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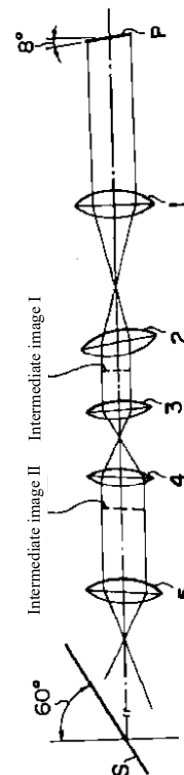
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(54) [Title of the Invention] Optical System for Projection Type Display Devices

(57) [Abstract]

[Objective] To provide an optical system for projection type display devices, wherein good imaging performance is obtained when a displayed image on a display is magnified by a projection lens and projected on a screen.

[Constitution] The system is characterized in that the projection lenses are composed of five lens groups, each thereof has positive refractive power and is eccentric to the optical reference axis.



[Scope of Patent Claims]

[Claim 1] An optical system for projection type display devices characterized in that in a projection type display device magnifying an original image on a display such as liquid crystal display panel, through projection lenses, to project the same on a screen, the projection lenses are composed of five lens groups, each thereof has positive refractive power and is eccentric to the optical reference axis.

[Claim 2] An optical system for projection type display devices stated in Claim 1, characterized in that the screen is tilted by 60° from a vertical condition.

[Claim 3] An optical system for projection type display devices stated in Claim 1 or 2, characterized in that aforementioned lens groups have:

$$|\Delta\theta_n| < 10^\circ$$

$$|\Delta S_n| < 7$$

wherein $\Delta\theta_n$ is eccentricity of inclination from the optical reference axis whereas ΔS_n is parallel eccentricity.

[Detailed Description of the Invention]

[0001]

[Industrial Field of Application] This invention concerns an optical system for projection type display devices, which is thin and for obtaining a large image.

[0002]

[Prior Art and Problems Thereof] As a display device to display by magnifying an image by use of a display device such as liquid crystal display panel and CRT, rear projection type display devices are known. For example, when looking at devices to obtain around 40 inches of image, in a case of a direct viewing tube TV as in Fig. 1 as the first format, the size of the CRT in itself nearly determines the size of the device to make the depth 70 cm or longer.

[0003] As the second format, in a format to project by use of an around 7 inches of small CRT as in Fig. 2, the CRT and projection lens are too large to make the device much thinner than by aforementioned format in Fig. 1. Nevertheless, this format is currently used for displays with a screen larger than 40 inches meanwhile manufacturing capacity for CRTs is around 40 inches at maximum in terms of cost.

[0004] In aforementioned format in Fig. 2, use of an around 3 inches of small and thin liquid crystal display panel instead of a small CRT attains downsizing and weight reduction as in Fig. 3. In order to make a device even thinner by securing a large screen, it has been considered to arrange a projection lens so that the same is obliquely opposed to the screen as shown in Fig. 4. The higher the degree of inclination is, the thinner the device can be. However, such arrangement as above attaining thinning has a problem that this optical system projects on a screen an image which is distorted in a trapezoidal manner as in Fig. 5. This is due to a difference in projection magnification among points. As a countermeasure therefor, use of a liquid crystal display panel or the like with a shape of reverse trapezoid, which can counteract trapezoidal distortion on the screen, is not practical in terms of manufacturing and cost.

