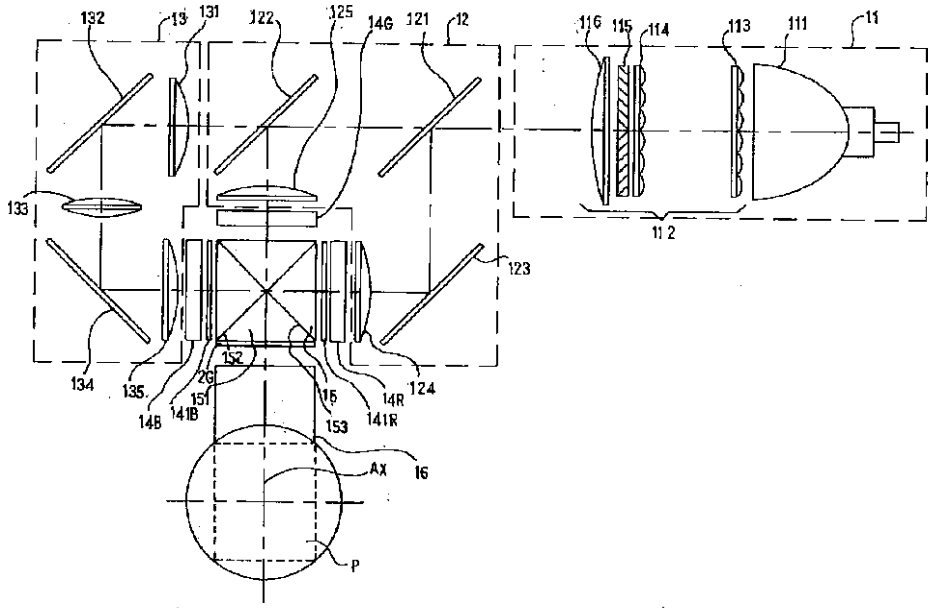
[FIG. 7]



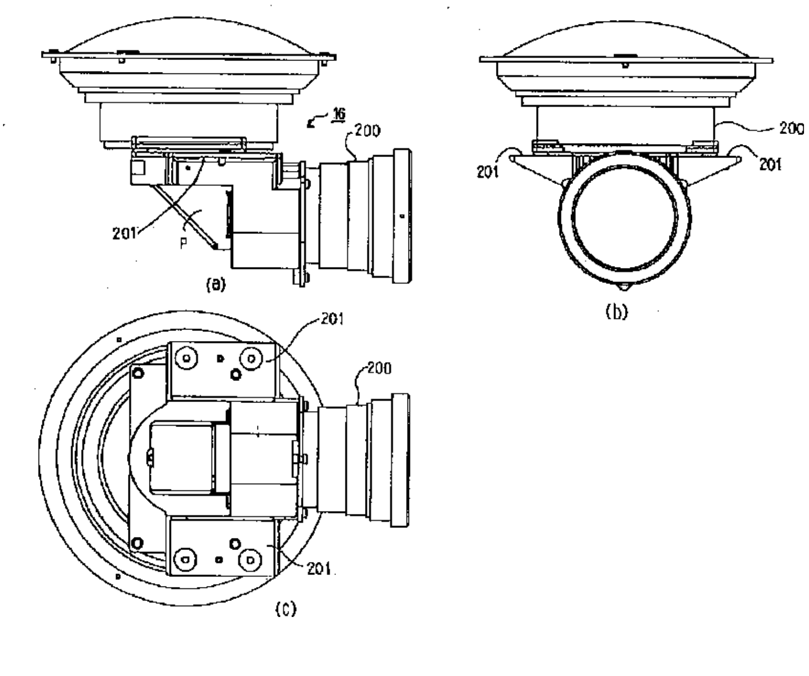
[FIG. 8]



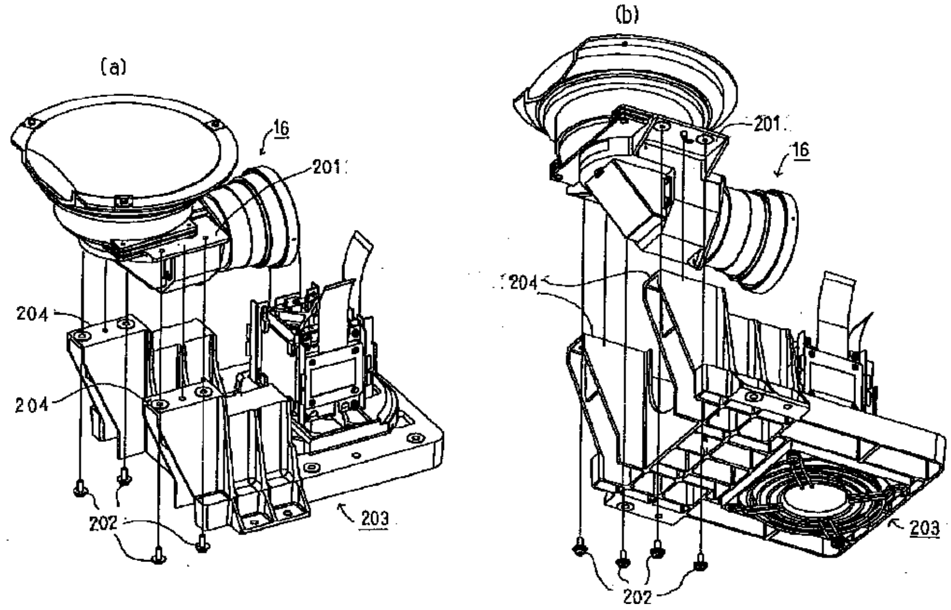
[FIG. 9]


132
13
131
122
125
14G
121
12
116
115
114
113
111
11
133
112
123
134
135
14B
141B
2G
151
152
15
153
14R
141R
124
AX
16
P

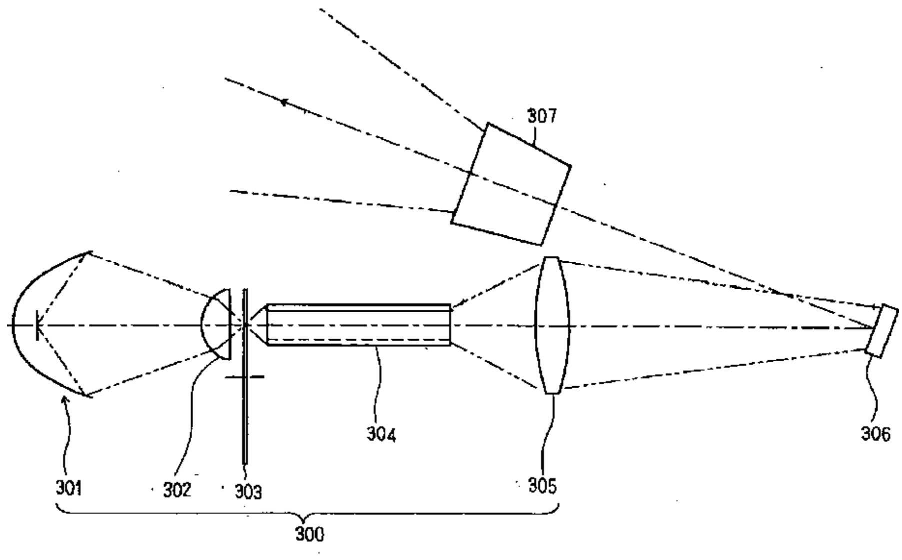
[FIG. 10]


16
200
201
P
(a)
200
201
201
(b)
201
200
201
(c)

[FIG. 11]



[FIG. 12]



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