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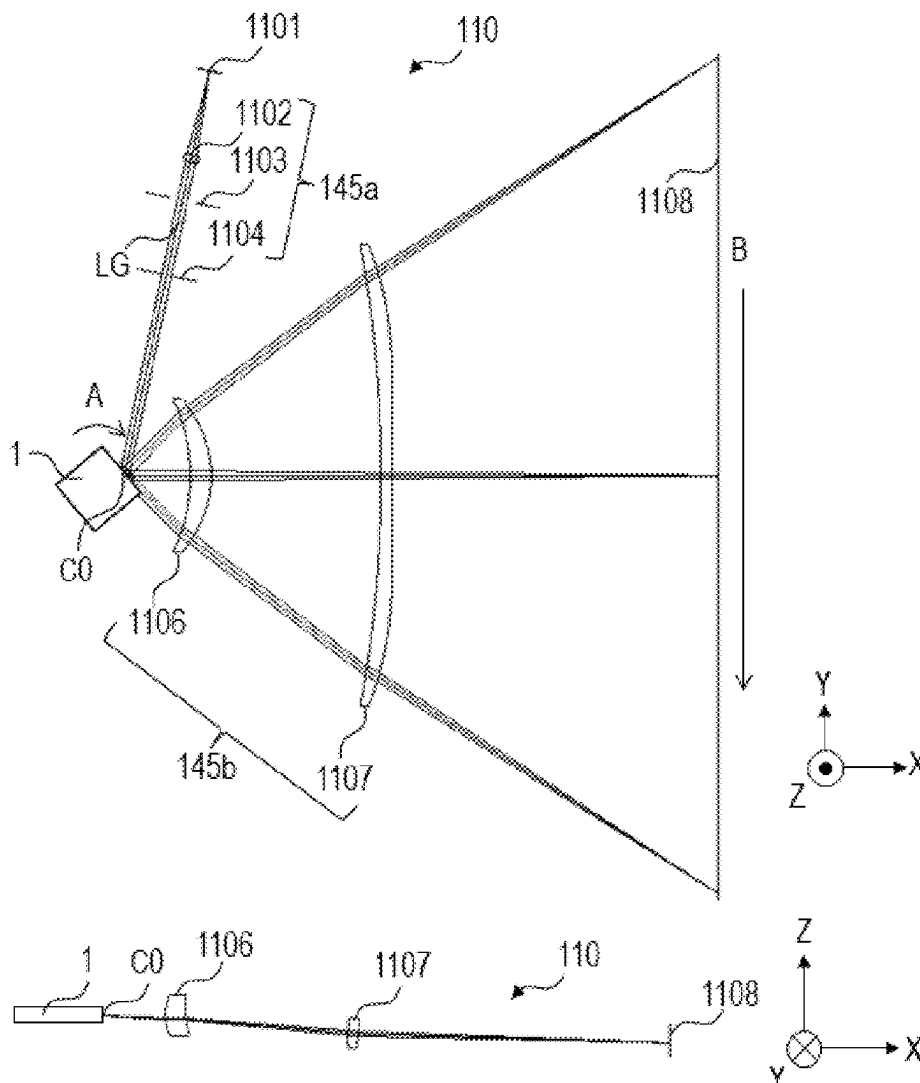