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[0005] Measures to correct this trapezoidal distortion include what is stated in Japanese Laid-Open Patent Application Publications 1989-257834 and 1990-79037. Figs. 6 and 7 are a configuration drawing of a working example disclosed in aforementioned Japanese Laid-Open Patent Application Publications 1989-257834 and 1990-79037, respectively. Although aforementioned Japanese Laid-Open Patent Application Publication 1989-257834, as in Fig. 6, uses a reflection mirror with a shape to have an optical action equivalent to a rotationally asymmetric and non-spherically surfaced mirror to correct trapezoidal distortion to achieve thinning of the device, the reflection mirror is large and required to have high precision due to being complex and a mirror, to be very expensive in terms of cost, and has limitation in correction of trapezoidal distortion as well. In addition, aforementioned Japanese Laid-Open Patent Application Publication 1990-79037, as shown in Fig. 7, proposes to form an image on a display panel through a projection lens (= an image with trapezoidal distortion) without distortion on a screen by setting another optical system to generate reverse trapezoidal distortion. However, for attaining thinning of the device, the display panel, first lens, second lens, and screen need to be tilted relatively substantially. The relation of inclination to correct trapezoidal distortion, which is as shown in aforementioned publication, causes a problem that relatively substantial inclination of the first and second lenses results in no relay of the optical beam, which passed through the first lens, to the second lens. For this reason, the second lens must have a considerably high effective diameter. In a normal optical system with neither inclination eccentricity nor parallel eccentricity, wherein the object plane and image plane are vertical to the optical axis, an optical beam which reaches image heights equally distant from the optical axis is supposed to pass through a point symmetric to the optical axis in the lens system as well. In the meanwhile, in the event where aberrations at the same image height are constant but lenses have inclination eccentricity and/or parallel eccentricity, an optical beam to an image heights equally distant from the optical reference axis in the eccentric meridional cross-section, as is clear from the status of the optical beam in Fig. 7, is difficult to be relayed and has substantially distinct incidence position and/or angle in each lens. Even if paraxial and geometrical image formation relation is mathematically acceptable, such event as above has problems that in terms of aberration, particularly distortion and astigmatism are generated very substantially and that quantity of curvature of an image surface differs substantially, among others, that are not at a level ignorable as a display device. In addition, no prior art proposes such an eccentric optical system with tilted lenses to project obliquely, wherein aforementioned aberrations are corrected.

[0006]

[Objective of the Invention] This invention aims to propose an optical system for projection type display devices, wherein in a device to project a displayed image on a display on a screen by magnifying the image through the projection lens, incidence angle is 60° to the screen in order to attain thinning of depth to approximately half of vertical projection, not only trapezoidal distortion of the image but also aberrations, that are generated by inclination eccentricity and parallel eccentricity of the lens, are

corrected to successfully provide good image performance.

[0007]

[Means of Solving the Problem] This invention, in order to achieve aforementioned objective, should be constituted of five lens groups with positive refractory power for the screen tilted by 60° from a vertical condition to the optical reference axis as in Fig. 8, to correct and divide paraxial trapezoidal distortion, AND to arrange the lenses so that each thereof has eccentricity meeting

$$|\Delta\theta n| < 10^\circ$$

$$|\Delta Sn| < 7$$

wherein $\Delta\theta n$ is eccentricity of inclination from the optical reference axis whereas ΔSn is parallel eccentricity.

[0008]

[Embodiment of the Invention] An optical system for projection type display devices of this invention is described below. Figure 8 shows the paraxial principle of the optical system of this invention, wherein the original image on the display P forms an intermediate image I with trapezoidal distortion, by the lens 1 and lens 2, and this intermediate image I forms an intermediate image II with trapezoidal distortion in the same direction by the lens 3 and lens 4. This intermediate image II is formed on the screen S through the lens 5, as an image wherein trapezoidal distortion is counteracted. The fact that the first-stage lens group of lenses 1 and 2 and the second-stage lens group of lenses 3 and 4 have near telecentric constitution in both sides and that the lens 5 has near telecentric constitution similarly, makes matching of the optical beam favorable despite of being an eccentric optical system. Fig. 9 (A) and (B) are a cross-sectional drawing and optical route drawing of lenses of a numerical working example of this invention. Meanwhile an image forming relation wherein trapezoidal distortion is corrected can be calculated in terms of paraxial calculation, generally, optical beam tracking using a real beam for multiple image heights symmetric to the optical reference axis on a display surface on a plane wherein lenses are eccentric to the optical reference axis as in Fig. 9 (A), formed images, that are supposed to be at positions symmetric to the optical reference axis on the screen, are distorted substantially. This is because the lenses are eccentric to cause different incidence position and angle by lens between the upper and lower beams, to cause substantially different quantity of generated distortion. In an eccentric optical system, rather than the inclination relation of the object plane and image plane to a lens to correct trapezoidal distortion, correction of distortions in the upper and lower sides of the optical reference axis in the plane including eccentricity is more important. Use of a rotationally asymmetric non-spherical lens instead of a spherical lens, wherein correction is easily speculated to be possible, for this correction is not practical in terms of processing and cost.