FIG. 1A

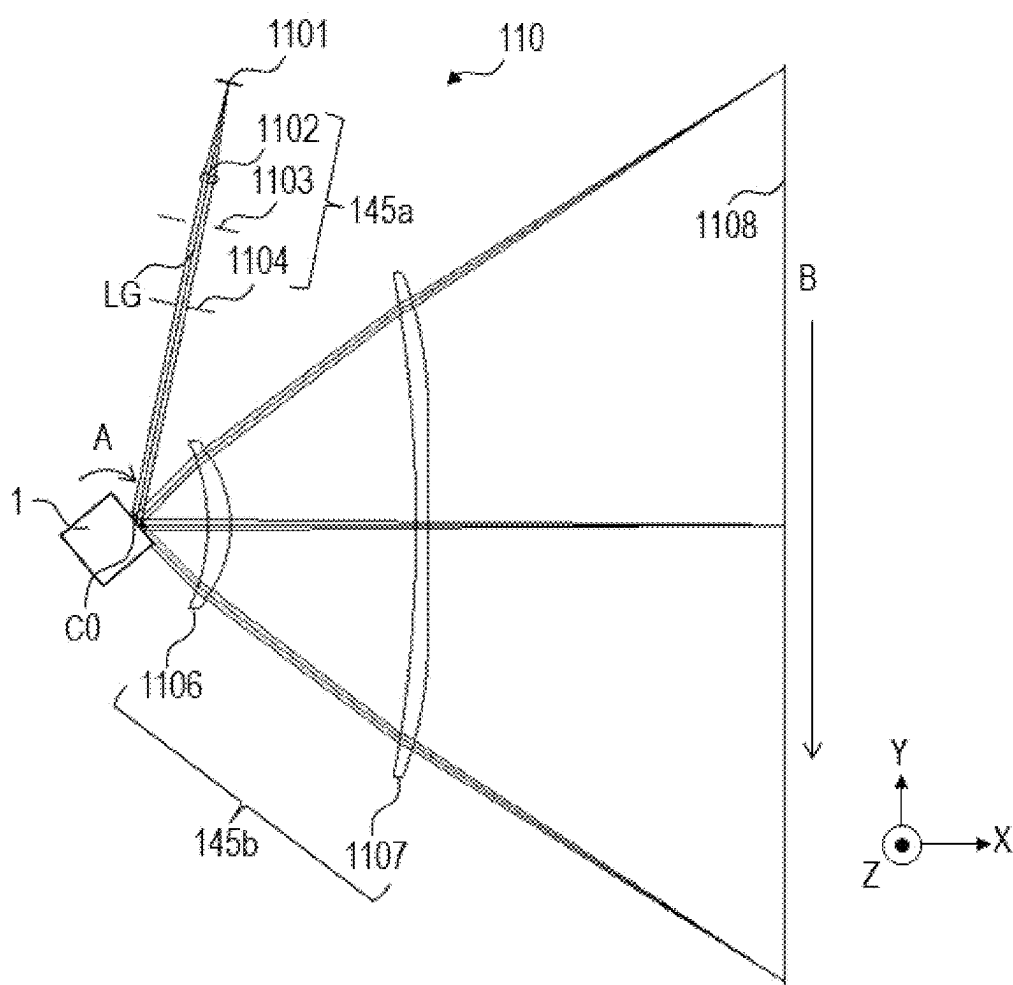


FIG. 1B

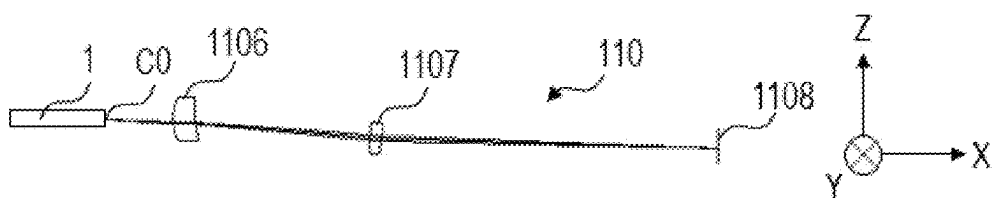


FIG. 2

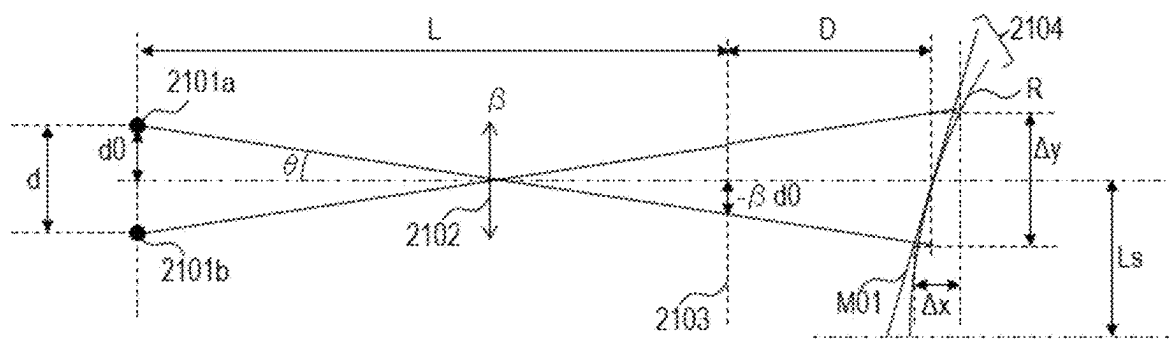


FIG. 3A

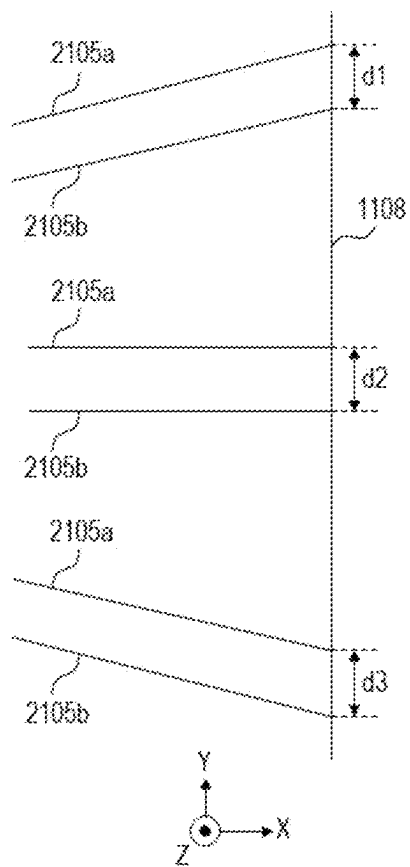


FIG. 3B

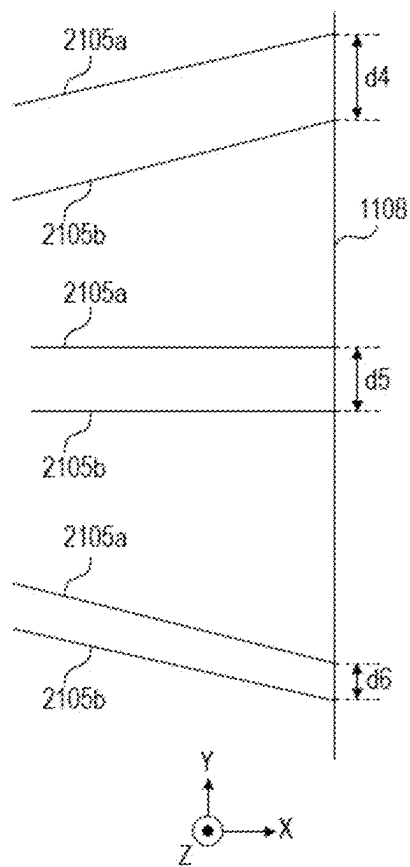


FIG. 4

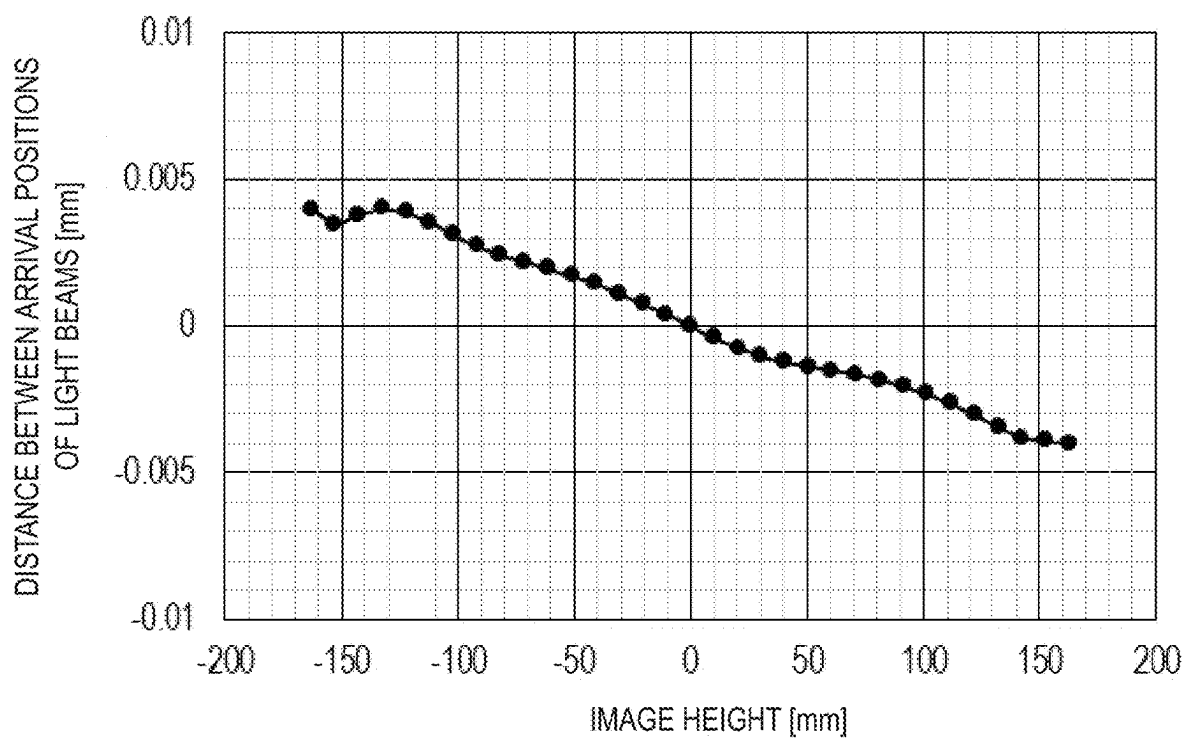


FIG. 5A

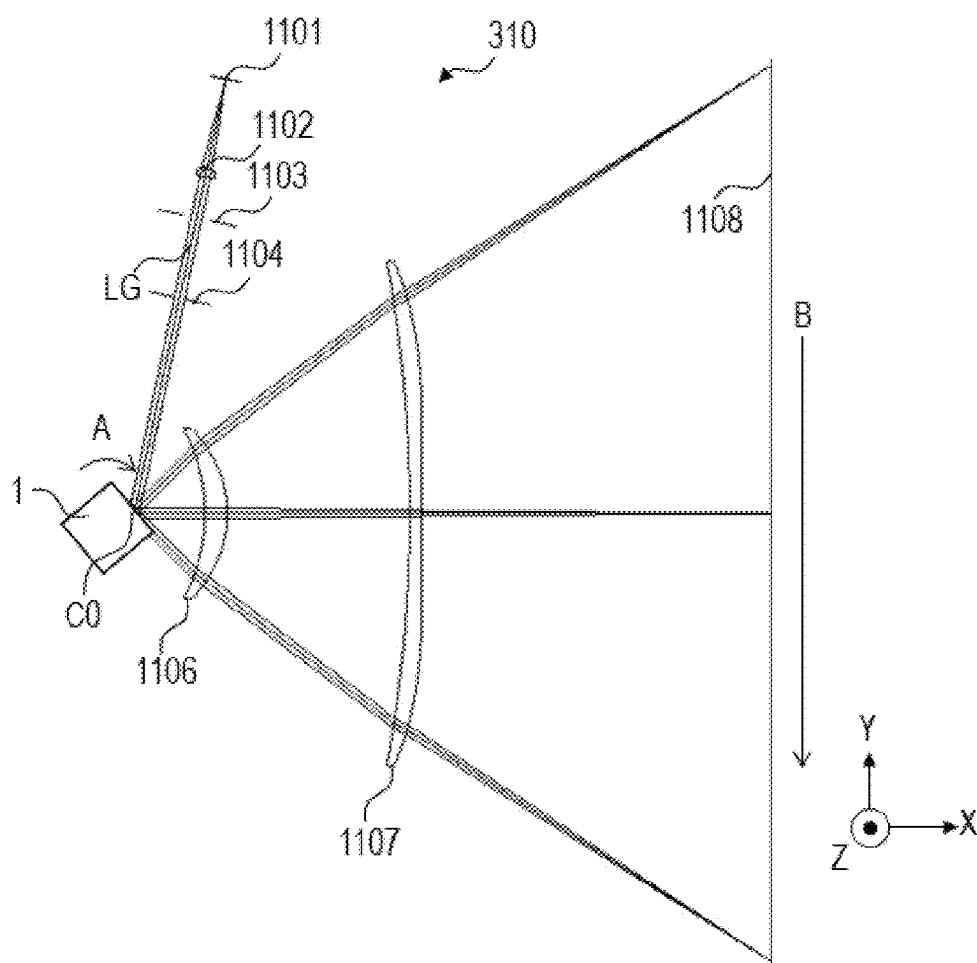


FIG. 5B

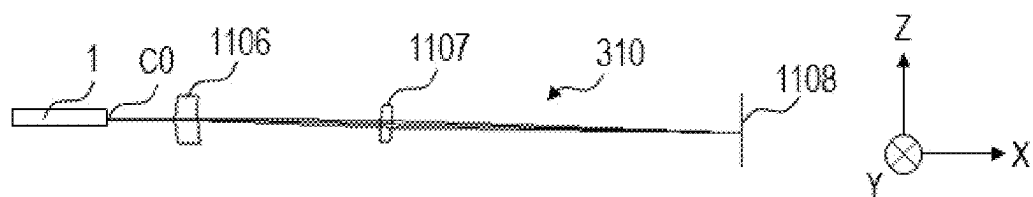


FIG. 6

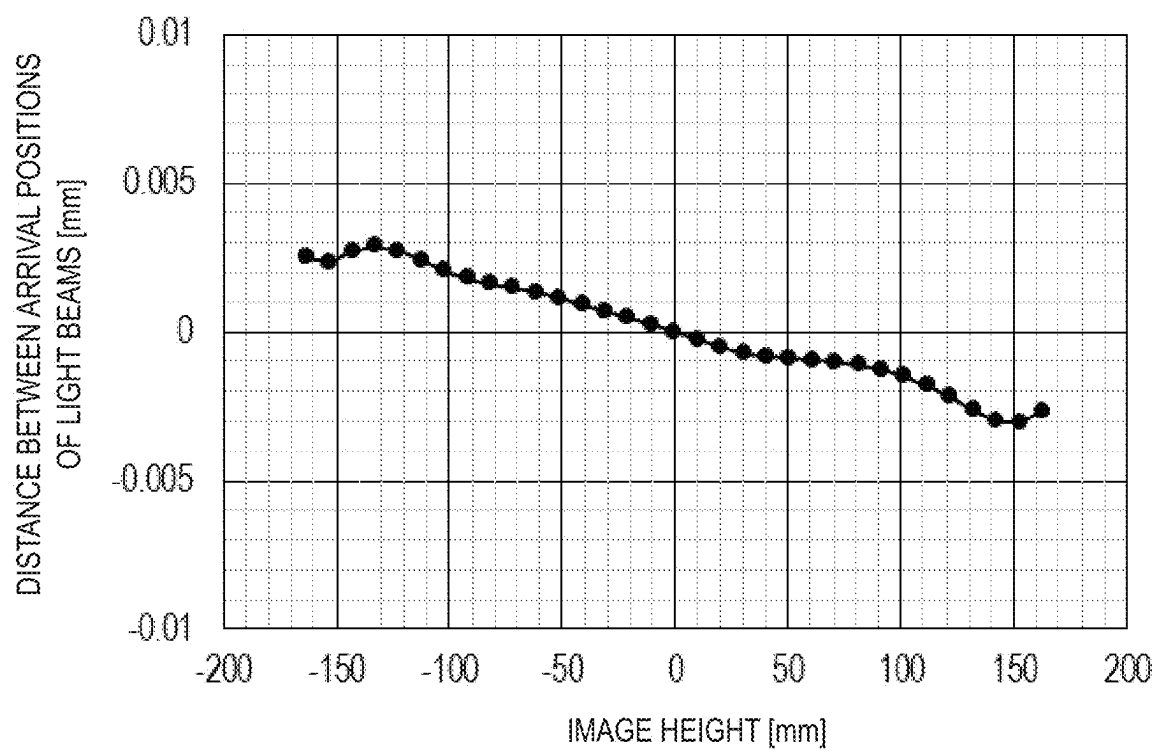


FIG. 7A

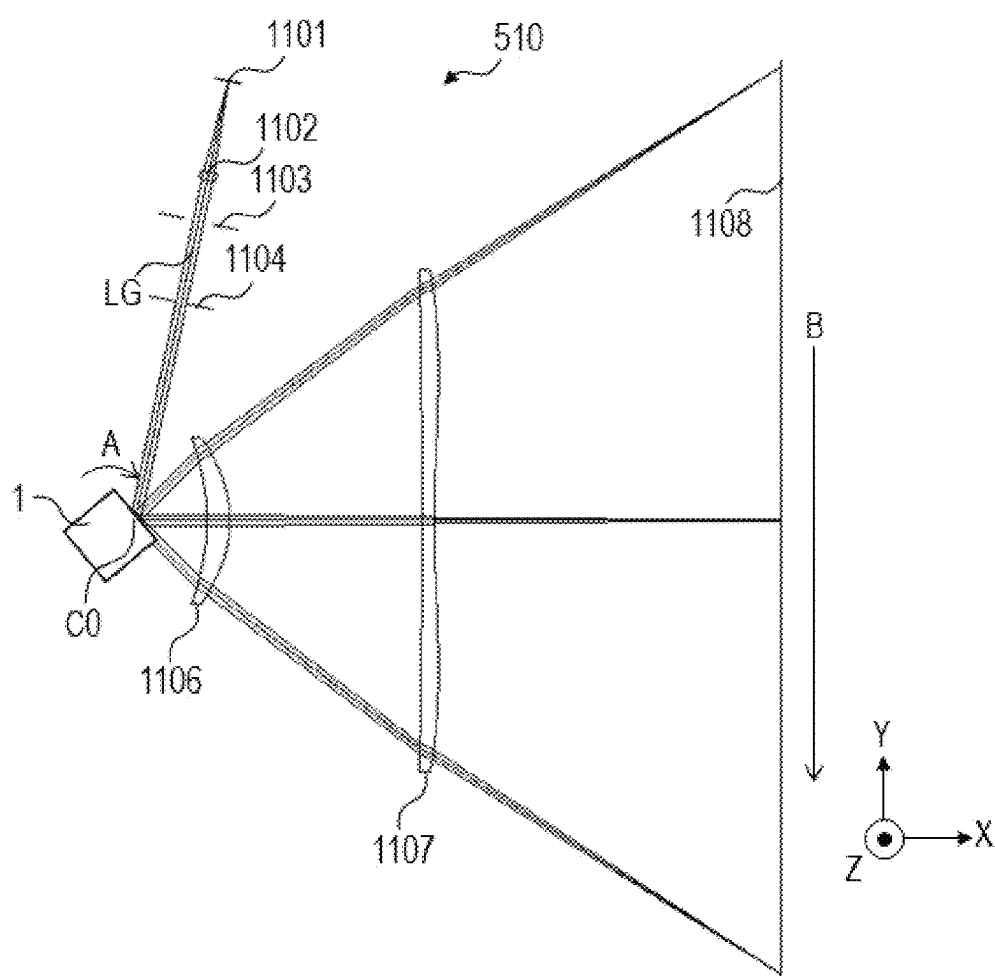


FIG. 7B

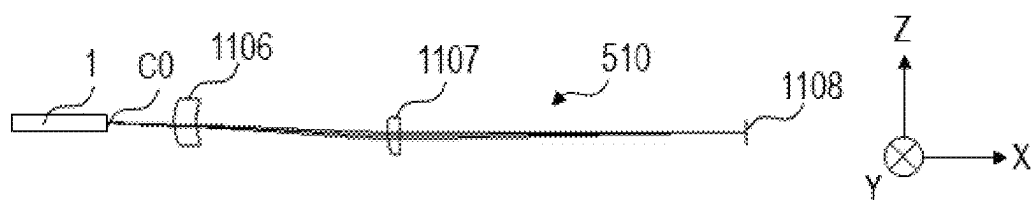


FIG. 8

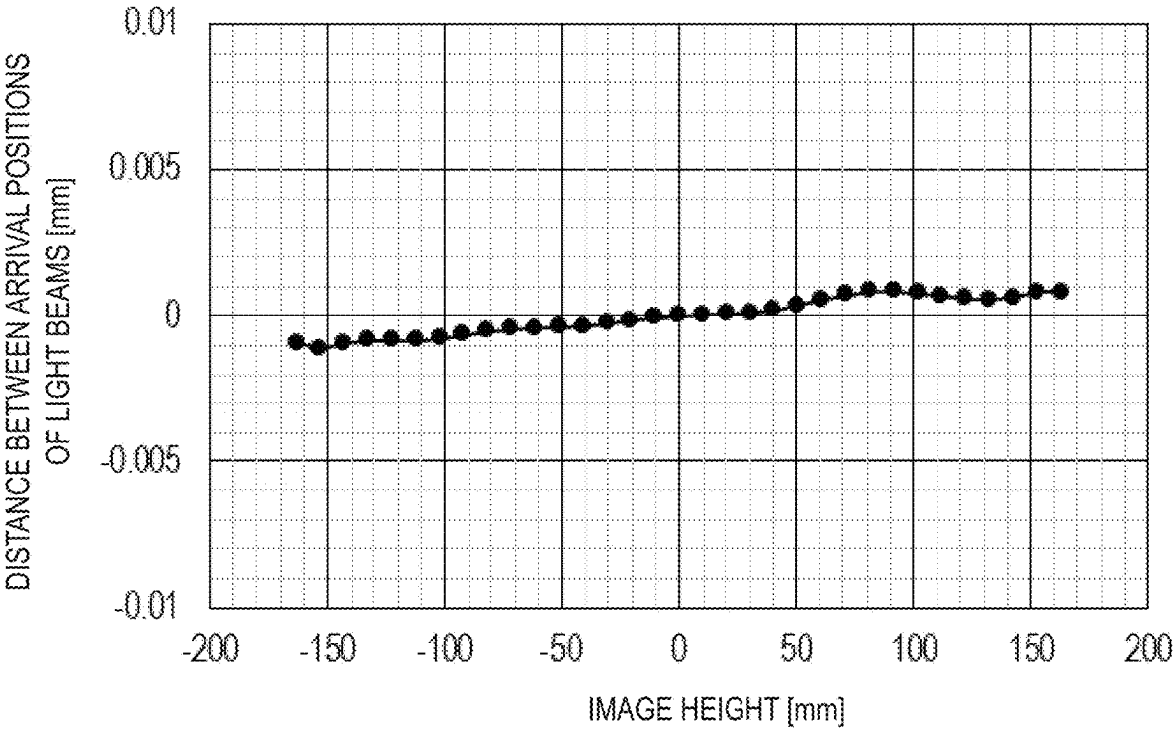


FIG. 9A

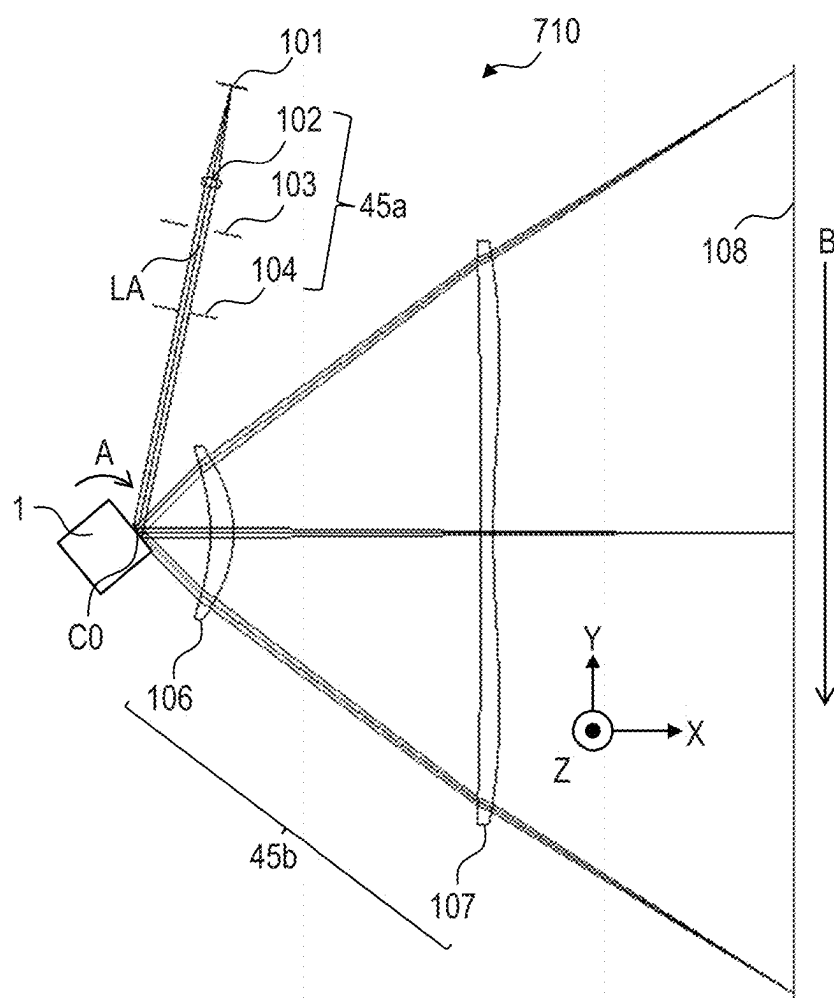


FIG. 9B

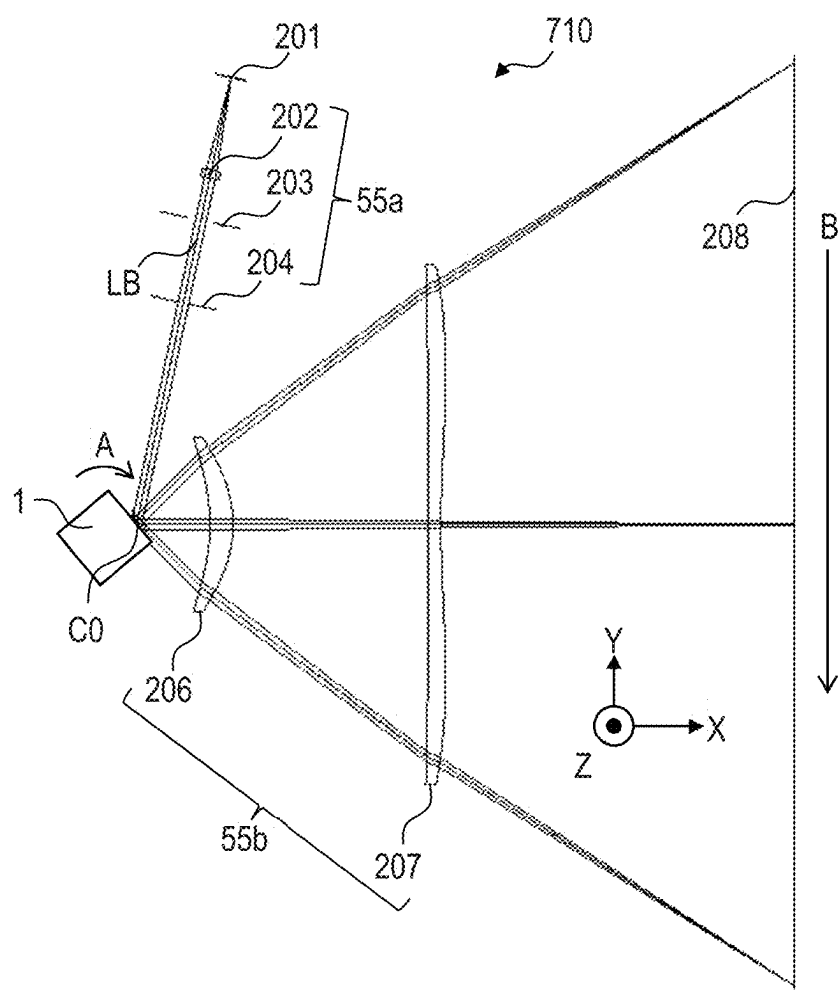


FIG. 10

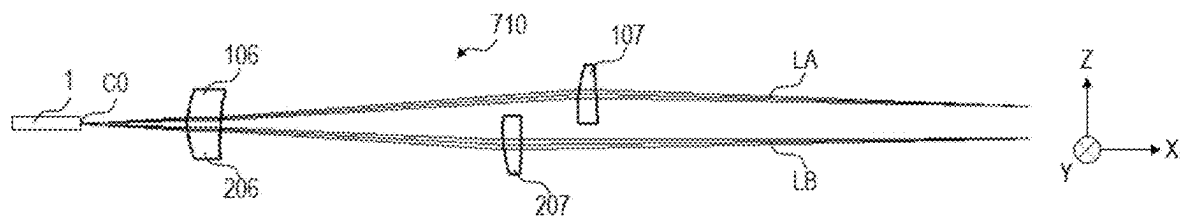


FIG. 11

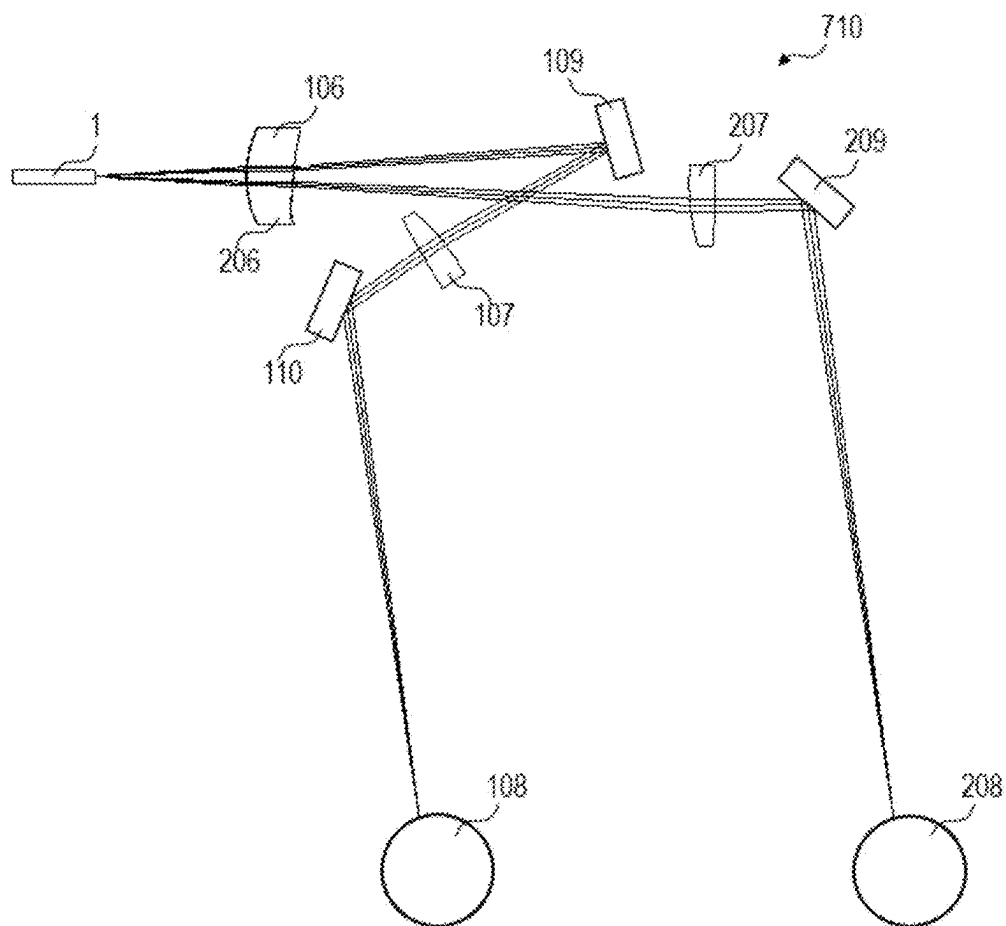


FIG. 12A

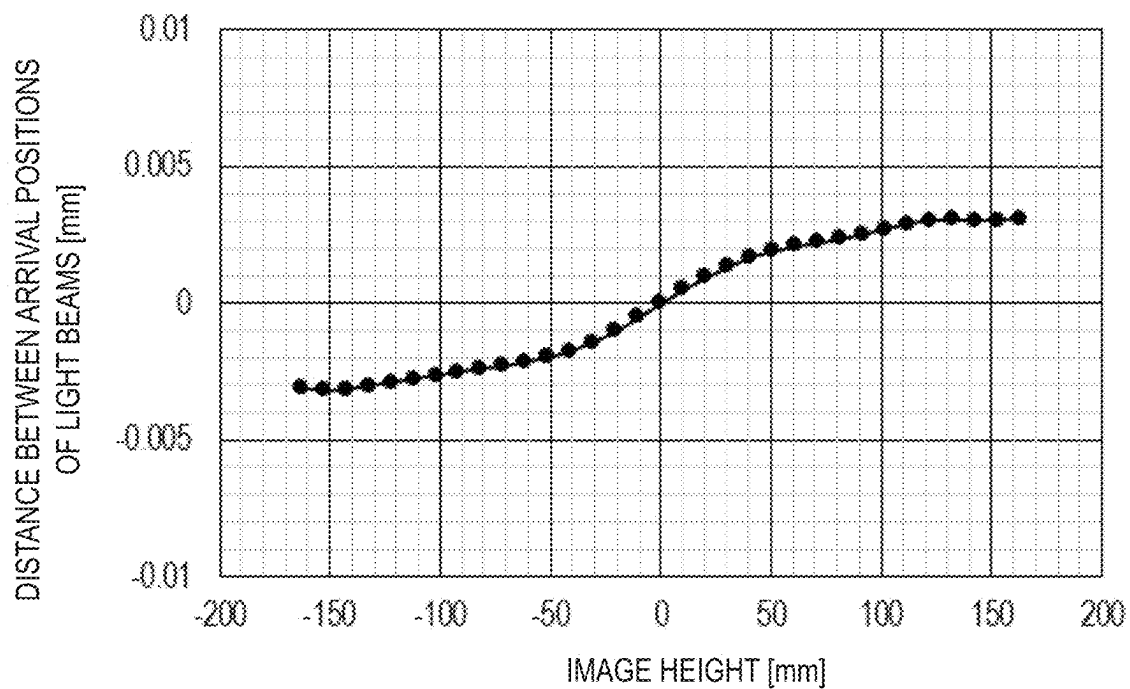


FIG. 12B

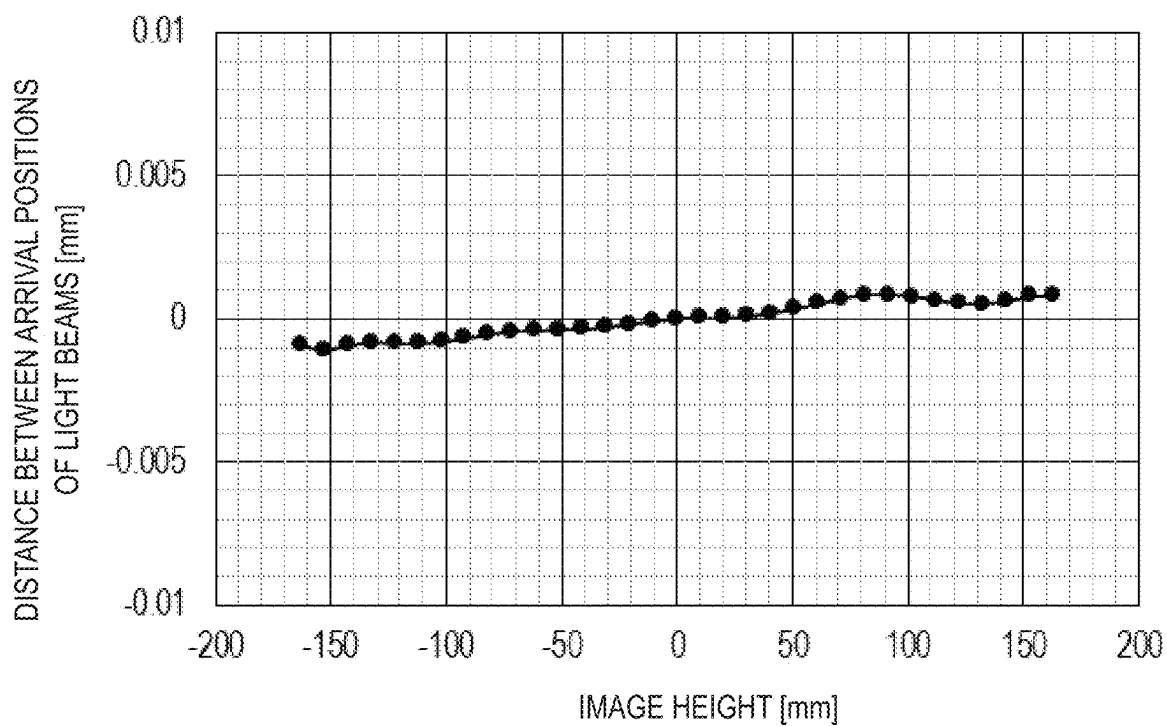


FIG. 13

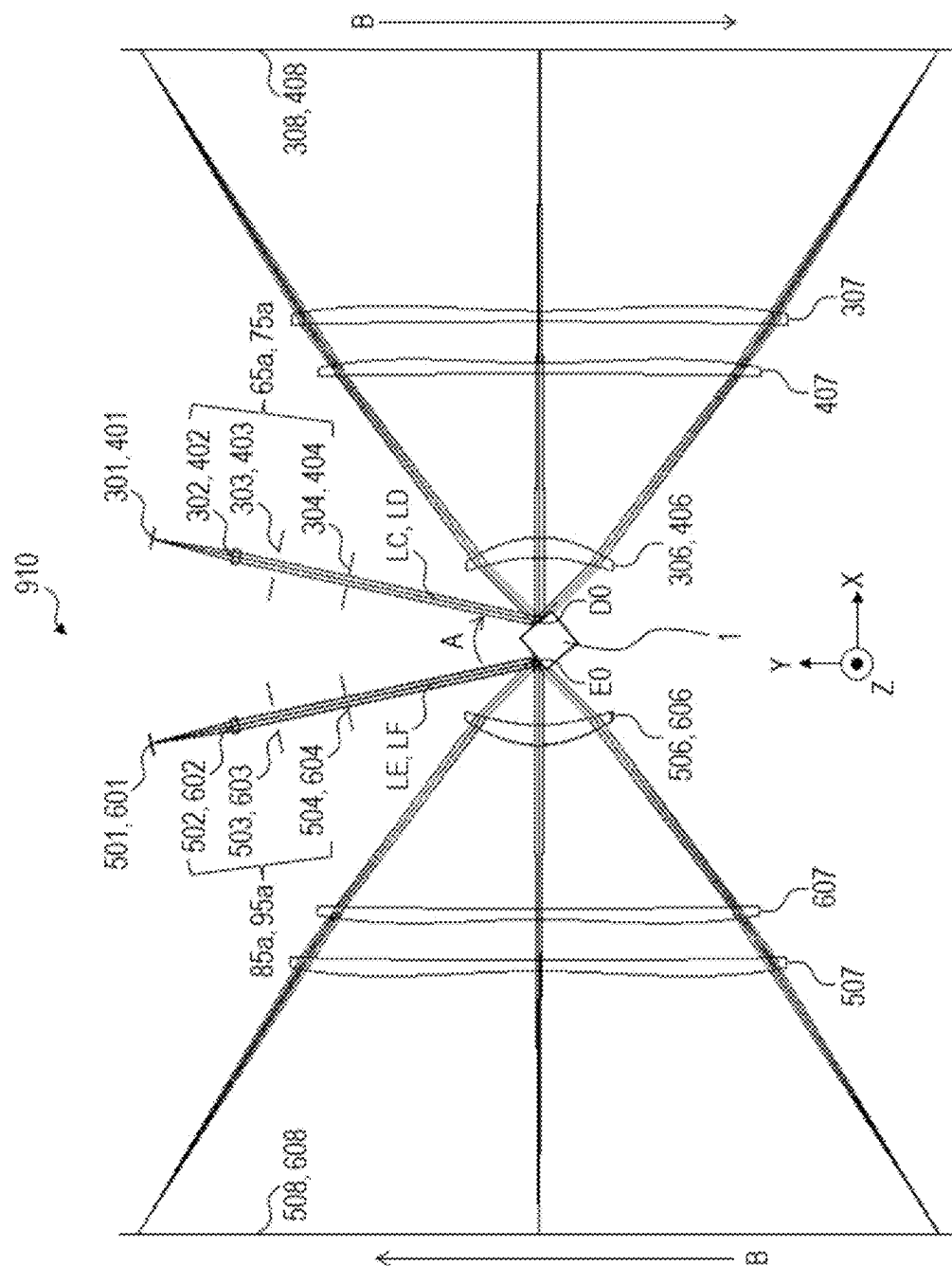


FIG. 14

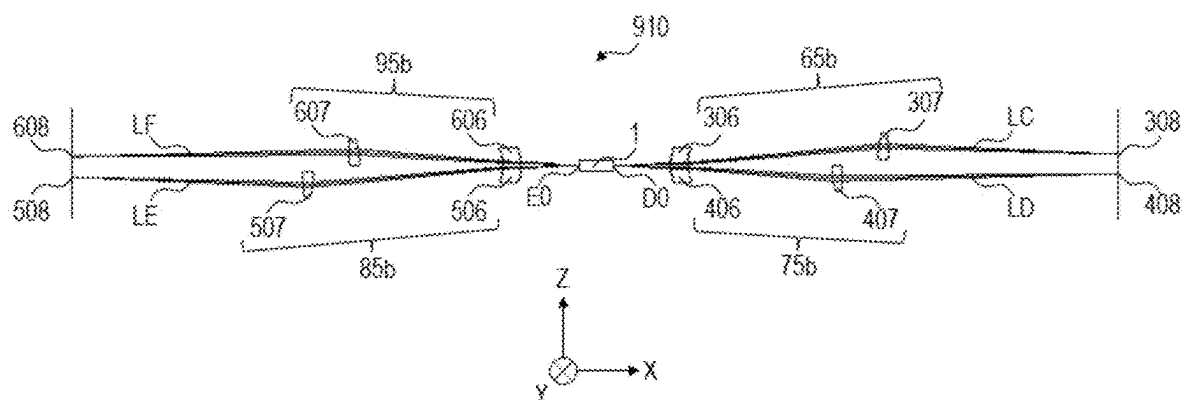


FIG. 15

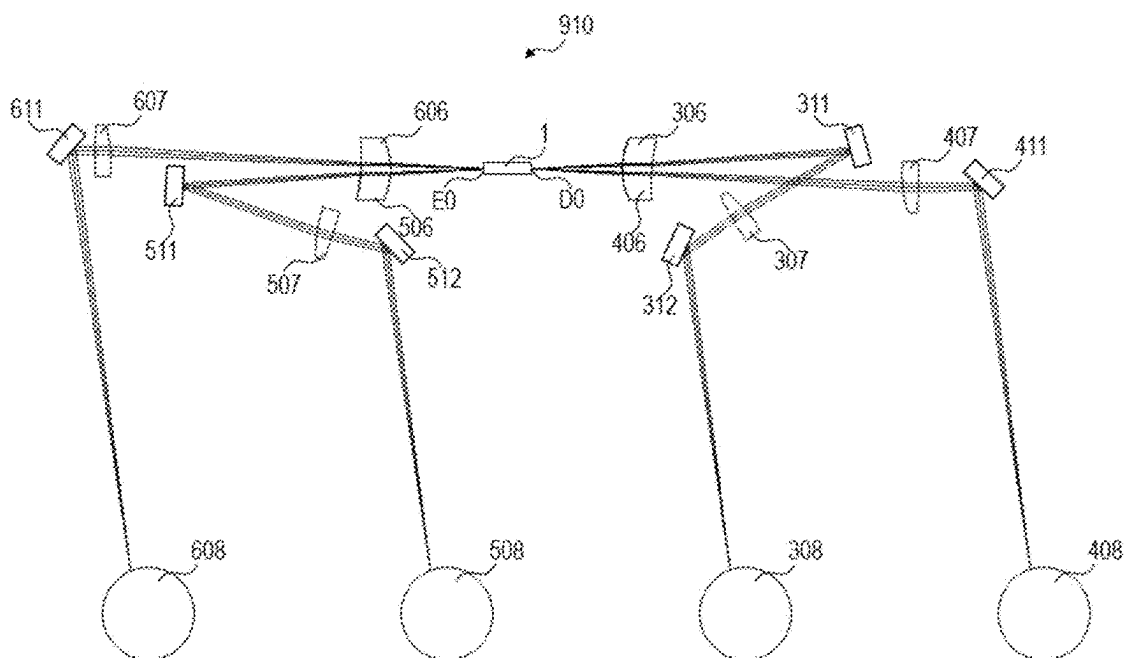
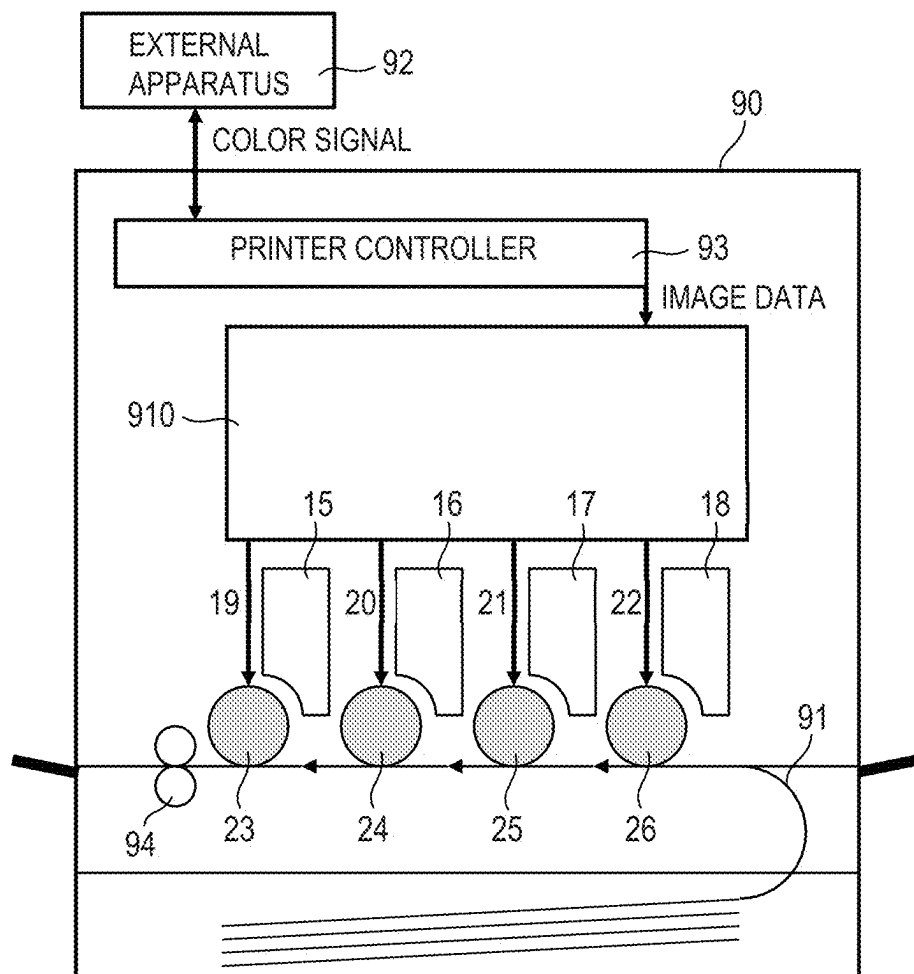


FIG. 16



LIGHT SCANNING APPARATUS AND IMAGE FORMING APPARATUS

BACKGROUND

Technical Field

[0001] The present disclosure is related to a light scanning apparatus, and more particularly to a light scanning apparatus suitably used in an image forming apparatus such as a laser beam printer (LBP), a digital copying machine and a multi-function printer (MFP).

Description of the Related Art

[0002] Conventionally, there is known a light scanning apparatus which scans a scanned surface by using multiple beams emitted from a light source with a plurality of light emitting points to increase a speed.

[0003] On the other hand, in such light scanning apparatus, it is also known that image quality may deteriorate due to an occurrence of a deviation between scanning widths (overall magnifications) of the multiple beams.

[0004] Japanese Patent Application Laid-open No. H09-197308 discloses a light scanning apparatus that reduces a deviation between scanning widths of multiple beams by using a deviation between scanning widths corresponding to incident angles of the multiple beams with respect to a scanned surface.

SUMMARY

[0005] The apparatus according to the embodiments includes a deflecting unit configured to deflect a plurality of light fluxes from a first light source with a plurality of light emitting points to scan a first scanned surface in a main scanning direction, a first element having a first surface and configured to guide the plurality of light fluxes deflected by a first deflecting surface of the deflecting unit to the first scanned surface, and a first incident system configured to cause the plurality of light fluxes from the first light source to be incident on the first deflecting surface, in which a following condition is satisfied:

$$0.05 < \left| M_{1i} \left[-\beta_1 + \frac{(1-\beta_1)D_1}{L_1} \right] \right| < 0.70,$$

[0006] where L_1 represents a distance between the first light source and the first deflecting surface on an optical axis of the first incident system, D_1 represents a distance between the first deflecting surface and the first surface on an optical axis of the first element, β_1 represents a lateral magnification in a sub-scanning cross section of the first incident system, and M_{1i} represents an inclination of the first surface at a position at which the light flux from an i -th light emitting point of the first light source arrives on the first surface.

[0007] Further features of the disclosure will become apparent from the following description of exemplary embodiments with reference to the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. 1A is a main scanning cross sectional view of a light scanning apparatus according to a first embodiment of the disclosure.

[0009] FIG. 1B is a partial sub-scanning cross sectional view of the light scanning apparatus according to the first embodiment.

[0010] FIG. 2 is a diagram for explaining an effect in the light scanning apparatus according to the first embodiment.

[0011] FIG. 3A is a view showing a state in which a plurality of light beams arrive at respective image heights on a scanned surface in the light scanning apparatus according to the first embodiment.

[0012] FIG. 3B is a view showing a state in which a plurality of light beams arrive at respective image heights on a scanned surface in the light scanning apparatus according to the first embodiment.

[0013] FIG. 4 is a graph showing an image height dependence of a distance between the arrival positions of light beams on the scanned surface in the light scanning apparatus according to the first embodiment.

[0014] FIG. 5A is a main scanning cross sectional view of a light scanning apparatus according to a second embodiment of the disclosure.

[0015] FIG. 5B is a partial sub-scanning cross sectional view of the light scanning apparatus according to the second embodiment.

[0016] FIG. 6 is a graph showing an image height dependence of a distance between arrival positions of light beams on a scanned surface in the light scanning apparatus according to the second embodiment.

[0017] FIG. 7A is a main scanning cross sectional view of a light scanning apparatus according to a third embodiment of the disclosure.

[0018] FIG. 7B is a partial sub-scanning cross sectional view of the light scanning apparatus according to the third embodiment.

[0019] FIG. 8 is a graph showing an image height dependence of a distance between arrival positions of light beams on a scanned surface in the light scanning apparatus according to the third embodiment.

[0020] FIG. 9A is a partial developed view in a main scanning cross section of a light scanning apparatus according to a fourth embodiment of the disclosure.

[0021] FIG. 9B is a partial developed view in the main scanning cross section of the light scanning apparatus according to the fourth embodiment.

[0022] FIG. 10 is a partial developed view in a sub-scanning cross section of the light scanning apparatus according to the fourth embodiment.

[0023] FIG. 11 is a partial sub-scanning cross sectional view of the light scanning apparatus according to the fourth embodiment.

[0024] FIG. 12A is a graph showing an image height dependence of a distance between arrival positions of light beams on a scanned surface in the light scanning apparatus according to the fourth embodiment.

[0025] FIG. 12B is a graph showing an image height dependence of a distance between arrival positions of light beams on a scanned surface in the light scanning apparatus according to the fourth embodiment.

[0026] FIG. 13 is a developed view in the main scanning cross section of a light scanning apparatus according to a fifth embodiment of the disclosure.

[0027] FIG. 14 is a partial developed view in the sub-scanning cross section of the light scanning apparatus according to the fifth embodiment.

[0028] FIG. 15 is a partial sub-scanning cross sectional view of the light scanning apparatus according to the fifth embodiment.

[0029] FIG. 16 is a sub-scanning cross sectional view of a main part of an image forming apparatus according to the aspect of the embodiments.

DESCRIPTION OF THE EMBODIMENTS

[0030] Hereinafter, a light scanning apparatus according to the aspect of the embodiments is described in detail with reference to accompanying drawings. Note that the drawings described below may be drawn on a scale different from an actual scale in order to facilitate understanding of the disclosure.

[0031] In the following description, a main scanning direction is a direction perpendicular to a rotation axis of a deflecting unit and an optical axis of an optical system. A sub-scanning direction is a direction parallel to the rotation axis of the deflecting unit. A main scanning cross section is a cross section perpendicular to the sub-scanning direction. The sub-scanning cross section is a cross section perpendicular to the main scanning direction.

[0032] Accordingly, in the following description, it should be noted that the main scanning direction and the sub-scanning cross section are different between an incident optical system and an imaging optical system.

First Embodiment

[0033] FIGS. 1A and 1B show a schematic main scanning cross sectional view and a schematic partial sub-scanning cross sectional view of a light scanning apparatus 110 according to a first embodiment of the disclosure, respectively.

[0034] The light scanning apparatus 110 according to the aspect of the embodiment includes a light source 1101 (first light source), an anamorphic collimator lens 1102, a sub-scanning stop 1103, a main scanning stop 1104, a deflecting unit 1, a first f θ lens 1106 (first optical element, first imaging optical element), and a second f θ lens 1107.

[0035] On an optical path, the first f θ lens 1106 is arranged between the deflecting unit 1 and the second f θ lens 1107.

[0036] As the light source 1101, a semiconductor laser (multibeam laser) or the like having a plurality of light emitting points is used.

[0037] The anamorphic collimator lens 1102 converts a light flux LG emitted from the light source 1101 into a parallel light flux in the main scanning cross section, and condenses the light flux LG in the sub-scanning cross section. The parallel light flux includes not only a strictly parallel light flux but also a substantially parallel light flux such as a weakly divergent light flux or a weakly convergent light flux.

[0038] The sub-scanning stop 1103 limits a light flux diameter in the sub-scanning direction of the light flux LG that has passed through the anamorphic collimator lens 1102.

[0039] The main scanning stop 1104 limits a light flux diameter in the main scanning direction of the light flux LG that has passed through the sub-scanning stop 1103.

[0040] With the above-described configuration, the light flux LG emitted from the light source 1101 is condensed in the sub-scanning direction in the vicinity of a deflecting surface of the deflecting unit 1, so that a line image elongated in the main scanning direction is formed.

[0041] The deflecting unit 1 deflects the incident light flux LG with rotating in a direction indicated by an arrow A in FIG. 1A by a driving unit such as a motor (not shown). The deflecting unit 1 is formed by a polygon mirror, for example.

[0042] The first f θ lens 1106 and the second f θ lens 1107 are anamorphic imaging lenses having different powers (refractive powers) between the main scanning cross section and the sub-scanning cross section, and condense (guide) the light flux LG deflected by the deflecting unit 1 on the scanned surface 1108 (first scanned surface).

[0043] In the light scanning apparatus 110 according to the aspect of the embodiment, an incident optical system 145a is formed by the anamorphic collimator lens 1102, the sub-scanning stop 1103 and the main scanning stop 1104.

[0044] Further, in the light scanning apparatus 110 according to the aspect of the embodiment, a scanning optical system 145b (first imaging optical system) is formed by the first f θ lens 1106 and the second f θ lens 1107.

[0045] Note that the refractive power in the sub-scanning cross section of the second f θ lens 1107 is stronger than the refractive power in the sub-scanning cross section of the first f θ lens 1106, namely the strongest in the scanning optical system 145b.

[0046] The light fluxes LG emitted from the respective light emitting points of the light source 1101 pass through the incident optical system 145a to be incident on the deflecting unit 1.

[0047] The light fluxes LG incident on the deflecting unit 1 from the light source 1101 are deflected by the deflecting unit 1 to be guided onto the scanned surface 1108 by the scanning optical system 145b, thereby the scanned surface 1108 is scanned at a constant speed.

[0048] Since the deflecting unit 1 rotates in the direction indicated by the arrow A in FIG. 1A, the light fluxes LG deflected by the deflecting unit 1 scan the scanned surface 1108 in a direction indicated by an arrow B in FIG. 1A.

[0049] In FIGS. 1A and 1B, CO represents a deflection point (on-axis deflection point) on the deflecting surface of the deflecting unit 1 for a principal ray of an on-axis light flux. The deflection point CO serves as a reference point of the scanning optical system 145b.

[0050] In the aspect of the embodiment, a photosensitive drum 1108 is used as the scanned surface 1108. An exposure distribution in the sub-scanning direction on the photosensitive drum 1108 is formed by rotating the photosensitive drum 1108 in the sub-scanning direction for each main scanning exposure.

[0051] Next, various characteristics of the incident optical system 145a and the scanning optical system 145b provided in the light scanning apparatus 110 according to the aspect of the embodiment are shown in the following Tables 1 and 2, respectively.