[0009] For correction of aberrations including this distortion, correction of aberrations by means of curvature pending, change of thickness and/or interval, and change of the glass material, that are general correction means, is difficult to do the correction in a well-balanced manner because the optical system is rotationally asymmetric, and the correction is enabled by properly providing lenses with inclination eccentricity and parallel eccentricity. However, it is difficult to correct well distortion and other aberrations generated by an eccentric optical system unless

$$|\Delta\theta n| < 10^\circ$$

$$|\Delta Sn| < 7$$

wherein $\Delta\theta n$ is eccentricity of inclination from the optical reference axis whereas ΔSn is parallel eccentricity of each lens, are met. At the same time, matching of the optical beam among

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lenses will deteriorate, disabling to secure a sufficient quantity of light as well.

[0010] A numerical working example of this invention is shown next. In the numerical working example, γ_i is the curvature radius of the lens surface in the order of i from the screen side, d_i is thickness and air interval of the lens before eccentricizing in the order of i from the screen side, n_i and v_i are refractive index and Abbe's number, respectively, at line d of lens in the order of i from the screen side. $\Delta\theta_i$ and ΔS_i are values eccentric by block or lens based on the surface in the order of i from the screen side as the reference. Regarding codes, in Fig. 9 (A), counterclockwise and clockwise rotations of inclination eccentricity $\Delta\theta_i$ are positive and negative, respectively. Regarding parallel eccentricity ΔS_i , upward and downward shifts from the optical reference axis are positive and negative, respectively. Lenses in parentheses are eccentric *en bloc*.

[0011] This working example hypothesizes a 3-inch liquid crystal display panel as display and 50 inches of diagonal length as screen size, to have 3545 mm of projection distance between the frontal lens surface and screen, 8° of inclination of display surface, and 60° of screen inclination. To correct magnification ratio to 1:1 of aspect ratio in this working example wherein the magnification ratio in the direction of Fig. 9 (B) rotated by 90° centering the optical reference axis as opposed to the direction of Fig. 9 (A) is 1/2, an anamorphic lens system with data below, which has refractive power in the direction of Fig. 9 (B), should be inserted in the anterior space of the fifth lens group in the screen side. In the reference example of anamorphic lens, A_{ri} is curvature radius of the cylindrical lens surface in the order of i from the screen side, A_{di} is thickness and air interval of the cylindrical lens in the order of i from the screen side, A_{ni} and A_{vi} are refractive index and Abbe's number, respectively, at line d of the cylindrical lens in the order of i from the screen side.

[0012].

[Numerical 1]