TABLE 1

Characteristics of light source 1101			
Wavelength		λ (nm)	790
Incident polarization to deflecting surface of deflecting unit 1			p-polarization
Full angle at half maximum in main scanning direction		FFPy(deg)	12.00
Full angle at half maximum in sub-scanning direction		FFPz(deg)	30.00
Shape of stop			
	Main scanning direction	Sub-scanning direction	
Sub-scanning stop 1103	10.000	2.840	
Main scanning stop 1104	3.750	—	
Refractive index			
Anamorphic collimator lens 1102 N1		1.5282	
Shape of optical element			
		Main scanning direction	Sub-scanning direction
Curvature radius of incident surface of anamorphic collimator lens 1102	r1a (mm)	∞	∞
Curvature radius of exit surface of anamorphic collimator lens 1102	r1b (mm)	-37.169	-26.170
Phase coefficient of incident surface of anamorphic collimator lens 1102	D2, 0	-7.847E-03	—
	D0, 2	—	-8.669E-03
Focal length			
		Main scanning direction	Sub-scanning direction
Anamorphic collimator lens 1102	fcol (mm)	33.94	27.15
Arrangement			
Light source 1101 -		d0 (mm)	33.59
Incident surface of anamorphic collimator lens 1102			
Incident surface of anamorphic collimator lens 1102 -		d1 (mm)	3.00
Exit surface of anamorphic collimator lens 1102			
Exit surface of anamorphic collimator lens 1102 -		d2 (mm)	15.15
Sub-scanning stop 1103			
Sub-scanning stop 1103 -		d4 (mm)	29.87
Main scanning stop 1104			
Main scanning stop 1104 -		d5 (mm)	80.09
Deflecting surface of deflecting unit 1			
Incident angle in main scanning cross section of light flux exiting from main scanning stop 1104 to deflecting surface		A1 (deg)	78.00
Incident angle in sub-scanning cross section of light flux exiting from main scanning stop 1104 to deflecting surface		A2 (deg)	-3.00

TABLE 2

f θ coefficient, Scanning width, Maximum angle of view				
f θ coefficient	k (mm/rad)	207		
Scanning width	W (mm)	330		
Maximum angle of view	θ (deg)	45.7		
Refractive index				
Refractive index of first f θ lens 1106	N5	1.5281915		
Refractive index of second f θ lens 1107	N6	1.5281915		
Deflecting unit 1				
Number of deflecting surfaces		4		
Circumscribed radius	Rpol (mm)	10		
Rotation center - Deflection reference point C0 (Optical axis direction)	Xpol (mm)	6.03		
Rotation center - Deflection reference point C0 (main scanning direction)	Ypol (mm)	3.79		
Arrangement in scanning optical system 145b				
Deflection reference point C0 -	d12 (mm)	26.00		
Incident surface of first f θ lens 1106				
Incident surface of first f θ lens 1106 -	d13 (mm)	8.20		
Exit surface of first f θ lens 1106				
Exit surface of first f θ lens 1106 -	d14 (mm)	66.60		
Incident surface of second f θ lens 1107				
Incident surface of second f θ lens 1107 -	d15 (mm)	4.30		
Exit surface of second f θ lens 1107				
Exit surface of second f θ lens 1107 -	d16 (mm)	127.90		
Scanned surface 1108				
Deflection reference point C0 -	L1 (mm)	26.00		
Incident surface of first f θ lens 1106				
Deflection reference point C0 -	L2 (mm)	100.80		
Incident surface of second f θ lens 1107				
Deflection reference point C0 -	T2 (mm)	233.00		
Scanned surface 1108				
Sub-scanning eccentricity of second f θ lens 1107	shiftZ (mm)	-6.99		
Meridional line shape of the first f θ lens 1106		Meridional line shape of the first f θ lens 1107		
	Incident surface Opposite light source side	Exit surface Opposite light source side	Incident surface Opposite light source side	Exit surface Opposite light source side
R	-70.147	-42.359	R	-503.226
ku	8.795E-01	-5.295E-01	ku	0
B4u	-2.896E-06	-1.582E-06	B4u	0
B6u	8.878E-09	1.735E-09	B6u	0
B8u	-8.004E-12	1.352E-12	B8u	0
B10u	2.358E-15	-1.720E-15	B10u	0
B12u	0	0	B12u	0
	Light source side	Light source side	Light source side	Light source side
kl	8.795E-01	-5.295E-01	kl	0
B4l	-2.896E-06	1.582E-06	B4l	0
B6l	8.878E-09	1.735E-09	B6l	0
B8l	-8.004E-12	1.352E-12	B8l	0
B10l	2.358E-15	-1.720E-15	B10l	0
B12l	0	0	B12l	0
Sagittal line shape of first f θ lens 1106		Sagittal line shape of second f θ lens 1107		
	Incident surface Sagittal line R change	Exit surface Sagittal line R change	Incident surface Sagittal line R change	Exit surface Sagittal line R change
r	20.000	41.166	r	54.140
E1	0	0	E1	0.000E+00
E2	0	5.090E-05	E2	-1.678E-06
E3	0	0	E3	0
E4	0	-3.069E-08	E4	0.000E+00
E5	0	0	E5	0
E6	0	8.900E-11	E6	0.000E+00

TABLE 2-continued

E7	0	0	E7	0	-2.168E-16
E8	0	-1.563E-13	E8	0.000E+00	-1.099E-18
E9	0	0	E9	0	1.406E-20
E10	0	9.853E-17	E10	0	3.050E-23

	Sagittal line tilt	Sagittal line tilt		Sagittal line tilt	Sagittal line tilt
M0_1	0	-9.182E-02	M0_1	3.060E-02	1.325E-01
M1_1	0	0	M1_1	-1.540E-05	-3.735E-06
M2_1	0	2.102E-05	M2_1	-2.250E-05	-2.951E-05
M3_1	0	0	M3_1	6.934E-08	5.610E-08
M4_1	0	0	M4_1	5.046E-09	7.008E-09
M5_1	0	0	M5_1	-3.700E-11	-2.746E-11
M6_1	0	0	M6_1	-1.752E-13	-8.318E-13
M7_1	0	0	M7_1	7.276E-15	4.760E-15
M8_1	0	0	M8_1	-4.737E-17	6.909E-17
M9_1	0	0	M9_1	-4.124E-19	-2.153E-19
M10_1	0	0	M10_1	1.935E-21	-5.004E-21
M11_1	0	0	M11_1	0	0
M12_1	0	0	M12_1	0	0

[0052] In Tables 1 and 2, the optical axis, an axis orthogonal to the optical axis in the main scanning cross section, and an axis orthogonal to the optical axis in the sub-scanning cross section are defined as an X-axis, a Y-axis, and a Z-axis, respectively, when an intersection between each lens surface and the optical axis is defined as an origin.

[0053] Further, in Table 2, “E-x” means “ $\times 10^{-x}$ ”.

[0054] An aspheric surface shape (meridional line shape) in the main scanning cross section of each lens surface of the first f θ lens 1106 and the second f θ lens 1107 provided in the light scanning apparatus 110 according to the aspect of the embodiment is represented by the following Expression (1):

$$X = \frac{\frac{Y^2}{R}}{1 + \sqrt{1 - (1+k)\left(\frac{Y}{R}\right)^2}} + \sum_{i=4,6,8,10,12} B_i Y^i. \quad (1)$$

[0055] In Expression (1), R represents a curvature radius, k represents an eccentricity, and B_i ($i=4, 6, 8, 10$ and 12) represent aspheric surface coefficients.

[0056] When the coefficient B_i is different between a positive side and a negative side with respect to Y, a subscript u is added to the coefficient on the positive side (namely, B_{iu}), and a subscript 1 is added to the coefficient on the negative side (namely, B_{i1}), as shown in Table 2.

[0057] An aspheric surface shape (sagittal line shape) in the sub-scanning cross section of each lens surface of the first f θ lens 1106 and the second f θ lens 1107 provided in the light scanning apparatus 110 according to the aspect of the embodiment is represented by the following Expression (2):

$$S = \frac{\frac{Z^2}{r'}}{1 + \sqrt{1 - \left(\frac{Z}{r'}\right)^2}} + \sum_{j=0}^{12} \sum_{k=1}^1 M_{jk} Y^j Z^k. \quad (2)$$

[0058] In Expression (2), M_{jk} ($j=0$ to 12 , and $k=1$) represent aspheric surface coefficients.

[0059] Note that a sagittal line tilt (sagittal line tilt amount) in the aspect of the embodiment indicates the M_{01} . Accordingly, a sagittal line tilt surface refers to a surface whose M_{01} is not 0.

[0060] Further, a curvature radius r' in the sub-scanning cross section of each lens surface of the first f θ lens 1106 and the second f θ lens 1107 provided in the light scanning apparatus 110 according to the aspect of the embodiment continuously varies in accordance with a position in the Y direction as represented by the following Expression (3):

$$r' = \frac{1}{\frac{1}{r} + \sum_{i=1}^{10} E_i Y^i}. \quad (3)$$

[0061] In Expression (3), r represents the curvature radius on the optical axis, and E_i ($i=1$ to 10) represent change coefficients.

[0062] Furthermore, the anamorphic collimator lens 1102 provided in the light scanning apparatus 110 according to the aspect of the embodiment has an incident surface formed by a diffracting surface defined by an optical path difference function of two variables Y and Z as represented by the following expression (4):

$$\varphi(Y, Z) = \frac{2\pi}{\lambda} \sum_{i=0, j=0} D_{ij} Y^i Z^j. \quad (4)$$

[0063] In Expression (4), λ represents a pitch of a diffraction grating, and D_{ij} represent phase coefficients.

[0064] Next, effects of the light scanning apparatus 110 according to the aspect of the embodiment are described.

[0065] FIG. 2 shows a diagram for explaining an effect of the light scanning apparatus 110 according to the aspect of the embodiment.

[0066] In FIG. 2, light emitting points 2101a and 2101b that are farthest from a center on opposite sides are shown among the plurality of light emitting points in the light source 1101.

[0067] Further, in FIG. 2, an arrow **2102** schematically illustrating the power of the anamorphic collimator lens **1102**, namely the power of the incident optical system **145a** is shown.

[0068] Furthermore, FIG. 2 shows a position **2103** of the deflecting surface of the deflecting unit **1**, and a combination **2104** of a straight line and a curved line schematically illustrating a shape of the exit surface (first sagittal line tilt surface, first optical surface) of the first f θ lens **1106**, namely the sagittal line tilt coefficient M_{01} and the curvature radius R , respectively.

[0069] FIG. 3A schematically illustrates a state in which the light beams **2105a** and **2105b** emitted from the light emitting points **2101a** and **2101b** of the light source **1101** arrive at the positive side outermost off-axis image height, the on-axis image height, and the negative side outermost off-axis image height on the scanned surface **1108** when $\Delta x/d=0$.

[0070] FIG. 3B schematically illustrates a state in which the light beams **2105a** and **2105b** emitted from the light emitting points **2101a** and **2101b** of the light source **1101** arrive at the positive side outermost off-axis image height, the on-axis image height, and the negative side outermost off-axis image height on the scanned surface **1108** when $\Delta x/d \neq 0$.

[0071] Here, Δx (mm) represents a distance in a direction parallel to the optical axis between the arrival positions of the light beams **2105a** and **2105b** on the exit surface of the first f θ lens **1106**, and d (mm) represents an interval in the sub-scanning direction between the light emitting point **2101a** and the light emitting point **2101b**.

[0072] Further, $d1$, $d2$ and $d3$ represent distances in the main scanning direction between the arrival positions of the light beam **2105a** and **2105b** at the positive side outermost off-axis image height, the on-axis image height, and the negative side outermost off-axis image height on the scanned surface **1108**, respectively, when $\Delta x/d$ is 0.

[0073] Furthermore, $d4$, $d5$, and $d6$ represent distances in the main scanning direction between the arrival positions of the light beam **2105a** and **2105b** at the positive side outermost off-axis image height, the on-axis image height, and the negative side outermost off-axis image height on the scanned surface **1108**, respectively, when $\Delta x/d$ is not 0.

[0074] As shown in FIG. 3A, when $\Delta x/d$ is 0, a relationship of $d1=d2=d3$ is satisfied, namely a width of an image formed by the light beam **2105a** and that of an image formed by the light beam **2105b** on the scanned surface **1108** are equal to each other.

[0075] On the other hand, when $\Delta x/d$ is not 0, a relationship of $d4 \neq d5 \neq d6$ is satisfied, namely a width of an image formed by the light beam **2105a** and that of the image formed by the light beam **2105b** on the scanned surface **1108** are different from each other.

[0076] In particular, when $\Delta x/d$ is larger than 0, a relationship of $d4 > d5 > d6$ is satisfied as shown in FIG. 3B, namely a width of an image formed by the light beam **2105a** is wider than that of the image formed by the light beam **2105b** on the scanned surface **1108**.

[0077] Here, a distance on the optical axis between the light source **1101** and the deflecting surface of the deflecting unit **1** is represented by L (mm), and a distance in the sub-scanning direction between a center of the light source

1101 and the light emitting point **2101a** or the light emitting point **2101b** is represented by d_0 (mm). That is, a relationship of $d_0=d/2$ is satisfied.

[0078] The position of the light source **1101** on the optical axis can be obtained as an intersection between a plane including the plurality of light emitting points provided in the light source **1101** and the optical axis.

[0079] Further, an angle formed by a straight line passing through the light emitting point **2101a** or the light emitting point **2101b**, and the center of the anamorphic collimator lens **1102** with respect to the optical axis in the sub-scanning cross section is represented by θ (degrees).

[0080] A lateral magnification of the anamorphic collimator lens **1102** in the sub-scanning cross section, namely the lateral magnification of the incident optical system **145a** in the sub-scanning cross section is represented by β .

[0081] At this time, a height in the sub-scanning direction of the arrival position of the light beam **2105a** or the light beam **2105b** on the deflecting surface of the deflecting unit **1** is represented by $-\beta \times d_0$, so that the following Expression (5) is obtained:

$$\tan \theta = \frac{(1 - \beta)d_0}{L}. \quad (5)$$

[0082] Next, the curvature radius in the sub-scanning cross section of the exit surface of the first f θ lens **1106** on the optical axis is represented by R (mm), and an eccentricity amount in the sub-scanning direction of the first f θ lens **1106** is represented by L_s (mm).

[0083] At this time, an inclination M at the arrival position of the light beam **2105a** or the light beam **2105b** on the exit surface of the first f θ lens **1106** can be approximately expressed by the following Expression (6) using the aspheric surface coefficient M_{01} shown in the Expression (2) corresponding to the sagittal line tilt amount on the optical axis:

$$M = \frac{L_s}{R} + M_{01}. \quad (6)$$

[0084] The inclination M of the exit surface of the first f θ lens **1106** is defined as an inclination of a normal of the exit surface of the first f θ lens **1106** with respect to the optical axis.

[0085] Further, when a distance in the sub-scanning direction between the arrival positions of the light beam **2105a** and the light beam **2105b** on the exit surface of the first f θ lens **1106** is represented by Δy (mm), the following Expression (7) is obtained:

$$\Delta x = M \times \Delta y. \quad (7)$$

[0086] When a distance on the optical axis between the deflecting surface of the deflecting unit **1** and the exit surface of the first fθ lens **1106** is represented by D (mm), Δy can be expressed by the following Expression (8):

$$\Delta y = 2(-\beta d_0 + D \tan \theta) = 2d_0 \left[-\beta + \frac{(1-\beta)D}{L} \right]. \quad (8)$$

[0087] Note that Expression (5) is used when Expression (8) is derived.

[0088] Accordingly, Δx/d can be expressed by the following Expression (9) using Expressions (7) and (8):

$$\frac{\Delta x}{d} = \frac{M \times \Delta y}{2d_0} = M \left[-\beta + \frac{(1-\beta)D}{L} \right]. \quad (9)$$

[0089] Further, Equation (9) can be rewritten as the following Expression (10) by using Expression (6):

$$\frac{\Delta x}{d} = \left[\frac{L_s}{R} + M_{01} \right] \times \left[-\beta + \frac{(1-\beta)D}{L} \right]. \quad (10)$$

[0090] When a value of Δx/d is small, a difference between an inclination of a light beam incident on the first fθ lens **1106** and an inclination of the light beam exiting from the first fθ lens **1106** becomes small.

[0091] Therefore, a degree of freedom in an arrangement of the second fθ lens **1107** and the photosensitive drum **1108** is reduced, so that it is difficult to sufficiently reduce the size.

[0092] On the other hand, when the value of Δx/d is large, the light beams **2105a** and **2105b** emitted from the light emitting points **2101a** and **2101b** pass through such first fθ lens **1106**, and thus the difference between the widths of the images formed by the light beams **2105a** and **2105b** becomes large as described above with reference to FIG. 3B.

[0093] Accordingly, in the light scanning apparatus **110** according to the aspect of the embodiment, both of down-sizing and high definition be achieved by satisfying the following Inequality (11) for an absolute value of Δx/d.

[0094] In other words, in the light scanning apparatus **110** according to the aspect of the embodiment, the following Inequality (11) be satisfied for all of the light emitting points of the light source **1101**:

$$0.05 < \left| M \left[-\beta + \frac{(1-\beta)D}{L} \right] \right| < 0.70. \quad (11)$$

[0095] In the light scanning apparatus **110** according to the aspect of the embodiment, the following Inequality (11a) be satisfied instead of Inequality (11) for all of the light emitting points of the light sources **1101**:

$$0.10 < \left| M \left[-\beta + \frac{(1-\beta)D}{L} \right] \right| < 0.65. \quad (11a)$$

[0096] Further, in the light scanning apparatus **110** according to the aspect of the embodiment, the following Inequality (11b) be satisfied instead of Inequality (11a) for all the light emitting points of the light sources **1101**:

$$0.15 < \left| M \left[-\beta + \frac{(1-\beta)D}{L} \right] \right| < 0.60. \quad (11b)$$

[0097] Note that the above-described effect can be obtained when Inequalities (11), (11a) and (11b) are satisfied for at least one of the light emitting points of the light sources **1101** although Inequalities (11), (11a) and (11b) are satisfied for all the light emitting points of the light sources **1101**.

[0098] In addition, as an inclination amount of the exit surface of the first fθ lens **1106**, namely the sagittal line tilt coefficient M₀₁ increases, the difference between the widths of the images formed by the light beams **2105a** and **2105b** increases.

[0099] Therefore, in the light scanning apparatus **110** according to the aspect of the embodiment, the following Inequality (12) be satisfied:

$$0 < \left| M_{01} \left[-\beta + \frac{(1-\beta)D}{L} \right] \right| < 0.185. \quad (12)$$

[0100] In addition, when the exit surface of the first fθ lens **1106** has a curvature, the inclination amounts at the arrival positions on the exit surface of the light beams emitted from the respective light emitting points of the light source **1101** is different from each other.

[0101] Therefore, in the light scanning apparatus **110** according to the aspect of the embodiment, the following Inequality (13) be satisfied:

$$0.05 < \left| \left[\frac{L_s}{R} + M_{01} \right] \times \left[-\beta + \frac{(1-\beta)D}{L} \right] \right| < 0.70. \quad (13)$$

[0102] Specifically, β is −3.65, D is 34.2 mm, L is 161.7 mm, and M is −0.127 in the light scanning apparatus **110** according to the aspect of the embodiment.

[0103] Accordingly, the value of each of Inequalities (11), (11a) and (11b) is calculated as 0.589, so that Inequalities (11), (11a) and (11b) are satisfied.

[0104] On the other hand, in the light scanning apparatus **110** according to the aspect of the embodiment, since M₀₁ is −0.0918, the value of Inequality (12) is calculated as 0.426, so that Inequality (12) is not satisfied.

[0105] Further, in the light scanning apparatus **110** according to the aspect of the embodiment, since L_s is −1.45 mm and R is 41.166 mm, the value of Inequality (13) is calculated as 0.589, so that Inequality (13) is satisfied.

[0106] The sagittal line tilt amount of the exit surface of the first fθ lens **1106** provided in the light scanning apparatus **110** according to the aspect of the embodiment varies according to the position in the main scanning direction.

[0107] Then, an absolute value of the sagittal line tilt amount of the exit surface of the first fθ lens **1106** is the largest on the optical axis.

[0108] Further, the first fθ lens **1106** has a positive power in the sub-scanning cross section.

[0109] Further, the first f θ lens **1106** closest to the deflecting unit **1** on the optical path of the light flux LG among the f θ lenses included in the scanning optical system **145b**, is an f θ lens having the strongest power in the main scanning cross section among the f θ lenses included in the scanning optical system **145b**.

[0110] FIG. 4 shows distances in the main scanning direction between the arrival positions of the light beams **2105a** and **2105b** at respective image heights on the scanned surface **1108** in the light scanning apparatus **110** according to the aspect of the embodiment.

[0111] That is, the distances include d4, d5 and d6 shown in FIG. 3B, and the distance at the on-axis image height is shown as 0 mm in FIG. 4.

[0112] As shown in FIG. 4, in the light scanning apparatus **110** according to the aspect of the embodiment, a difference between a maximum value and a minimum value of the distances is 8.0 μm .

[0113] Since the difference corresponds to a deviation of about 9.4% with respect to 300 dpi, namely a pitch of 84.7 μm , an influence of the deviation of the arrival position of each light beam on the scanned surface **1108** on the image quality can be reduced.

[0114] As described above, in the light scanning apparatus **110** according to the aspect of the embodiment, it is possible

to suppress a deterioration of the image quality due to the deviation of the arrival position of each light beam on the scanned surface **1108** by satisfying Inequality (11).

[0115] In addition, in the light scanning apparatus **110** according to the aspect of the embodiment, it is possible to achieve downsizing by forming the exit surface of the first f θ lens **1106** as a sagittal line tilt surface.

Second Embodiment

[0116] FIGS. 5A and 5B show a schematic main scanning cross sectional view and a schematic partial sub-scanning cross sectional view of a light scanning apparatus **310** according to a second embodiment of the disclosure, respectively.

[0117] The light scanning apparatus **310** according to the aspect of the embodiment has the same configuration as the light scanning apparatus **110** according to the first embodiment except that the specification values are different, so that the same members are denoted by the same reference numerals, and description thereof is omitted.

[0118] Specifically, various characteristics of the incident optical system **145a** and the scanning optical system **145b** provided in the light scanning apparatus **310** according to the aspect of the embodiment are shown in the following Tables 3 and 4, respectively.

TABLE 3

Characteristics of light source 1101			
Wavelength	$\lambda(\text{nm})$	790	
Incident polarization to deflecting surface of deflecting unit 1		p polarization	
Full angle at half maximum in main scanning direction	FFPy(deg)	12.00	
Full angle at half maximum in sub-scanning direction	FFPz(deg)	30.00	
Shape of stop			
	Main scanning direction	Sub-scanning direction	
Sub-scanning stop 1103	10.000	2.840	
Main scanning stop 1104	3.750	—	
Refractive index			
Anamorphic collimator lens 1102	N1	1.5282	
Shape of optical element			
		Main scanning direction	Sub-scanning direction
Curvature radius of incident surface of anamorphic collimator lens 1102	r1a (mm)	∞	∞
Curvature radius of exit surface of anamorphic collimator lens 1102	r1b (mm)	-37.169	-26.170
Phase coefficient of incident surface of anamorphic collimator lens 1102	D2, 0	-7.847E-03	—
	D0, 2	—	-8.669E-03

TABLE 3-continued

Focal length			
		Main scanning direction	Sub-scanning direction
Anamorphic collimator lens 1102	fcol (mm)	33.94	27.15
Arrangement			
Light source 1101 -		d0	33.59
Incident surface of anamorphic collimator lens 1102		(mm)	
Incident surface of anamorphic collimator lens 1102 -		d1	3.00
Exit surface of anamorphic collimator lens 1102		(mm)	
Exit surface of anamorphic collimator lens 1102 -		d2	15.15
Sub-scanning stop 1103		(mm)	
Sub-scanning stop 1103 -		d4	29.87
Main scanning stop 1104		(mm)	
Main scanning stop 1104 -		d5	80.09
Deflecting surface of deflecting unit 1		(mm)	
Incident angle in main scanning cross section of light flux exiting from main scanning stop 1104 to deflecting surface		A1 (deg)	78.00
Incident angle in sub-scanning cross section of light flux exiting from main scanning stop 1104 to deflecting surface		A2 (deg)	-3.00

TABLE 4

f θ coefficient, Scanning width, Maximum angle of view			
f θ coefficient	k (mm/rad)		207
Scanning width	W (mm)		330
Maximum angle of view	θ (deg)		45.7
Refractive index			
Refractive index of first f θ lens 1106	N5		1.5281915
Refractive index of second f θ lens 1107	N6		1.5281915
Deflecting unit 1			
Number of deflecting surfaces			4
Circumscribed radius	Rpol (mm)		10
Rotation center - Deflection reference point C0 (Optical axis direction)	Xpol (mm)		6.03
Rotation center - Deflection reference point C0 (main scanning direction)	Ypol (mm)		3.79
Arrangement in scanning optical system 145b			
Deflection reference point C0 -	d12 (mm)		26.00
Incident surface of first f θ lens 1106			
Incident surface of first f θ lens 1106 -	d13 (mm)		8.20
Exit surface of first f θ lens 1106			
Exit surface of first f θ lens 1106 -	d14 (mm)		66.60
Incident surface of second f θ lens 1107			
Incident surface of second f θ lens 1107 -	d15 (mm)		4.30
Exit surface of second f θ lens 1107			
Exit surface of second f θ lens 1107 -	d16 (mm)		127.90
Scanned surface 1108			
Deflection reference point C0 -	L1 (mm)		26.00
Incident surface of first f θ lens 1106			
Deflection reference point C0 -	L2 (mm)		100.80
Incident surface of second f θ lens 1107			

TABLE 4-continued

Deflection reference point C0 - Scanned surface 1108			T2 (mm)		233.00
Sub-scanning eccentricity of second fθ lens 1107			shiftZ (mm)		-1.37
Meridional line shape of first fθ lens 1106			Meridional line shape of first fθ lens 1107		
	Incident surface Opposite light source side	Exit surface Opposite light source side		Incident surface Opposite light source side	Exit surface Opposite light source side
R	-66.242	-40.841	R	-494.7832	802.295
ku	8.020E-01	-5.277E-01	ku	0	-6.789E+02
B4u	-2.796E-06	-1.602E-06	B4u	0	-2.895E-07
B6u	8.876E-09	1.735E-09	B6u	0	2.255E-11
B8u	-7.979E-12	1.355E-12	B8u	0	-1.522E-15
B10u	2.370E-15	-1.715E-15	B10u	0	4.450E-20
B12u	0	0	B12u	0	0.000E+00
	Light source side	Light source side		Light source side	Light source side
k1	8.020E-01	-5.277E-01	k1	0	-6.789E+02
B41	-2.796E-06	-1.602E-06	B41	0	-2.895E-07
B61	8.876E-09	1.735E-09	B61	0	2.255E-11
B81	-7.979E-12	1.355E-12	B81	0	-1.522E-15
B101	2.370E-15	-1.715E-15	B101	0	4.450E-20
B121	0	0	B121	0	0.000E+00
Sagittal line shape of first fθ lens 1106			Sagittal line shape of first fθ lens 1107		
	Incident surface Sagittal line R change	Exit surface Sagittal line R change		Incident surface Sagittal line R change	Exit surface Sagittal line R change
r	50.000	76.858	r	46.640	-79.14512
E1	0	0	E1	0.000E+00	-1.460E-06
E2	0	2.018E-05	E2	-1.990E-06	3.054E-07
E3	0	0	E3	0	-1.037E-09
E4	0	-1.126E-08	E4	0.000E+00	-2.859E-10
E5	0	0	E5	0	7.163E-13
E6	0	6.930E-11	E6	0.000E+00	1.866E-14
E7	0	0	E7	0	-1.675E-16
E8	0	-2.386E-14	E8	0.000E+00	-1.281E-19
E9	0	0	E9	0	1.2395E-20
E10	0	-7.962E-17	E10	0	-4.877E-23
	Sagittal line tilt	Sagittal line tilt		Sagittal line tilt	Sagittal line tilt
M0_1	0	-3.850E-02	M0_1	8.966E-02	7.878E-02
M1_1	0	0	M1_1	-3.516E-06	-2.624E-06
M2_1	0	-4.057E-05	M2_1	-2.739E-05	-2.545E-05
M3_1	0	0	M3_1	6.075E-08	5.025E-08
M4_1	0	0	M4_1	5.534E-09	6.347E-09
M5_1	0	0	M5_1	-3.749E-11	-2.803E-11
M6_1	0	0	M6_1	-2.101E-13	-8.019E-13
M7_1	0	0	M7_1	7.252E-15	4.725E-15
M8_1	0	0	M8_1	-5.256E-17	7.298E-17
M9_1	0	0	M9_1	-4.108E-19	-2.157E-19
M10_1	0	0	M10_1	2.174E-21	-5.879E-21
M11_1	0	0	M11_1	0	0
M12_1	0	0	M12_1	0	0

[0119] In Tables 3 and 4, an optical axis, an axis orthogonal to the optical axis in the main scanning cross section, and an axis orthogonal to the optical axis in the sub-scanning cross section are defined as an X-axis, a Y-axis, and a Z-axis, respectively, when an intersection between each lens surface and the optical axis is defined as an origin.

[0120] Further, in Table 4, “E-x” means “ $\times 10^{-x}$ ”.

[0121] An aspheric surface shape (meridional line shape) in the main scanning cross section of each lens surface of the first f θ lens 1106 and the second f θ lens 1107 provided in the light scanning apparatus 310 according to the aspect of the embodiment is represented by the above-described Expression (1).

[0122] An aspheric surface shape (sagittal line shape) in the sub-scanning cross section of each lens surface of the first f θ lens 1106 and the second f θ lens 1107 provided in the light scanning apparatus 310 according to the aspect of the embodiment is represented by the above-described Expression (2).

[0123] A curvature radius r' in the sub-scanning cross section of each lens surface of the first f θ lens 1106 and the second f θ lens 1107 provided in the light scanning apparatus 310 according to the aspect of the embodiment continuously varies in accordance with a position in the Y direction as represented by the above-described Expression (3).

[0124] The anamorphic collimator lens 1102 provided in the light scanning apparatus 310 according to the aspect of the embodiment has an incident surface formed by a diffracting surface defined by the optical path difference function of two variables Y and Z as represented by the above-described Expression (4).

[0125] Further, in the light scanning apparatus 310 according to the aspect of the embodiment, Inequality (11) be satisfied, Inequality (11a) be satisfied, and Inequality (11b) be satisfied.

[0126] In the light scanning apparatus 310 according to the aspect of the embodiment, Inequalities (12) and (13) be satisfied.

[0127] Specifically, in the light scanning apparatus 310 according to the aspect of the embodiment, β is -3.65 , D is 34.2 mm, Lis 161.7 mm, and M is -0.0385 .

[0128] Therefore, a value of each of Inequalities (11), (11a) and (11b) is calculated as 0.179, so that Inequalities (11), (11a) and (11b) are satisfied.

[0129] Further, in the light scanning apparatus 310 according to the aspect of the embodiment, since M_{01} is -0.0385 , a value of Inequality (12) is calculated as 0.179, so that Inequality (12) is satisfied.

[0130] Furthermore, in the light scanning apparatus 310 according to the aspect of the embodiment, since L_s is 0 mm and R is 76.858 mm, a value of Inequality (13) is calculated as 0.179, so that Inequality (13) is satisfied.

[0131] FIG. 6 shows distances in the main scanning direction between arrival positions of light beams 2105a and 2105b at respective image heights on the scanned surface 1108 in the light scanning apparatus 310 according to the aspect of the embodiment.

[0132] That is, the distances include d4, d5, and d6 shown in FIG. 3B, and the distance at the on-axis image height is shown as 0 mm in FIG. 6.

[0133] As shown in FIG. 6, in the light scanning apparatus 310 according to the aspect of the embodiment, a difference between a maximum value and a minimum value of the distances is 5.9 μ m.

[0134] Since the difference corresponds to a deviation of about 7.0% with respect to 300 dpi, namely a pitch of 84.7 μ m, an influence of the deviation of the arrival position of each light beam on the scanned surface 1108 on the image quality can be reduced. As described above, in the light scanning apparatus 310 according to the aspect of the embodiment, it is possible to suppress a deterioration of the image quality due to the deviation of the arrival position of each light beam on the scanned surface 1108 by satisfying Inequality (11).

Third Embodiment

[0135] FIGS. 7A and 7B show a schematic main scanning cross sectional view and a schematic partial sub-scanning cross sectional view of a light scanning apparatus 510 according to a third embodiment of the disclosure, respectively.

[0136] The light scanning apparatus 510 according to the aspect of the embodiment has the same configuration as the light scanning apparatus 110 according to the first embodiment except that the specification values are different, so that the same members are denoted by the same reference numerals, and description thereof is omitted.

[0137] Specifically, various characteristics of the incident optical system 145a and the scanning optical system 145b provided in the light scanning apparatus 510 according to the aspect of the embodiment are shown in the following Tables 5 and 6, respectively.

TABLE 5

Characteristics of light source 1101			
Wavelength	$\lambda(\text{nm})$		790
Incident polarization to deflecting surface of deflecting unit 1			p polarization
Full angle at half maximum in main scanning direction	FFPy(deg)	12.00	
Full angle at half maximum in sub-scanning direction	FFPz(deg)	30.00	
Shape of stop			
	Main scanning direction	Sub-scanning direction	
Sub-scanning stop 1103	10.000	2.840	
Main scanning stop 1104	3.750	—	
Refractive index			
Anamorphic collimator lens 1102	N1	1.5282	
Shape of optical element			
		Main scanning direction	Sub-scanning direction
Curvature radius of incident surface of anamorphic collimator lens 1102	r1a (mm)	∞	∞
Curvature radius of exit surface of anamorphic collimator lens 1102	r1b (mm)	-37.169	-26.170
Phase coefficient of incident surface of anamorphic collimator lens 1102	D2, 0	-7.847E-03	—
	D0, 2	—	-8.669E-03
Focal length			
		Main scanning direction	Sub-scanning direction
Anamorphic collimator lens 1102	fcol (mm)	33.94	27.15
Arrangement			
Light source 1101 - Incident surface of anamorphic collimator lens 1102	d0 (mm)	33.59	
Incident surface of anamorphic collimator lens 1102 - Exit surface of anamorphic collimator lens 1102	d1 (mm)	3.00	
Exit surface of anamorphic collimator lens 1102 - Sub-scanning stop 1103	d2 (mm)	15.15	
Sub-scanning stop 1103 - Main scanning stop 1104	d4 (mm)	29.87	
Main scanning stop 1104 - Deflecting surface of deflecting unit 1	d5 (mm)	80.09	
Incident angle in main scanning cross section of light flux exiting from main scanning stop 1104 to deflecting surface	A1 (deg)	78.00	
Incident angle in sub-scanning cross section of light flux exiting from main scanning stop 1104 to deflecting surface	A2 (deg)	-3.00	

TABLE 6

fθ coefficient, Scanning width, Maximum angle of view					
fθ coefficient	k (mm/rad)	207			
Scanning width	W (mm)	330			
Maximum angle of view	θ(deg)	45.7			
Refractive index					
Refractive index of first fθ lens 1106	N5	1.5281915			
Refractive index of second fθ lens 1107	N6	1.5281915			
Deflecting unit 1					
Number of deflecting surfaces		4			
Circumscribed radius	Rpol (mm)	10			
Rotation center - Deflection reference point C0 (Optical axis direction)	Xpol (mm)	6.03			
Rotation center - Deflection reference point C0 (main scanning direction)	Ypol (mm)	3.79			
Arrangement in scanning optical system 145b					
Deflection reference point C0 - Incident surface of first fθ lens 1106	d12 (mm)	26.00			
Exit surface of first fθ lens 1106 - Incident surface of second fθ lens 1107	d13 (mm)	8.20			
Exit surface of first fθ lens 1106 - Incident surface of second fθ lens 1107	d14 (mm)	69.30			
Exit surface of second fθ lens 1107 - Incident surface of second fθ lens 1107	d15 (mm)	4.30			
Exit surface of second fθ lens 1107 - Scanned surface 1108	d16 (mm)	125.20			
Deflection reference point C0 - Incident surface of first fθ lens 1106	L1 (mm)	26.00			
Deflection reference point C0 - Incident surface of second fθ lens 1107	L2 (mm)	103.50			
Deflection reference point C0 - Scanned surface 1108	T2 (mm)	233.00			
Sub-scanning eccentricity of second fθ lens 1107	shiftZ (mm)	-5.03			
Meridional line shape of first fθ lens 1106		Meridional line shape of first fθ lens 1107			
Incident surface	Exit surface	Incident surface	Exit surface		
Opposite light source side	Opposite light source side	Opposite light source side	Opposite light source side		
R	-71.101	-42.946	R	-4000	350.123
ku	9.464E-01	-5.155E-01	ku	0	-8.753E+01
B4u	-9.147E-07	-3.477E-07	B4u	0	-2.020E-07
B6u	6.784E-09	1.690E-09	B6u	0	1.609E-11
B8u	-5.767E-12	1.110E-12	B8u	0	-9.313E-16
B10u	1.638E-15	-1.224E-15	B10u	0	2.524E-20
B12u	0	0	B12u	0	0.000E+00
Light source side	Light source side	Light source side	Light source side		
k1	9.464E-01	-5.155E-01	k1	0	-8.753E+01
B41	-9.147E-07	-3.477E-07	B41	0	-2.020E-07
B61	6.784E-09	1.690E-09	B61	0	1.609E-11

TABLE 6-continued

B81	-5.767E-12	1.110E-12	B81	0	-9.313E-16
B101	1.638E-15	-1.224E-15	B101	0	2.524E-20
B121	0	0	B121	0	0.000E+00
Sagittal line shape of first fθ lens 1106			Sagittal line shape of second fθ lens 1107		
Incident surface Sagittal line R change		Exit surface Sagittal line R change	Incident surface Sagittal line R change		Exit surface Sagittal line R change
r	20.000	25.004	r	37.079	-154.0078
E1	0	0	E1	0.000E+00	-1.278E-07
E2	0	1.522E-05	E2	-7.458E-07	1.813E-06
E3	0	0	E3	0	-3.240E-09
E4	0	8.486E-10	E4	0.000E+00	-3.041E-10
E5	0	0	E5	0	1.339E-12
E6	0	-2.508E-11	E6	0.000E+00	3.082E-14
E7	0	0	E7	0	-2.009E-16
E8	0	7.607E-15	E8	0.000E+00	-1.954E-18
E9	0	0	E9	0	9.85865E-21
E10	0	1.610E-17	E10	0	5.812E-23
Sagittal line tilt		Sagittal line tilt	Sagittal line tilt		Sagittal line tilt
M0_1	0	-2.124E-02	M0_1	-1.007E-01	2.315E-02
M1_1	0	0	M1_1	-2.129E-04	-2.002E-04
M2_1	0	3.321E-05	M2_1	-1.314E-05	-2.370E-05
M3_1	0	0	M3_1	1.161E-07	1.056E-07
M4_1	0	0	M4_1	1.765E-09	3.675E-09
M5_1	0	0	M5_1	-1.616E-11	-1.409E-11
M6_1	0	0	M6_1	3.014E-13	-3.052E-13
M7_1	0	0	M7_1	1.061E-15	9.733E-16
M8_1	0	0	M8_1	-1.306E-17	6.574E-17
M9_1	0	0	M9_1	-1.657E-20	-1.728E-20
M10_1	0	0	M10_1	-8.536E-22	-3.960E-21
M11_1	0	0	M11_1	0	0
M12_1	0	0	M12_1	0	0

[0138] In Tables 5 and 6, an optical axis, an axis orthogonal to the optical axis in the main scanning cross section, and an axis orthogonal to the optical axis in the sub-scanning cross section are defined as an X-axis, a Y-axis, and a Z-axis, respectively, when an intersection between each lens surface and the optical axis is defined as an origin.

[0139] Further, in Table 6, “E-x” means “ $\times 10^{-x}$ ”.

[0140] An aspheric surface shape (meridional line shape) in the main scanning cross section of each lens surface of the first fθ lens 1106 and the second fθ lens 1107 provided in the light scanning apparatus 510 according to the aspect of the embodiment is represented by the above-described Expression (1).

[0141] An aspheric surface shape (sagittal line shape) in the sub-scanning cross section of each lens surface of the first fθ lens 1106 and the second fθ lens 1107 provided in the light scanning apparatus 510 according to the aspect of the embodiment is represented by the above-described Expression (2).

[0142] A curvature radius r' in the sub-scanning cross section of each lens surface of the first fθ lens 1106 and the second fθ lens 1107 provided in the light scanning apparatus 510 according to the aspect of the embodiment continuously varies in accordance with a position in the Y direction as represented by the above-described Expression (3).

[0143] The anamorphic collimator lens 1102 provided in the light scanning apparatus 510 according to the aspect of the embodiment has an incident surface formed by a dif-

fracting surface defined by the optical path difference function of two variables Y and Z as represented by the above-described Expression (4).

[0144] Further, in the light scanning apparatus 510 according to the aspect of the embodiment, Inequality (11) be satisfied, Inequality (11a) be satisfied, and Inequality (11b) be satisfied.

[0145] In the light scanning apparatus 510 according to the aspect of the embodiment, Inequalities (12) and (13) be satisfied.

[0146] Specifically, in the light scanning apparatus 510 according to the aspect of the embodiment, β is -3.65, D is 34.2 mm, Lis 161.7 mm, and M is -0.0735.

[0147] Therefore, a value of each of Inequalities (11), (11a) and (11b) is calculated as 0.341, and Inequalities (11), (11a) and (11b) are satisfied.

[0148] Further, in the light scanning apparatus 510 according to the aspect of the embodiment, since M_{01} is -0.0212, a value of Inequality (12) is calculated as 0.098, so that Inequality (12) is satisfied.

[0149] Furthermore, in the light scanning apparatus 510 according to the aspect of the embodiment, since L_s is -1.31 mm and R is 25.004 mm, a value of Inequality (13) is calculated as 0.341, so that Inequality (13) is satisfied.

[0150] FIG. 8 shows distances in the main scanning direction between arrival positions of light beams 2105a and

2105b at respective image heights on the scanned surface **1108** in the light scanning apparatus **510** according to the aspect of the embodiment.