Numerical Working Example 1

$r_1 = 59.403$	$d_1 = 9$	$n_1 = 1.72916$	$\nu_1 = 54.7$	$\Delta \theta_1 = -5^\circ$	$\Delta S_1 = 1$
$r_2 = 496.989$	$d_2 = 7.5$			(En bloc eccentricity)	
$r_3 = -51.343$	$d_3 = 2.5$	$n_2 = 1.6727$	$\nu_2 = 32.1$		
$r_4 = 83.665$	$d_4 = 6.5$				
$r_5 = 74.461$	$d_5 = 13$	$n_3 = 1.72916$	$\nu_3 = 54.7$		
$r_6 = -74.461$	$d_6 = 96.1$				
$r_7 = -37.0$	$d_7 = 2.5$	$n_4 = 1.84666$	$\nu_4 = 23.9$	$\Delta \theta_7 = -4^\circ$	$\Delta S_7 = 1$
$r_8 = 37.0$	$d_8 = 20.5$	$n_5 = 1.6779$	$\nu_5 = 55.3$		
$r_9 = -37.0$	$d_9 = 0.8$				
$r_{10} = -292.758$	$d_{10} = 10$	$n_6 = 1.7725$	$\nu_6 = 49.6$	$\Delta \theta_{10} = -4^\circ$	$\Delta S_{10} = 1$
$r_{11} = -59.367$	$d_{11} = 0.8$				
$r_{12} = 55.155$	$d_{12} = 14$	$n_7 = 1.7725$	$\nu_7 = 49.6$	$\Delta \theta_{12} = -4^\circ$	$\Delta S_{12} = 1$
$r_{13} = -572.384$	$d_{13} = 75.3$				
$r_{14} = 37.246$	$d_{14} = 2.5$	$n_8 = 1.5927$	$\nu_8 = 35.3$	$\Delta \theta_{14} = 1^\circ$	$\Delta S_{14} = -1.5$
$r_{15} = 21.231$	$d_{15} = 14$	$n_9 = 1.72916$	$\nu_9 = 54.7$		
$r_{16} = -373.332$	$d_{16} = 80.2$				
$r_{17} = 82.045$	$d_{17} = 9$	$n_{10} = 1.6968$	$\nu_{10} = 55.5$	$\Delta \theta_{17} = 9^\circ$	$\Delta S_{17} = 0$
$r_{18} = -82.045$	$d_{18} = 0.8$				
$r_{19} = 31.109$	$d_{19} = 21$	$n_{11} = 1.72$	$\nu_{11} = 50.2$	$\Delta \theta_{19} = 9^\circ$	$\Delta S_{19} = -2$
$r_{20} = -47.5$	$d_{20} = 2.5$	$n_{12} = 1.78472$	$\nu_{12} = 25.7$		
$r_{21} = 25.736$	$d_{21} = 30.6$				
$r_{22} = \text{絞り}$	$d_{22} = 43$				
				$\Delta \theta_{22} = 0^\circ$	$\Delta S_{22} = -2.3$

【 0 0 1 3 】

[Numerical 2]

$r_{z3} = -41.548$	$d_{z3} = 2.5$	$n_{13} = 1.5927$	$\nu_{13} = 35.3$	$\Delta \theta_{z3} = 0^\circ$ $\Delta S_{z3} = -5$ <i>(En bloc eccentricity)</i>
$r_{z4} = 114.002$	$d_{z4} = 12$			
$r_{z5} = -87.49$	$d_{z5} = 12$	$n_{14} = 1.834$	$\nu_{14} = 37.2$	
$r_{z6} = -51.816$	$d_{z6} = 0.8$			
$r_{z7} = 162.522$	$d_{z7} = 2.5$	$n_{15} = 1.78472$	$\nu_{15} = 25.7$	
$r_{z8} = 64.435$	$d_{z8} = 28$	$n_{16} = 1.72$	$\nu_{16} = 50.2$	
$r_{z9} = -101.77$				

A reference example of anamorphic lens

$Ar_1 = \infty$	$Ad_1 = 5$	$An_1 = 1.51633$	$A\nu_1 = 64.1$
$Ar_2 = 65$	$Ad_2 = 118.5$		
$Ar_3 = \infty$	$Ad_3 = 11.5$	$An_2 = 1.51633$	$A\nu_2 = 64.1$
$Ar_4 = -138$			

[0014]

[Effects of the Invention] As has been described above, in the optical system for projection type display devices pertaining to this invention, the optical system is divided into five groups, AND quantities of inclination eccentricity and parallel eccentricity of lenses are specified, to achieve an optical system with 30° of incidence to the screen, to be able to provide an optical system for projection type display devices, which is thin and maintains imaging performance.