[0151] That is, the distances include d4, d5 and d6 shown in FIG. 3B, and the distance at the on-axis image height is shown as 0 mm in FIG. 8.

[0152] As shown in FIG. 8, in the light scanning apparatus **510** according to the aspect of the embodiment, a difference between a maximum value and a minimum value of the distances is 2.0 μm .

[0153] Then, the difference corresponds to a deviation of about 9.2% with respect to the 1200 dpi, namely a pitch of 21.2 μm , and a deviation of about 2.3% with respect to 300 dpi, namely a pitch of 84.7 μm .

[0154] Therefore, an influence of the deviation of the arrival position of each light beam on the scanned surface **1108** on the image quality can be reduced.

[0155] As described above, in the light scanning apparatus **510** according to the aspect of the embodiment, it is possible to suppress a deterioration of the image quality due to the deviation of the arrival position of each light beam on the scanned surface **1108** by satisfying Inequality (11).

Fourth Embodiment

[0156] Each of FIGS. 9A and 9B shows a schematic partially developed view in the main scanning cross section of a light scanning apparatus **710** according to a fourth embodiment of the disclosure.

[0157] FIGS. 10 and 11 show a schematic partial developed view in the sub-scanning cross section and a schematic partial sub-scanning cross sectional view of the light scanning apparatus **710** according to the fourth embodiment, respectively.

[0158] The light scanning apparatus **710** according to the aspect of the embodiment includes first and second light sources **101** and **201**, first and second anamorphic collimator lenses **102** and **202**, and first and second sub-scanning stops **103** and **203**.

[0159] Further, the light scanning apparatus **710** according to the aspect of the embodiment includes first and second main scanning stops **104** and **204**, a deflecting unit **1**, first f θ lenses **106** and **206**, and second f θ lenses **107** and **207**.

[0160] On optical paths, the first f θ lens **106** is arranged between the deflecting unit **1** and the second f θ lens **107**, and the first f θ lens **206** is arranged between the deflecting unit **1** and the second f θ lens **207**.

[0161] As each of the first and second light sources **101** and **201**, a semiconductor laser (multibeam laser) or the like having a plurality of light emitting points is used.

[0162] The first and second anamorphic collimator lenses **102** and **202** convert light fluxes LA and LB emitted from the first and second light sources **101** and **201** into parallel light fluxes in the main scanning cross section, respectively, and condense the light fluxes LA and LB in the sub-scanning cross section, respectively. The parallel light flux includes not only a strictly parallel light flux but also a substantially parallel light flux such as a weakly divergent light flux or a weakly convergent light flux.

[0163] The first and second sub-scanning stops **103** and **203** limit light flux diameters in the sub-scanning direction of the light fluxes LA and LB that have passed through the first and second anamorphic collimator lenses **102** and **202**, respectively.

[0164] The first and second main scanning stops **104** and **204** limit light flux diameters in the main scanning direction of the light fluxes LA and LB that have passed through the first and second sub-scanning stops **103** and **203**, respectively.

[0165] In this way, the light fluxes LA and LB emitted from the first and second light sources **101** and **201** are condensed in the sub-scanning direction in the vicinity of a first deflecting surface of the deflecting unit **1**, thereby line images elongated in the main scanning direction are formed.

[0166] The deflecting unit **1** deflects the incident light fluxes LA and LB with rotating by a driving unit such as a motor (not shown) in a direction indicated by an arrow A in FIGS. 9A and 9B. The deflecting unit **1** is formed by a polygon mirror, for example.

[0167] The first f θ lens **106** (first optical element, first imaging optical element) and the second f θ lens **107** are anamorphic imaging lenses having different powers between the main scanning cross section and the sub-scanning cross section, and condense (guide) the light flux LA deflected by the first deflecting surface of the deflecting unit **1** onto the first scanned surface **108**.

[0168] The first f θ lens **206** (second optical element, second imaging optical element) and the second f θ lens **207** are anamorphic imaging lenses having different powers between the main scanning cross section and the sub-scanning cross section, and condense (guide) the light flux LB deflected by the first deflecting surface of the deflecting unit **1** onto the second scanned surface **208**.

[0169] In the light scanning apparatus **710** according to the aspect of the embodiment, a first incident optical system **45a** is formed by the first anamorphic collimator lens **102**, the first sub-scanning stop **103** and the first main scanning stop **104**.

[0170] A second incident optical system **55a** is formed by the second anamorphic collimator lens **202**, the second sub-scanning stop **203** and the second main scanning stop **204**.

[0171] Further, in the light scanning apparatus **710** according to the aspect of the embodiment, a first scanning optical system **45b** is formed by the first f θ lens **106** and the second f θ lens **107**.

[0172] A second scanning optical system **55b** is formed by the first f θ lens **206** and the second f θ lens **207**.

[0173] Note that the refractive powers in the sub-scanning cross section of the second f θ lenses **107** and **207** are stronger than the refractive powers in the sub-scanning cross section of the first f θ lenses **106** and **206**, namely the strongest among the first and second scanning optical systems **45b** and **55b**, respectively.

[0174] The light fluxes LA emitted from the respective light emitting points of the first light source **101** pass through the first incident optical system **45a** to be incident on the first deflecting surface of the deflecting unit **1**.

[0175] Then, the light fluxes LA incident on the first deflecting surface of the deflecting unit **1** from the first light source **101** are deflected by the first deflecting surface of the deflecting unit **1** to be guided onto the first scanned surface **108** by the first scanning optical system **45b**, thereby the first scanned surface **108** is scanned at a constant speed.

[0176] The light fluxes LB emitted from the respective light emitting points of the second light source **201** pass through the second incident optical system **55a** to be incident on the first deflecting surface of the deflecting unit **1**.

[0177] Then, the light fluxes LB incident on the first deflecting surface of the deflecting unit 1 from the second light source 201 are deflected by the first deflecting surface of the deflecting unit 1 to be guided onto the second scanned surface 208 by the second scanning optical system 55b, thereby the second scanned surface 208 is scanned at a constant speed.

[0178] Since the deflecting unit 1 rotates in the direction indicated by the arrow A in FIGS. 9A and 9B, the light fluxes LA and LB deflected by the deflecting unit 1 scan the first and second scanned surfaces 108 and 208 in a direction indicated by an arrow B in FIGS. 9A and 9B, respectively.

[0179] In FIG. 9A and FIG. 9B, CO represents a deflection point (on-axis deflection point) on the first deflecting surface of the deflecting unit 1 with respect to a principal ray of an on-axis light flux. The deflection point CO serves as a reference point for the first and second scanning optical systems 45b and 55b.

[0180] In the aspect of the embodiment, first and second photosensitive drums 108 and 208 are used as the first and second scanned surfaces 108 and 208.

[0181] Exposure distributions in the sub-scanning direction on the first and second photosensitive drums 108 and 208 are formed by rotating the first and second photosensitive drums 108 and 208 in the sub-scanning direction for each main scanning exposure.

[0182] Next, various characteristics of the first and second incident optical systems 45a and 55a and the first and second scanning optical systems 45b and 55b provided in the light scanning apparatus 710 according to the aspect of the embodiment are shown in the following Tables 7 to 9.

TABLE 7

Characteristics of first and second light sources 101 and 102		
Wavelength	λ (nm)	790
Incident polarization to first deflecting surface of deflecting unit 1		p polarization
Full angle at half maximum in main scanning direction	FFPy(deg)	12.00
Full angle at half maximum in sub-scanning direction	FFPz(deg)	30.00
Shape of stop		
	Main scanning direction	Sub-scanning direction
First and second sub-scanning stops 103 and 203	10.000	2.840

TABLE 7-continued

First and second main scanning stops 104 and 204		3.750	—
Refractive index			
First and second anamorphic collimator lenses 102 and 202		N1	1.5282
Shape of optical element			
		Main scanning direction	Sub- scanning direction
Curvature radius of incident surface of first and second anamorphic collimator lenses 102 and 202	r1a (mm)	∞	∞
Curvature radius of exit surface of first and second anamorphic collimator lenses 102 and 202	r1b (mm)	−37.169	−26.170
Phase coefficient of incident surface of first and second anamorphic collimator lenses 102 and 202	D2, 0 D0, 2	−7.847E−03 —	— −8.669E−03
Focal length			
		Main scanning direction	Sub- scanning direction
First and second anamorphic collimator lenses 102 and 202	fcol (mm)	33.94	27.15
Arrangement			
First and second light sources 101 and 201 - Incident surface of first and second anamorphic collimator lenses 102 and 202		d0 (mm)	33.59
Incident surface of first and second anamorphic collimator lenses 102 and 202 - Exit surface of first and second anamorphic collimator lenses 102 and 202		d1 (mm)	3.00
Exit surface of first and second anamorphic collimator lenses 102 and 202 - First and second sub-scanning stops 103 and 203		d2 (mm)	15.15
First and second sub-scanning stops 103 and 203 - First and second main scanning stops 104 and 204		d4 (mm)	29.87
First and second main scanning stops 104 and 204 - First deflecting surface of deflecting unit 1		d5 (mm)	80.09
Incident angle in main scanning cross section of light flux LA exiting from first main scanning stop 104 to first deflecting surface		A1 (deg)	78.00
Incident angle in main scanning cross section of light flux LB exiting from second main scanning stop 204 to first deflecting surface		A2 (deg)	78.00
Incident angle in sub-scanning cross section of light flux LA exiting from first main scanning stop 104 to first deflecting surface		A3 (deg)	2.70
Incident angle in sub-scanning cross section of light flux LB exiting from second main scanning stop 204 to first deflecting surface		A4 (deg)	−2.70

TABLE 8

f θ coefficient, Scanning width, Maximum angle of view				
f θ coefficient	k (mm/rad)		207	
Scanning width	W (mm)		330	
Maximum angle of view	θ (deg)		45.7	
Refractive index				
Refractive index of first f θ lens 106	N5		1.52819	
Refractive index of second f θ lens 107	N6		1.52819	
Deflecting unit 1				
Number of deflecting surfaces			4	
Circumscribed radius	Rpol (mm)		10	
Rotation center - Deflection reference point C0 (Optical axis direction)	Xpol (mm)		6.03	
Rotation center - Deflection reference point C0 (main scanning direction)	Ypol (mm)		3.79	
Arrangement in first scanning optical system 45b				
Deflection reference point C0 - Incident surface of first f θ lens 106	d12 (mm)		26.00	
Exit surface of first f θ lens 106 - Incident surface of second f θ lens 107	d13 (mm)		8.20	
Exit surface of first f θ lens 106 - Incident surface of second f θ lens 107	d14 (mm)		87.80	
Exit surface of second f θ lens 107 - Incident surface of second f θ lens 107	d15 (mm)		4.30	
Exit surface of second f θ lens 107 - First scanned surface 108	d16 (mm)		106.70	
Deflection reference point C0 - Incident surface of first f θ lens 106	L1(mm)		26.00	
Deflection reference point C0 - Incident surface of second f θ lens 107	L2(mm)		122.00	
Deflection reference point C0 - First scanned surface 108	T2(mm)		233.00	
Sub-scanning eccentricity of second f θ lens 107	shiftZ(mm)		7.21	
Meridional line shape of first f θ lens 106				
	Incident surface	Exit surface		
	Opposite light source side	Opposite light source side		
R	-71.101	-43.800	R	
ku	9.464E-01	-9.321E-01	ku	
B4u	-9.147E-07	1.355E-06	B4u	
B6u	6.784E-09	1.719E-09	B6u	
B8u	-5.767E-12	8.761E-13	B8u	
B10u	1.638E-15	-1.069E-15	B10u	
B12u	0	0	B12u	
Meridional line shape of first f θ lens 107				
	Incident surface	Exit surface		
	Opposite light source side	Opposite light source side		
R	-4000	379.967	R	
ku	0	-7.412E+01	ku	
B4u	0	-1.332E-07	B4u	
B6u	0	7.206E-12	B6u	
B8u	0	-3.070E-16	B8u	
B10u	0	6.089E-21	B10u	
B12u	0	0.000E+00	B12u	
Light source side				
	Light source side	Light source side		
k1	9.464E-01	-9.321E-01	k1	
B41	-9.147E-07	-1.355E-06	B41	
B61	6.784E-09	1.719E-09	B61	

TABLE 8-continued

B81	-5.767E-12	8.761E-13	B81	0	-3.070E-16
B101	1.638E-15	-1.069E-15	B101	0	6.089E-21
B121	0	0	B121	0	0.000E+00
Sagittal line shape of first f θ lens 106			Sagittal line shape of second f θ lens 107		
Incident surface Sagittal line R change	Exit surface Sagittal line R change		Incident surface Sagittal line R change	Exit surface Sagittal line R change	
r	20.000	55.261	r	37.426	-249.9931
E1	0	0	E1	0.000E+00	9.40981E-09
E2	0	6.894E-06	E2	-3.482E-07	1.44641E-06
E3	0	0	E3	0	-1.61579E-09
E4	0	8.425E-08	E4	0.000E+00	-2.7926E-10
E5	0	0	E5	0	4.72069E-13
E6	0	-2.679E-10	E6	0.000E+00	4.45476E-14
E7	0	0	E7	0	-5.35403E-17
E8	0	3.4364E-13	E8	0.000E+00	-3.93574E-18
E9	0	0	E9	0	2.02748E-21
E10	0	-1.53852E-16	E10	0	1.36304E-22
Sagittal line tilt	Sagittal line tilt		Sagittal line tilt	Sagittal line tilt	
M0_1	0	7.661E-02	M0_1	1.211E-01	-5.801E-02
M1_1	0	0.000E+00	M1_1	2.129E-04	2.002E-04
M2_1	0	-3.906E-05	M2_1	1.111E-05	2.292E-05
M3_1	0	0.000E+00	M3_1	-1.419E-07	-1.288E-07
M4_1	0	0.000E+00	M4_1	-5.557E-10	-2.627E-09
M5_1	0	0	M5_1	2.589E-11	2.174E-11
M6_1	0	0	M6_1	-2.459E-13	2.067E-13
M7_1	0	0	M7_1	-2.150E-15	-1.675E-15
M8_1	0	0	M8_1	1.182E-17	-3.209E-17
M9_1	0	0	M9_1	6.130E-20	4.199E-20
M10_1	0	0	M10_1	9.717E-23	1.487E-21
M11_1	0	0	M11_1	0	0
M12_1	0	0	M12_1	0	0

TABLE 9

f θ coefficient, Scanning width, Maximum angle of view		
f θ coefficient	k (mm/rad)	207
Scanning width	W (mm)	330
Maximum angle of view	θ (deg)	45.7
Refractive index		
Refractive index of first f θ lens 206	N5	1.52819
Refractive index of second f θ lens 207	N6	1.52819
Deflecting unit 1		
Number of deflecting surfaces		4
Circumscribed radius	Rpol (mm)	10
Rotation center - Deflection reference point C0 (Optical axis direction)	Xpol (mm)	6.03
Rotation center - Deflection reference point C0 (main scanning direction)	Ypol (mm)	3.79
Arrangement in second scanning optical system 55b		
Deflection reference point C0 -	d12 (mm)	26.00
Incident surface of first f θ lens 206		
Incident surface of first f θ lens 206 -	d13 (mm)	8.20
Exit surface of first f θ lens 206		

TABLE 9-continued

Exit surface of first f θ lens 206 -	d14 (mm)	69.30			
Incident surface of second f θ lens 207					
Incident surface of second f θ lens 207 -	d15 (mm)	4.30			
Exit surface of second f θ lens 207					
Exit surface of second f θ lens 207 -	d16 (mm)	125.20			
Second scanned surface 208					
Deflection reference point C0 -	L3(mm)	26.00			
Incident surface of first f θ lens 206					
Deflection reference point C0 -	L4(mm)	103.50			
Incident surface of second f θ lens 207					
Deflection reference point C0 -	T2(mm)	233.00			
Second scanned surface 208					
Sub-scanning eccentricity of second f θ lens 207	shiftZ(mm)	5.03			
Meridional line shape of second f θ lens 206			Meridional line shape of second f θ lens 207		
	Incident surface Opposite light source side	Exit surface Opposite light source side		Incident surface Opposite light source side	Exit surface Opposite light source side
R	-71.101	-42.946	R	-4000	350.123
ku	9.464E-01	-5.155E-01	ku	0	-8.753E+01
B4u	-9.147E-07	-3.477E-07	B4u	0	-2.020E-07
B6u	6.784E-09	1.690E-09	B6u	0	1.609E-11
B8u	-5.767E-12	1.110E-12	B8u	0	-9.313E-16
B10u	1.638E-15	-1.224E-15	B10u	0	2.524E-20
B12u	0	0	B12u	0	0
	Light source side	Light source side		Light source side	Light source side
k1	9.464E-01	-5.155E-01	k1	0	-8.753E+01
B41	-9.147E-07	-3.477E-07	B41	0	-2.020E-07
B61	6.784E-09	1.690E-09	B61	0	1.609E-11
B81	-5.767E-12	1.110E-12	B81	0	-9.313E-16
B101	1.638E-15	-1.224E-15	B101	0	2.524E-20
B121	0	0	B121	0	0
Sagittal line shape of first f θ lens 206			Sagittal line shape of second f θ lens 207		
	Incident surface Sagittal line R change	Exit surface Sagittal line R change		Incident surface Sagittal line R change	Exit surface Sagittal line R change
r	20.000	25.004	r	37.079	-154.0078
E1	0	0	E1	0	-1.27778E-07
E2	0	1.522E-05	E2	-7.458E-07	1.81313E-06
E3	0	0	E3	0	-3.2397E-09
E4	0	8.486E-10	E4	0	-3.04103E-10
E5	0	0	E5	0	1.33875E-12
E6	0	-2.508E-11	E6	0	3.08183E-14
E7	0	0	E7	0	-2.00884E-16
E8	0	7.60678E-15	E8	0	-1.95419E-18
E9	0	0	E9	0	9.85865E-21
E10	0	1.60971E-17	E10	0	5.81192E-23
	Sagittal line tilt	Sagittal line tilt		Sagittal line tilt	Sagittal line tilt
M0_1	0	2.124E-02	M0_1	-1.007E-01	2.315E-02
M1_1	0	0	M1_1	-2.129E-04	-2.002E-04
M2_1	0	-3.321E-05	M2_1	-1.314E-05	-2.370E-05
M3_1	0	0	M3_1	1.161E-07	1.056E-07
M4_1	0	0	M4_1	1.765E-09	3.675E-09
M5_1	0	0	M5_1	-1.616E-11	-1.409E-11

TABLE 9-continued

M6_1	0	0	M6_1	3.014E-13	-3.052E-13
M7_1	0	0	M7_1	1.061E-15	9.733E-16
M8_1	0	0	M8_1	-1.306E-17	6.574E-17
M9_1	0	0	M9_1	-1.657E-20	-1.728E-20
M10_1	0	0	M10_1	-8.536E-22	-3.960E-21
M11_1	0	0	M11_1	0	0
M12_1	0	0	M12_1	0	0

[0183] In Tables 7 to 9, an optical axis, an axis orthogonal to the optical axis in the main scanning cross section, and an axis orthogonal to the optical axis in the sub-scanning cross section are defined as an X-axis, a Y-axis, and a Z-axis, respectively, when an intersection between each lens surface and the optical axis is defined as an origin.

[0184] Further, in Tables 8 and 9, “E-x” means “ $\times 10^{-x}$ ”.

[0185] An aspheric surface shape (meridional line shape) in the main scanning cross section of each lens surface of the first f θ lenses 106 and 206 and the second f θ lenses 107 and 207 provided in the light scanning apparatus 710 according to the aspect of the embodiment is expressed by the above-described Expression (1).

[0186] An aspheric surface shape (sagittal line shape) in the sub-scanning cross section of each lens surface of the first f θ lenses 106 and 206 and the second f θ lenses 107 and 207 provided in the light scanning apparatus 710 according to the aspect of the embodiment is expressed by the above-described Expression (2).

[0187] A curvature radius r' in the sub-scanning cross section of each lens surface of the first f θ lenses 106 and 206 and the second f θ lenses 107 and 207 provided in the light scanning apparatus 710 according to the aspect of the embodiment continuously varies in accordance with a position in the Y direction as expressed by the above-described Expression (3).

[0188] Each of the first and second anamorphic collimator lenses 102 and 202 provided in the light scanning apparatus 710 according to the aspect of the embodiment has an incident surface formed by a diffracting surface defined by an optical path difference function of two variables Y and Z as expressed by the above-described Expression (4).

[0189] Further, Inequality (11) be satisfied in the first incident optical system 45a and the first scanning optical system 45b provided in the light scanning apparatus 710 according to the aspect of the embodiment.

[0190] In other words, an inclination at the arrival position of the light beam from the i-th light emitting point of the first light source 101 on the exit surface (first sagittal line tilt surface, first optical surface) of the first f θ lens 106 provided in the light scanning apparatus 710 according to the aspect of the embodiment is represented by M_{1i} . A lateral magnification in the sub-scanning cross section of the first incident optical system 45a is represented by β_1 .

[0191] A distance on the optical axis of the first incident optical system 45a between the first light source 101 and the first deflecting surface of the deflecting unit 1 provided in the light scanning apparatus 710 according to the aspect of the embodiment is represented by L_1 (mm).

[0192] A distance on the optical axis of the first scanning optical system 45b between the first deflecting surface of the deflecting unit 1 and the exit surface of the first f θ lens 106 provided in the light scanning apparatus 710 according to the aspect of the embodiment is represented by D_1 (mm).

[0193] At this time, in the first incident optical system 45a and the first scanning optical system 45b provided in the light scanning apparatus 710 according to the aspect of the embodiment, the following Inequality (11c) be satisfied:

$$0.05 < \left| M_{1i} \left[-\beta_1 + \frac{(1-\beta_1)D_1}{L_1} \right] \right| < 0.70. \quad (11c)$$

[0194] In the first incident optical system 45a and the first scanning optical system 45b provided in the light scanning apparatus 710 according to the aspect of the embodiment, Inequality (11a) be satisfied, and it is more preferred that Inequality (11b) be satisfied.

[0195] Further, in the first incident optical system 45a and the first scanning optical system 45b provided in the light scanning apparatus 710 according to the aspect of the embodiment, Inequalities (12) and (13) be satisfied.

[0196] In other words, the following Inequality (12a) be satisfied by using the aspheric surface coefficient M_{01} of the exit surface of the first f θ lens 106 provided in the light scanning apparatus 710 according to the aspect of the embodiment:

$$0 < \left| M_{01} \left[-\beta_1 + \frac{(1-\beta_1)D_1}{L_1} \right] \right| < 0.185. \quad (12a)$$

[0197] Further, in other words, a curvature radius in the sub-scanning cross section of the exit surface of the first f θ lens 106 on the optical axis of the first scanning optical system 45b is represented by R (mm), and an eccentricity amount in the sub-scanning direction of the first f θ lens 106 is represented by L_s (mm).

[0198] At this time, the following Inequality (13a) be satisfied:

$$0.05 < \left[\frac{L_s}{R} + M_{01} \right] \times \left[-\beta_1 + \frac{(1-\beta_1)D_1}{L_1} \right] < 0.70. \quad (13a)$$

[0199] Specifically, in the first incident optical system 45a and the first scanning optical system 45b provided in the light scanning apparatus 710 according to the aspect of the embodiment, β is -3.65, D is 34.2 mm, L is 161.7 mm, and M is 0.100.

[0200] Therefore, the value of each of Inequalities (11), (11a) and (11b) is calculated as 0.465, so that Inequalities (11), (11a) and (11b) are satisfied.

[0201] On the other hand, in the first incident optical system 45a and the first scanning optical system 45b provided in the light scanning apparatus 710 according to the

aspect of the embodiment, since M_{01} is 0.0766, the value of Inequality (12) is calculated as 0.355, so that Inequality (12) is not satisfied.

[0202] Further, in the first incident optical system **45a** and the first scanning optical system **45b** provided in the light scanning apparatus **710** according to the aspect of the embodiment, L_s is 1.31 mm and R is 55.261 mm. Therefore, the value of Inequality (13) is calculated as 0.465, so that Inequality (13) is satisfied.

[0203] In addition, in the second incident optical system **55a** and the second scanning optical system **55b** provided in the light scanning apparatus **710** according to the aspect of the embodiment, Inequality (11) be satisfied.

[0204] In other words, an inclination at the arrival position of the light beam from the j -th light emitting point of the second light source **201** on the exit surface (second sagittal line tilt surface, second optical surface) of the first f θ lens **206** provided in the light scanning apparatus **710** according to the aspect of the embodiment is represented by M_{2j} .

[0205] A lateral magnification in the sub-scanning cross section of the second incident optical system **55a** is represented by β_2 .

[0206] A distance on the optical axis of the second incident optical system **55a** between the second light source **201** and the first deflecting surface of the deflecting unit **1** provided in the light scanning apparatus **710** according to the aspect of the embodiment is represented by L_2 (mm).

[0207] A distance on the optical axis of the second scanning optical system **55b** between the first deflecting surface of the deflecting unit **1** and the exit surface of the first f θ lens **206** provided in the light scanning apparatus **710** according to the aspect of the embodiment is represented by D_2 (mm).

[0208] At this time, in the second incident optical system **55a** and the second scanning optical system **55b** provided in the light scanning apparatus **710** according to the aspect of the embodiment, the following Inequality (11d) be satisfied:

$$0.05 < \left| M_{2j} \left[-\beta_2 + \frac{(1 - \beta_2)D_2}{L_2} \right] \right| < 0.70. \quad (11d)$$

[0209] Further, in the second incident optical system **55a** and the second scanning optical system **55b** provided in the light scanning apparatus **710** according to the aspect of the embodiment, Inequality (11a) be satisfied, and it is more preferred that Inequality (11b) be satisfied.

[0210] In addition, in the second incident optical system **55a** and the second scanning optical system **55b** provided in the light scanning apparatus **710** according to the aspect of the embodiment, Inequalities (12) and (13) be satisfied.

[0211] Specifically, in the second incident optical system **55a** and the second scanning optical system **55b** provided in the light scanning apparatus **710** according to the aspect of the embodiment, β is -3.65 , D is 34.2 mm, L is 161.7 mm, and M is 0.0735.

[0212] Therefore, the value of each of Inequalities (11), (11a) and (11b) is calculated as 0.341, so that Inequalities (11), (11a) and (11b) are satisfied.

[0213] Further, in the second incident optical system **55a** and the second scanning optical system **55b** provided in the light scanning apparatus **710** according to the aspect of the embodiment, since M_{01} is 0.0212, the value of Inequality (12) is calculated as 0.098, so that Inequality (12) is satisfied.

[0214] Furthermore, in the second incident optical system **55a** and the second scanning optical system **55b** provided in the light scanning apparatus **710** according to the aspect of the embodiment, since L_s is 1.31 mm and R is 25.004 mm, the value of Inequality (13) is calculated as 0.341, so that Inequality (13) is satisfied.

[0215] Note that, in the light scanning apparatus **710** according to the aspect of the embodiment, an absolute value of the sagittal line tilt amount M_{01} on the optical axis of the exit surface of the first f θ lens **106** and an absolute value of the sagittal line tilt amount M_{01} on the optical axis of the exit surface of the first f θ lens **206** are different from each other.

[0216] FIG. 12A shows distances in the main scanning direction between the arrival position of the light beam **2105a** and the arrival position of the light beam **2105b** at the respective image heights on the first scanned surface **108** in the light scanning apparatus **710** according to the aspect of the embodiment.

[0217] That is, the distances include d_4 , d_5 , and d_6 shown in FIG. 3B, and the distance at the on-axis image height is shown as 0 mm in FIG. 12A.

[0218] FIG. 12B shows distances in the main scanning direction between the arrival position of the light beam **2105a** and the arrival position of the light beam **2105b** at the respective image heights on the second scanned surface **208** in the light scanning apparatus **710** according to the aspect of the embodiment.

[0219] That is, the distances include d_4 , d_5 , and d_6 shown in FIG. 3B, and the distance at the on-axis image height is shown as 0 mm in FIG. 12B.

[0220] As shown in FIG. 12A, in the light scanning apparatus **710** according to the aspect of the embodiment, a difference between a maximum value and a minimum value of the distances on the first scanned surface **108** is 6.3 μm .

[0221] Since the difference corresponds to a deviation of about 7.4% with respect to 300 dpi, namely a pitch of 84.7 μm , an influence of the deviation of the arrival position of each light beam on the first scanned surface **108** on the image quality can be reduced.

[0222] Further, as shown in FIG. 12B, in the light scanning apparatus **710** according to the aspect of the embodiment, a difference between a maximum value and a minimum value of the distances on the second scanned surface **208** is 2.0 μm .

[0223] Since the difference corresponds to a deviation of about 2.3% with respect to 300 dpi, namely the pitch of 84.7 μm , an influence of the deviation of the arrival position of each light beam on the second scanned surface **208** on the image quality can be reduced.

[0224] As described above, in the light scanning apparatus **710** according to the aspect of the embodiment, Inequalities (11) and (13) are satisfied for the first incident optical system **45a** and the first scanning optical system **45b**.

[0225] On the other hand, all of Inequalities (11), (12) and (13) are satisfied for the second incident optical system **55a** and the second scanning optical system **55b**.

[0226] This makes it possible to reduce the distances in the main scanning direction between the arrival position of the light beam **2105a** and the arrival position of the light beam **2105b** at the respective image heights on the second scanned surface **208** than on the first scanned surface **108**.

[0227] As described above, in the light scanning apparatus **710** according to the aspect of the embodiment, Inequality (11) is satisfied in the first incident optical system **45a** and the first scanning optical system **45b**, thereby it is possible

to suppress a deterioration of the image quality due to the deviation of the arrival position of each light beam on the first scanned surface **108**.

[0228] Further, in the light scanning apparatus **710** according to the aspect of the embodiment, Inequality (11) is satisfied in the second incident optical system **55a** and the second scanning optical system **55b**, thereby it is possible to suppress a deterioration of the image quality due to the deviation of the arrival position of each light beam on the second scanned surface **208**.

Fifth Embodiment

[0229] FIG. 13 shows a schematic developed view in the main scanning cross section of a light scanning apparatus **910** according to a fifth embodiment of the disclosure.

[0230] FIGS. 14 and 15 show a schematic partial developed view in the sub-scanning cross section and a schematic partial sub-scanning cross sectional view of the light scanning apparatus **910** according to the fifth embodiment, respectively.

[0231] The light scanning apparatus **910** according to the aspect of the embodiment includes first, second, third and fourth light sources **301**, **401**, **501** and **601**, and first, second, third and fourth anamorphic collimator lenses **302**, **402**, **502** and **602**.

[0232] Further, the light scanning apparatus **910** according to the aspect of the embodiment includes first, second, third and fourth sub-scanning stops **303**, **403**, **503**, and **603**, and first, second, third and fourth main scanning stops **304**, **404**, **504** and **604**.

[0233] Furthermore, the light scanning apparatus **910** according to the aspect of the embodiment includes a deflecting unit **1**, first f θ lenses **306**, **406**, **506** and **606**, second f θ lenses **307**, **407**, **507** and **607**, and folding mirrors **311**, **312**, **411**, **511**, **512** and **611**.

[0234] On optical paths, the first f θ lens **306** is arranged between the deflecting unit **1** and the second f θ lens **307**, and the first f θ lens **406** is arranged between the deflecting unit **1** and the second f θ lens **407**.

[0235] On optical paths, the first f θ lens **506** is arranged between the deflecting unit **1** and the second f θ lens **507**, and the first f θ lens **606** is arranged between the deflecting unit **1** and the second f θ lens **607**.

[0236] As each of the first, second, third and fourth light sources **301**, **401**, **501** and **601**, a semiconductor laser or the like having a plurality of light emitting points is used.

[0237] The first, second, third and fourth anamorphic collimator lenses **302**, **402**, **502** and **602** convert the light fluxes LC, LD, LE and LF emitted from the first, second, third and fourth light sources **301**, **401**, **501** and **601** into parallel light fluxes in the main scanning cross section, respectively, and condense the light fluxes LC, LD, LE and LF in the sub-scanning cross section, respectively.

[0238] The parallel light flux includes not only a strictly parallel light flux but also a substantially parallel light flux such as a weakly divergent light flux or a weakly convergent light flux.

[0239] The first, second, third and fourth sub-scanning stops **303**, **403**, **503** and **603** limit light flux diameters in the sub-scanning direction of the light fluxes LC, LD, LE and LF that have passed through the first, second, third and fourth anamorphic collimator lenses **302**, **402**, **502** and **602**, respectively.

[0240] The first, second, third and fourth main scanning stops **304**, **404**, **504** and **604** limit light flux diameters in the main scanning direction of the light fluxes LC, LD, LE, and LF that have passed through the first, second, third and fourth sub-scanning stops **303**, **403**, **503** and **603**, respectively.

[0241] In this way, the light fluxes LC and LD emitted from the first and second light sources **301** and **401** are condensed in the sub-scanning direction in the vicinity of a first deflecting surface of the deflecting unit **1**, respectively, so that line images elongated in the main scanning direction are formed.

[0242] Further, the light fluxes LE and LF emitted from the third and fourth light sources **501** and **601** are condensed in the sub-scanning direction in the vicinity of a second deflecting surface of the deflecting unit **1**, respectively, so that line images elongated in the main scanning direction are formed.

[0243] The deflecting unit **1** deflects the incident light fluxes LC, LD, LE and LF with rotating in a direction indicated by an arrow A in FIG. 13 by a driving unit such as a motor (not shown). The deflecting unit **1** is formed by a polygon mirror, for example.

[0244] The first f θ lens **306** (first optical element, first imaging optical element) and the second f θ lens **307** are anamorphic imaging lenses having different powers between the main scanning cross section and the sub-scanning cross section, and condense (guide) the light flux LC deflected by the first deflecting surface of the deflecting unit **1** onto the first scanned surface **308**.

[0245] The first f θ lens **406** (second optical element, second imaging optical element) and the second f θ lens **407** are anamorphic imaging lenses having different powers between the main scanning cross section and the sub-scanning cross section, and condense (guide) the light flux LD deflected by the first deflecting surface of the deflecting unit **1** onto the second scanned surface **408**.

[0246] The first f θ lens **506** (third optical element, third imaging optical element) and the second f θ lens **507** are anamorphic imaging lenses having different powers between the main scanning cross section and the sub-scanning cross section, and condense (guide) the light flux LE deflected by the second deflecting surface of the deflecting unit **1** onto the third scanned surface **508**.

[0247] The first f θ lens **606** (fourth optical element, fourth imaging optical element) and the second f θ lens **607** are anamorphic imaging lenses having different powers between the main scanning cross section and the sub-scanning cross section, and condense (guide) the light flux LF deflected by the second deflecting surface of the deflecting unit **1** on the fourth scanned surface **608**.

[0248] The folding mirrors **311** and **312** reflect the light flux LC deflected by the first deflecting surface of the deflecting unit **1** so as to fold the optical path of the light flux LC, and the folding mirror **411** reflects the light flux LD deflected by the first deflecting surface of the deflecting unit **1** so as to fold the optical path of the light flux LD.

[0249] The folding mirrors **511** and **512** reflect the light flux LE deflected by the second deflecting surface of the deflecting unit **1** so as to fold the optical path of the light flux LE, and the folding mirror **611** reflects the light flux LF deflected by the second deflecting surface of the deflecting unit **1** so as to fold the optical path of the light flux LF.

[0250] In the light scanning apparatus 910 according to the aspect of the embodiment, a first incident optical system 65a is formed by the first anamorphic collimator lens 302, the first sub-scanning stop 303 and the first main scanning stop 304.

[0251] A second incident optical system 75a is formed by the second anamorphic collimator lens 402, the second sub-scanning stop 403 and the second main scanning stop 404.

[0252] A third incident optical system 85a is formed by the third anamorphic collimator lens 502, the third sub-scanning stop 503 and the third main scanning stop 504.

[0253] A fourth incident optical system 95a is formed by the fourth anamorphic collimator lens 602, the fourth sub-scanning stop 603 and the fourth main scanning stop 604.

[0254] Further, in the light scanning apparatus 910 according to the aspect of the embodiment, a first scanning optical system 65b is formed by the first f θ lens 306 and the second f θ lens 307, and a second scanning optical system 75b is formed by the first f θ lens 406 and the second f θ lens 407.

[0255] A third scanning optical system 85b is formed by the first f θ lens 506 and the second f θ lens 507, and a fourth scanning optical system 95b is formed by the first f θ lens 606 and the second f θ lens 607.

[0256] A refractive power in the sub-scanning cross section of the second f θ lenses 307, 407, 507 and 607 is stronger than a refractive power in the sub-scanning cross section of the first f θ lenses 306, 406, 506 and 606, namely the strongest in the first, second, third and fourth scanning optical systems 65b, 75b, 85b and 95b, respectively.

[0257] The light fluxes LC emitted from the respective light emitting points of the first light source 301 pass through the first incident optical system 65a to be incident on the first deflecting surface of the deflecting unit 1.

[0258] Then, the light fluxes LC incident on the first deflecting surface of the deflecting unit 1 from the first light source 301 are deflected by the first deflecting surface of the deflecting unit 1 to be guided onto the first scanned surface 308 by the first scanning optical system 65b, thereby the first scanned surface 308 is scanned at a constant speed.

[0259] The light fluxes LD emitted from the respective light emitting points of the second light source 401 pass through the second incident optical system 75a to be incident on the first deflecting surface of the deflecting unit 1.

[0260] Then, the light fluxes LD incident on the first deflecting surface of the deflecting unit 1 from the second light source 401 are deflected by the first deflecting surface of the deflecting unit 1 to be guided onto the second scanned surface 408 by the second scanning optical system 75b, thereby the second scanned surface 408 is scanned at a constant speed.

[0261] The light fluxes LE emitted from the respective light emitting points of the third light source 501 pass through the third incident optical system 85a to be incident on the second deflecting surface of the deflecting unit 1.

[0262] Then, the light fluxes LE incident on the second deflecting surface of the deflecting unit 1 from the third light source 501 are deflected by the second deflecting surface of the deflecting unit 1 to be guided onto the third scanned surface 508 by the third scanning optical system 85b, thereby the third scanned surface 508 is scanned at a constant speed.

[0263] The light fluxes LF emitted from the respective light emitting points of the fourth light source 601 pass

through the fourth incident optical system 95a to be incident on the second deflecting surface of the deflecting unit 1.

[0264] Then, the light fluxes LF incident on the second deflecting surface of the deflecting unit 1 from the fourth light source 601 are deflected by the second deflecting surface of the deflecting unit 1 to be guided onto the fourth scanned surface 608 by the fourth scanning optical system 95b, thereby the fourth scanned surface 608 is scanned at a constant speed.

[0265] Since the deflecting unit 1 rotates in the direction indicated by the arrow A in FIG. 13, the light fluxes LC, LD, LE and LF deflected by the deflecting unit 1 scan the first, second, third and fourth scanned surfaces 308, 408, 508 and 608 in a direction indicated by an arrow B in FIG. 13, respectively.

[0266] In FIGS. 13 to 15, D0 and E0 represent deflection points (on-axis deflection points) on the first and second deflecting surfaces of the deflecting unit 1 with respect to a principal ray of an on-axis light flux, respectively.

[0267] The deflection point D0 serves as a reference point of the first and second scanning optical systems 65b and 75b, and the deflection point E0 serves as a reference point of the third and fourth scanning optical systems 85b and 95b.

[0268] In the aspect of the embodiment, first, second, third and fourth photosensitive drums 308, 408, 508 and 608 are used as the first, second, third and fourth scanned surfaces 308, 408, 508 and 608.

[0269] Exposure distributions in the sub-scanning direction on the first, second, third and fourth photosensitive drums 308, 408, 508, and 608 are formed by rotating the first, second, third and fourth photosensitive drums 308, 408, 508 and 608 in the sub-scanning direction for each main scanning exposure, respectively.

[0270] Next, various characteristics of the first, second, the third and fourth incident optical systems 65a, 75a, 85a and 95a, and first, second, third and fourth scanning optical systems 65b, 75b, 85b and 95b provided in the light scanning apparatus 910 according to the aspect of the embodiment are shown in the following Tables 10 to 12.