[Brief Description of the Drawings]

[Figure 1] A cross-sectional drawing of a conventional injection type display device,

[Figure 2] A cross-sectional drawing of a conventional injection type display device,

[Figure 3] A cross-sectional drawing of a conventional injection type display device,

[Figure 4] A cross-sectional drawing of a conventional injection type display device in an oblique injection format,

[Figure 5] A figure showing an image formation relation between a display and a projected image in the oblique projection format,

[Figure 6] A conventional working example wherein trapezoidal distortion is corrected in the oblique projection format,

[Figure 7] A conventional working example wherein trapezoidal distortion is corrected in the oblique projection format,

[Figure 8] A figure showing the basic optical system of this working example,

[Figure 9] (A) and (B) are configuration drawing and optical route drawing of this working example,

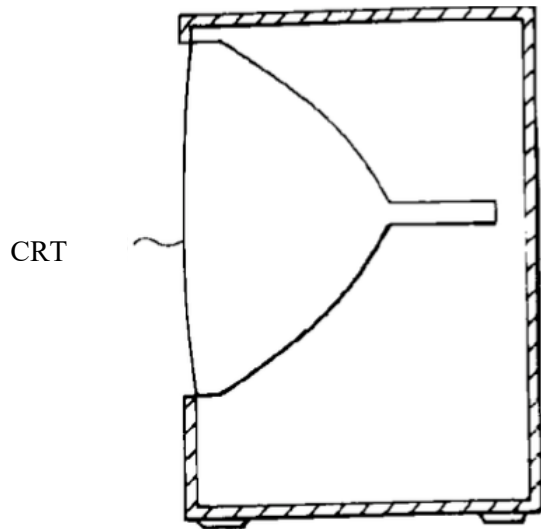
[Figure 10] An explanatory drawing showing spot performance and distortion in a condition wherein an anamorphic lens is attached, for on-screen evaluation. The spot is magnified by 5

times to the screen. The spot per site is shown by 100 optical beams.

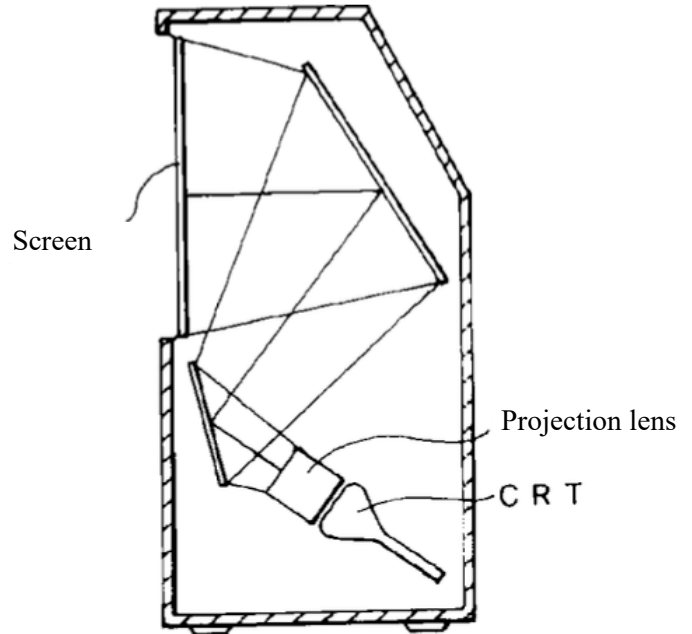
[Description of Codes]

1	Lens
2	Lens
3	Lens
4	Lens
5	Lens
P	Display
S	Screen
I	Intermediate image
II	Intermediate image

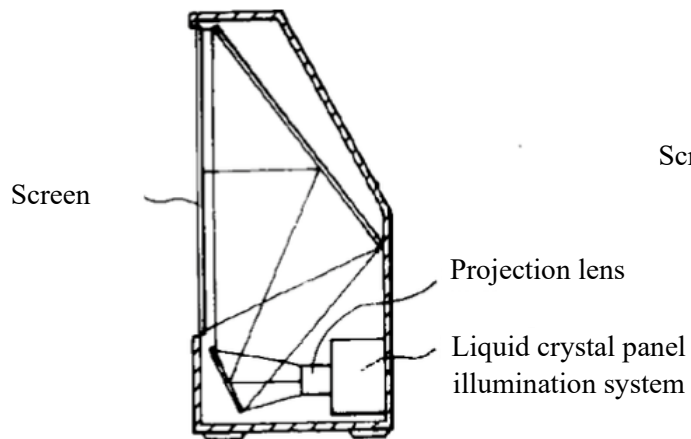
[Figure 1]



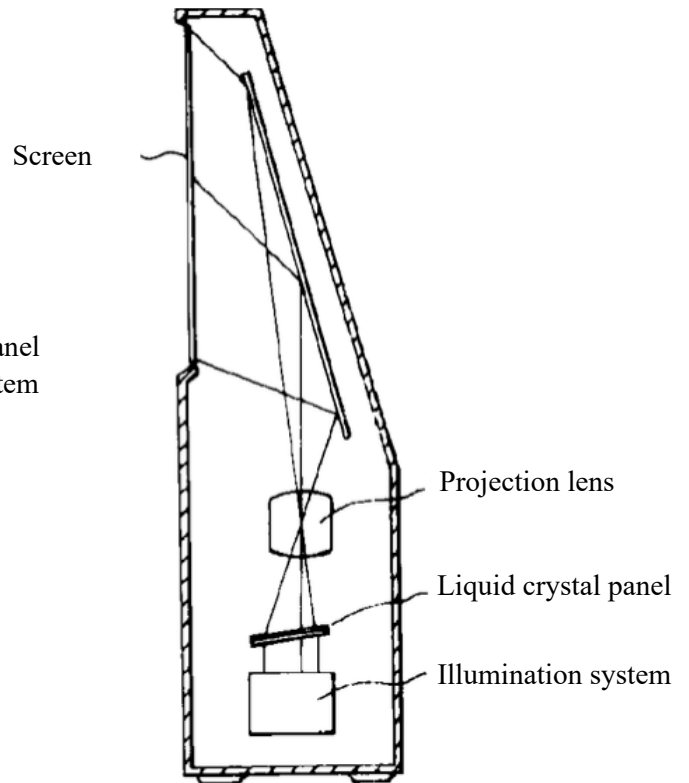
[Figure 2]



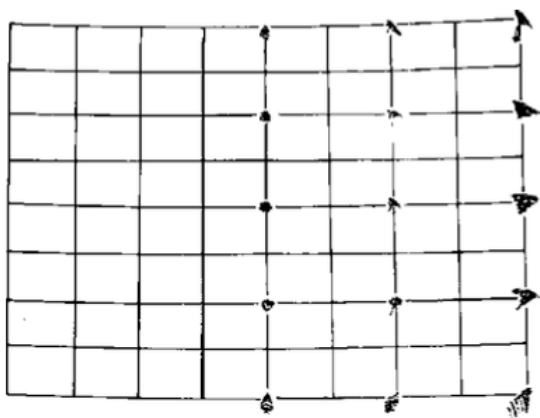
[Figure 3]



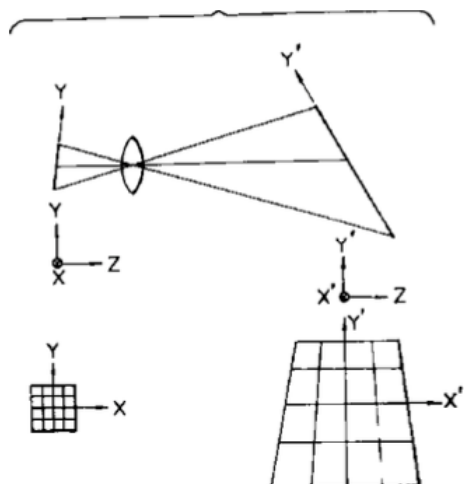
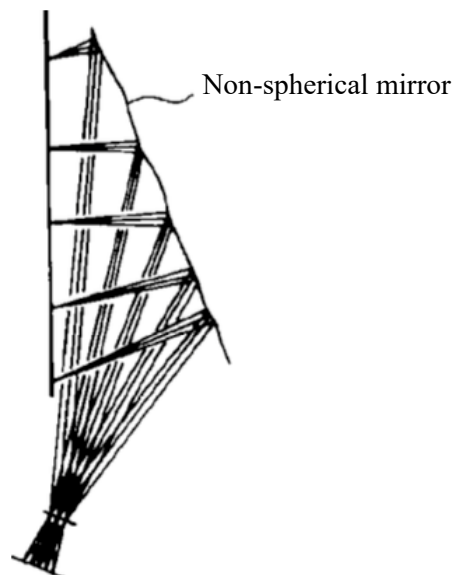
[Figure 4]



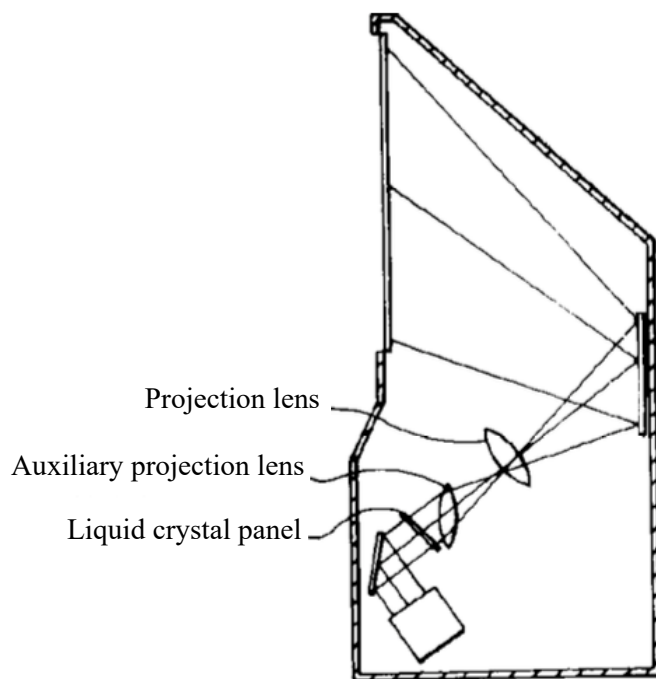
[Figure 10]

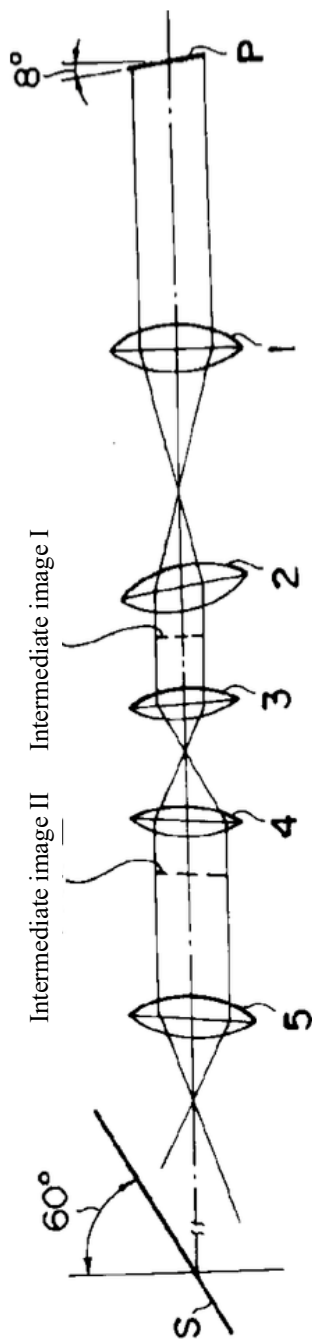


[Figure 5]

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[Figure 6]

[Figure 7]





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[Figure 9]