TABLE 10

Characteristics of first, second, third and fourth light sources 301, 401, 501 and 601		
Wavelength	λ (nm)	790
Incident polarization to first and second deflecting surfaces of deflecting unit 1		p polarization
Full angle at half maximum in main scanning direction	FFPy(deg)	12.00
Full angle at half maximum in sub-scanning direction	FFPz(deg)	30.00
Shape of stop		
	Main scanning direction	Sub-scanning direction
First, second, third and fourth sub-scanning stops 303, 403, 503 and 603	10.000	2.840

TABLE 10-continued

First, second, third and fourth main scanning stops 304, 404, 504 and 604	3.750	—	
Refractive index			
First, second, third and fourth anamorphic collimator lenses 302, 402, 502 and 602	N1	1.5282	
Shape of optical element			
		Main scanning direction	Sub-scanning direction
Curvature radius of incident surface of first, second, third and fourth anamorphic collimator lenses 302, 402, 502 and 602	r1a (mm)	∞	∞
Curvature radius of exit surface of first, second, third and fourth anamorphic collimator lenses 302, 402, 502 and 602	r1b (mm)	-37.169	-26.170
Phase coefficient of incident surface of first, second, third and fourth anamorphic collimator lenses 302, 402, 502 and 602	D2, 0 D0, 2	-7.847E-03 —	— -8.669E-03
Focal length			
		Main scanning direction	Sub-scanning direction
First to fourth anamorphic collimator lenses 302 to 602	fcol (mm)	33.94	27.15
Arrangement			
First to fourth light sources 301 to 601 - Incident surface of first to fourth anamorphic collimator lenses 302 to 602		d0 (mm)	33.59

TABLE 10-continued

Incident surface of first to fourth anamorphic collimator lenses 302 to 602 - Exit surface of first to fourth anamorphic collimator lenses 302 to 602	d1 (mm)	3.00
Exit surface of first to fourth anamorphic collimator lenses 302 to 602 - First to fourth sub-scanning stops 303 to 603	d2 (mm)	15.15
First to fourth sub-scanning stops 303 to 603 - First to fourth main scanning stop 304 to 604	d4 (mm)	29.87
First to fourth main scanning stop 304 to 604 - First and second deflecting surfaces of deflecting unit 1	d5 (mm)	80.09
Incident angle in main scanning cross section of light flux LC exiting from first main scanning stop 304 to first deflecting surface	A1 (deg)	78.00
Incident angle in main scanning cross section of light flux LD exiting from second main scanning stop 404 to first deflecting surface	A2 (deg)	78.00
Incident angle in main scanning cross section of light flux LE exiting from third main scanning stop 504 to second deflecting surface	A3 (deg)	102.00
Incident angle in main scanning cross section of light flux LF exiting from fourth main scanning stop 604 to second deflecting surface	A4 (deg)	102.00
Incident angle in sub-scanning cross section of light flux LC exiting from first main scanning stop 304 to first deflecting surface	A5 (deg)	2.70
Incident angle in sub-scanning cross section of light flux LD exiting from second main scanning stop 404 to first deflecting surface	A6 (deg)	-2.70
Incident angle in sub-scanning cross section of light flux LE exiting from third main scanning stop 504 to second deflecting surface	A7 (deg)	-2.70
Incident angle in sub-scanning cross section of light flux LF exiting from fourth main scanning stop 604 to second deflecting surface	A8 (deg)	2.70

TABLE 11

f θ coefficient, Scanning width, Maximum angle of view		
f θ coefficient	k (mm/rad)	207
Scanning width	W (mm)	330
Maximum angle of view	θ (deg)	45.7
Refractive index		
Refractive index of first f θ lenses 306 and 506	N5	1.52819
Refractive index of second f θ lenses 307 and 507	N6	1.52819
Deflecting unit 1		
Number of deflecting surfaces		4
Circumscribed radius	Rpol (mm)	10
Rotation center - Deflection reference points D0 and E0 (Optical axis direction)	Xpol (mm)	6.03
Rotation center - Deflection reference points D0 and E0 (main scanning direction)	Ypol (mm)	3.79
Arrangement in first and third scanning optical systems 65b and 85b		
Deflection reference points D0 and E0 - Incident surface of first f θ lenses 306 and 506	d12 (mm)	26.00
Incident surface of first f θ lenses 306 and 506 - Exit surface of first f θ lenses 306 and 506	d13 (mm)	8.20
Exit surface of first f θ lenses 306 and 506 - Incident surface of second f θ lenses 307 and 507	d14 (mm)	87.80

TABLE 11-continued

Incident surface of second f0 lenses 307 and 507 -	d15 (mm)	4.30		
Exit surface of second f0 lenses 307 and 507				
Exit surface of second f0 lenses 307 and 507 -	d16 (mm)	106.70		
First and third scanned surfaces 308 and 508				
Deflection reference points D0 and E0 -	L1 (mm)	26.00		
Incident surface of first f0 lenses 306 and 506				
Deflection reference points D0 and E0 -	L2 (mm)	122.00		
Incident surface of second f1 lenses 307 and 507				
Deflection reference points D0 and E0 -	T2 (mm)	233.00		
First and third scanned surfaces 308 and 508				
Sub-scanning eccentricity of second f0 lenses 307 and 507	shiftZ (mm)	9.06		
Meridional line shape of first f0 lenses 306 and 506		Meridional line shape of second f0 lenses 307 and 507		
	Incident surface Opposite light source side	Exit surface Opposite light source side		Incident surface Opposite light source side Exit surface Opposite light source side
R	-71.974	-44.323	R	-4000 383.925
Ku	8.921E-01	-1.162E+00	ku	0 -7.626E+01
B4u	-7.612E-07	-1.519E-06	B4U	0 -1.344E-07
B6u	6.789E-09	1.750E-09	B6u	0 7.455E-12
B8u	-5.889E-12	9.640E-13	B8u	0 -3.304E-16
B10u	1.617E-15	-1.195E-15	B10u	0 7.016E-21
B12u	0	0	B12u	0 0.000E+00
	Light source side	Light source side		Light source side Light source side
k1	8.921E-01	-1.162E+00	k1	0 -7.626E+01
B41	-7.612E-07	-1.519E-06	B41	0 -1.344E-07
B61	6.789E-09	1.750E-09	B61	0 7.455E-12
B81	-5.889E-12	9.640E-13	B81	0 -3.304E-16
B101	1.617E-15	-1.195E-15	B101	0 7.016E-21
B121	0	0	B121	0 0.000E+00
Sagittal line shape of first f0 lenses 306 and 506		Sagittal line shape of first f0 lenses 307 and 507		
	Incident surface Sagittal line R change	Exit surface Sagittal line R change		Incident surface Sagittal line R change Exit surface Sagittal line R change
r	20.000	54.586	r	46.180 -110.3864
E1	0	0	E1	0 -7.53378E-07
E2	0	3.970E-06	E2	5.267E-09 1.78758E-06
E3	0	0	E3	0 -7.47644E-10
E4	0	9.864E-08	E4	0 -2.81187E-10
E5	0	0	E5	0 1.8249E-13
E6	0	-2.887E-10	E6	0 4.07154E-14
E7	0	0	E7	0 -1.73958E-17
E8	0	3.62156E-13	E8	0 -3.24923E-18
E9	0	0	E9	0 5.08768E-22
E10	0	-1.61888E-16	E10	0 9.97713E-23
	Sagittal line tilt	Sagittal line tilt		Sagittal line tilt Sagittal line tilt
M0_1	0	1.136E-01	M0_1	1.499E-01 -7.953E-02
M1_1	0	0	M1_1	2.041E-05 1.318E-05
M2_1	0	-5.071E-05	M2_1	3.507E-08 1.547E-05
M3_1	0	0	M3_1	-4.837E-08 -4.462E-08
M4_1	0	0	M4_1	5.229E-10 -1.812E-09
M5_1	0	0	M5_1	1.018E-11 8.807E-12
M6_1	0	0	M6_1	-2.073E-13 1.663E-13
M7_1	0	0	M7_1	-9.447E-16 -7.761E-16
M8_1	0	0	M8_1	2.868E-18 -2.426E-17
M9_1	0	0	M9_1	2.861E-20 2.113E-20
M10_1	0	0	M10_1	-7.599E-23 4.798E-22
M11_1	0	0	M11_1	0 0
M12_1	0	0	M12_1	0 0

TABLE 12

fθ coefficient, Scanning width, Maximum angle of view					
fθ coefficient	k (mm/rad)	207			
Scanning width	W (mm)	330			
Maximum angle of view	θ(deg)	45.7			
Refractive index					
Refractive index of first fθ lenses 406 and 406	N5	1.52819			
Refractive index of second fθ lenses 407 and 607	N6	1.52819			
Deflecting unit 1					
Number of deflecting surfaces		4			
Circumscribed radius	Rpol (mm)	10			
Rotation center - Deflection reference points D0 and E0 (Optical axis direction)	Xpol (mm)	-6.03			
Rotation center - Deflection reference points D0 and E0 (main scanning direction)	Ypol (mm)	3.79			
Arrangement in second and fourth scanning optical systems 75b and 95b					
Deflection reference points D0 and E0 -	d12 (mm)	26.00			
Incident surface of first fθ lenses 406 and 606					
Incident surface of first fθ lenses 406 and 606 -	d13 (mm)	8.20			
Exit surface of first fθ lenses 406 and 606					
Exit surface of first fθ lenses 406 and 606 -	d14 (mm)	66.60			
Incident surface of second fθ lenses 407 and 607					
Incident surface of second fθ lenses 407 and 607 -	d15 (mm)	4.30			
Exit surface of second fθ lenses 407 and 607					
Exit surface of second fθ lenses 407 and 607 -	d16 (mm)	127.90			
Second and fourth scanned surfaces 408 and 608					
Deflection reference points D0 and E0 -	L3 (mm)	26.00			
Incident surface of first fθ lenses 406 and 606					
Deflection reference points D0 and E0 -	L4 (mm)	100.80			
Incident surface of second fθ lenses 407 and 607					
Deflection reference points D0 and E0 -	T2 (mm)	233.00			
Second and fourth scanned surfaces 408 and 608					
Sub-scanning eccentricity of second fθ lenses 407 and 607	shiftZ (mm)	5.96			
Meridional line shape of first fθ lenses 406 and 606		Meridional line shape of second fθ lenses 407 and 607			
	Incident surface Opposite light source side	Exit surface Opposite light source side		Incident surface Opposite light source side	Exit surface Opposite light source side
R	-71.974	-43.211	R	-4000	345.598
ku	8.921E-01	-5.727E-01	ku	0	-9.021E+01
B4u	-7.612E-07	-1.995E-07	B4u	0	-2.166E-07
B6u	6.789E-09	1.645E-09	B6U	0	1.801E-11
B8u	-5.889E-12	1.272E-12	B8u	0	-1.069E-15
B10u	1.617E-15	-1.418E-15	B10u	0	2.983E-20
B12u	0	0	B12u	0	0
	Light source side	Light source side		Light source side	Light source side
k1	8.921E-01	-5.727E-01	k1	0	-9.021E+01
B41	-7.612E-07	-1.995E-07	B41	0	-2.166E-07
B61	6.789E-09	1.645E-09	B61	0	1.801E-11

TABLE 12-continued

B81	-5.889E-12	1.272E-12	B81	0	-1.069E-15
B101	1.617E-15	-1.418E-15	B101	0	2.983E-20
B121	0	0	B121	0	0
Sagittal line shape of first f θ lenses 406 and 606			Sagittal line shape of second f θ lenses 407 and 607		
Incident surface Sagittal line R change	Exit surface Sagittal line R change		Incident surface Sagittal line R change	Exit surface Sagittal line R change	
r	20.000	20.586	r	26.855	294.0214
E1	0	0	E1	0	1.96971E-07
E2	0	1.558E-05	E2	-5.144E-06	-2.36769E-06
E3	0	0	E3	0	-3.44358E-09
E4	0	-3.394E-08	E4	0	-2.46843E-10
E5	0	0	E5	0	1.49969E-12
E6	0	3.964E-11	E6	0	1.69237E-14
E7	0	0	E7	0	-2.50442E-16
E8	0	-6.55816E-14	E8	0	-1.79515E-18
E9	0	0	E9	0	1.40544E-20
E10	0	5.40111E-17	E10	0	7.11738E-23
Sagittal line tilt	Sagittal line tilt		Sagittal line tilt	Sagittal line tilt	
M0_1	0	3.928E-02	M0_1	-1.514E-01	1.072E-02
M1_1	0	0	M1_1	-5.638E-06	2.983E-06
M2_1	0	-3.676E-05	M2_1	-2.604E-05	-4.002E-05
M3_1	0	0	M3_1	1.312E-07	1.175E-07
M4_1	0	0	M4_1	5.689E-09	7.909E-09
M5_1	0	0	M5_1	-3.827E-11	-3.145E-11
M6_1	0	0	M6_1	8.340E-14	-6.667E-13
M7_1	0	0	M7_1	5.134E-15	3.847E-15
M8_1	0	0	M8_1	-2.894E-17	8.307E-17
M9_1	0	0	M9_1	-2.202E-19	-1.374E-19
M10_1	0	0	M10_1	-5.517E-22	-5.821E-21
M11_1	0	0	M11_1	0	0
M12_1	0	0	M12_1	0	0

[0271] In Tables 10 to 12, an optical axis, an axis orthogonal to the optical axis in the main scanning cross section, and an axis orthogonal to the optical axis in the sub-scanning cross section are defined as an X-axis, a Y-axis and a Z-axis, respectively, when an intersection between each lens surface and the optical axis is defined as an origin. Further, in Tables 11 and 12, “E-x” means “ $\times 10^{-x}$ ”.

[0272] An aspherical shape (meridional line shape) in the main scanning cross section of each lens surface of the first f θ lenses 306, 406, 506 and 606 and the second f θ lenses 307, 407, 507 and 607 provided in the light scanning apparatus 910 according to the aspect of the embodiment is expressed by the above-described Expression (1).

[0273] An aspherical shape (sagittal line shape) in the sub-scanning cross section of each lens surface of the first f θ lenses 306, 406, 506 and 606 and the second f θ lenses 307, 407, 507 and 607 provided in the light scanning apparatus 910 according to the aspect of the embodiment is expressed by the above-described Expression (2).

[0274] A curvature radius r' in the sub-scanning cross section of each lens surface of the first f θ lenses 306, 406, 506 and 606 and the second f θ lenses 307, 407, 507 and 607 provided in the light scanning apparatus 910 according to the aspect of the embodiment continuously varies in accordance with a position in the Y direction as expressed by the above-described Expression (3).

[0275] Each of the first, second, third and fourth anamorphic collimator lenses 302, 402, 502 and 602 provided in the

light scanning apparatus 910 according to the aspect of the embodiment has an incident surface formed by a diffracting surface defined by an optical path difference function of two variables Y and Z as expressed by the above-described Expression (4).

[0276] Further, in the first incident optical system 65a and the first scanning optical system 65b provided in the light scanning apparatus 910 according to the aspect of the embodiment, Inequality (11) be satisfied, Inequality (11a) be satisfied, and Inequality (11b) be satisfied.

[0277] Furthermore, in the first incident optical system 65a and the first scanning optical system 65b provided in the light scanning apparatus 910 according to the aspect of the embodiment, Inequalities (12) and (13) be satisfied.

[0278] Specifically, in the first incident optical system 65a and the first scanning optical system 65b provided in the light scanning apparatus 910 according to the aspect of the embodiment, β is -3.65 , D is 34.2 mm, Lis 161.7 mm, and M is 0.138.

[0279] Therefore, the value of each of the Inequalities (11), (11a) and (11b) are calculated as 0.638, so that Inequalities (11) and (11a) are satisfied.

[0280] On the other hand, in the first incident optical system 65a and the first scanning optical system 65b provided in the light scanning apparatus 910 according to the aspect of the embodiment, M_{01} is 0.114.

[0281] Therefore, the value of the Inequality (12) is calculated as 0.527, so that Inequality (12) is not satisfied.

[0282] Further, in the first incident optical system **65a** and the first scanning optical system **65b** provided in the light scanning apparatus **910** according to the aspect of the embodiment, L_s is 1.31 mm, and R is 54.586 mm.

[0283] Therefore, the value of the Inequality (13) is calculated as 0.638, so that Inequality (13) is satisfied.

[0284] In the second incident optical system **75a** and the second scanning optical system **75b** provided in the light scanning apparatus **910** according to the aspect of the embodiment, Inequality (11) be satisfied, Inequality (11a) be satisfied, and Inequality (11b) be satisfied.

[0285] Further, in the second incident optical system **75a** and the second scanning optical system **75b** provided in the light scanning apparatus **910** according to the aspect of the embodiment, Inequalities (12) and (13) be satisfied.

[0286] Specifically, in the second incident optical system **75a** and the second scanning optical system **75b** provided in the light scanning apparatus **910** according to the aspect of the embodiment, β is -3.65 , D is 34.2 mm, L is 161.7 mm and M is 0.103.

[0287] Therefore, the value of each of the Inequalities (11), (11a) and (11b) is calculated as 0.476, so that Inequalities (11), (11a) and (11b) are satisfied.

[0288] Further, in the second incident optical system **75a** and the second scanning optical system **75b** provided in the light scanning apparatus **910** according to the aspect of the embodiment, M_{01} is 0.0393.

[0289] Therefore, the value of Inequality (12) is calculated as 0.182, so that Inequality (12) is satisfied.

[0290] Furthermore, in the second incident optical system **75a** and the second scanning optical system **75b** provided in the light scanning apparatus **910** according to the aspect of the embodiment, L_s is 1.31 mm, and R is 20.586 mm.

[0291] Therefore, the value of Inequality (13) is calculated as 0.476, and Inequality (13) is satisfied.

[0292] Further, in the third incident optical system **85a** and the third scanning optical system **85b** provided in the light scanning apparatus **910** according to the aspect of the embodiment, Inequality (11) be satisfied.

[0293] In other words, an inclination at the arrival position of the light beam from the k -th light emitting point of the third light source **501** on the exit surface (third sagittal line tilt surface, third optical surface) of the first f θ lens **506** provided in the light scanning apparatus **910** according to the aspect of the embodiment is represented by M_{3k} .

[0294] A lateral magnification in the sub-scanning cross section of the third incident optical system **85a** is represented by β_3 .

[0295] A distance on the optical axis of the third incident optical system **85a** between the third light source **501** and the second deflecting surface of the deflecting unit **1** provided in the light scanning apparatus **910** according to the aspect of the embodiment is represented by L_3 (mm).

[0296] A distance on the optical axis of the third scanning optical system **85b** between the second deflecting surface of the deflecting unit **1** and the exit surface of the first f θ lens **506** provided in the light scanning apparatus **910** according to the aspect of the embodiment is represented by D_3 (mm).

[0297] At this time, in the third incident optical system **85a** and the third scanning optical system **85b** provided in the light scanning apparatus **910** according to the aspect of the embodiment, the following Inequality (11e) be satisfied:

$$0.05 < \left| M_{3k} \left[-\beta_3 + \frac{(1-\beta_3)D_3}{L_3} \right] \right| < 0.70. \quad (11e)$$

[0298] Further, in the third incident optical system **85a** and the third scanning optical system **85b** provided in the light scanning apparatus **910** according to the aspect of the embodiment, Inequality (11a) be satisfied, and it is more preferred that Inequality (11b) be satisfied.

[0299] Furthermore, in the third incident optical system **85a** and the third scanning optical system **85b** provided in the light scanning apparatus **910** according to the aspect of the embodiment, Inequalities (12) and (13) be satisfied.

[0300] Specifically, in the third incident optical system **85a** and the third scanning optical system **85b** provided in the light scanning apparatus **910** according to the aspect of the embodiment, β is -3.65 , D is 34.2 mm, L is 161.7 mm, and M is 0.138.

[0301] Therefore, the value of each of Inequalities (11), (11a) and (11b) is calculated as 0.638, so that Inequalities (11) and (11a) are satisfied.

[0302] On the other hand, in the third incident optical system **85a** and the third scanning optical system **85b** provided in the light scanning apparatus **910** according to the aspect of the embodiment, M_{01} is 0.114.

[0303] Therefore, the value of Inequality (12) is calculated as 0.527, so that Inequality (12) is not satisfied.

[0304] Further, in the third incident optical system **85a** and the third scanning optical system **85b** provided in the light scanning apparatus **910** according to the aspect of the embodiment, L_s is 1.31 mm, and R is 54.586 mm.

[0305] Therefore, the value of Inequality (13) is calculated as 0.638, so that Inequality (13) is satisfied.

[0306] In addition, in the fourth incident optical system **95a** and the fourth scanning optical system **95b** provided in the light scanning apparatus **910** according to the aspect of the embodiment, Inequality (11) be satisfied.

[0307] In other words, an inclination at the arrival position of the light beam from the 1-th light emitting point of the fourth light source **601** on the exit surface (fourth sagittal line tilt surface, fourth optical surface) of the first f θ lens **606** provided in the light scanning apparatus **910** according to the aspect of the embodiment is represented by M_{4l} .

[0308] A lateral magnification in the sub-scanning cross section of the fourth incident optical system **95a** is represented by β_4 .

[0309] A distance on the optical axis of the fourth incident optical system **95a** between the fourth light source **601** and the second deflecting surface of the deflecting unit **1** provided in the light scanning apparatus **910** according to the aspect of the embodiment is represented by L_4 (mm).

[0310] A distance on the optical axis of the fourth scanning optical system **95b** between the second deflecting surface of the deflecting unit **1** and the exit surface of the first f θ lens **606** provided in the light scanning apparatus **910** according to the aspect of the embodiment is represented by D_4 (mm).

[0311] At this time, in the fourth incident optical system **95a** and the fourth scanning optical system **95b** provided in the light scanning apparatus **910** according to the aspect of the embodiment, the following Inequality (11f) be satisfied:

$$0.05 < \left| M_{4l} \left[-\beta_4 + \frac{(1-\beta_4)D_4}{L_4} \right] \right| < 0.70. \quad (11f)$$

[0312] Further, in the fourth incident optical system **95a** and the fourth scanning optical system **95b** provided in the light scanning apparatus **910** according to the aspect of the embodiment, Inequality (11a) be satisfied, and it is more preferred that Inequality (11b) be satisfied.

[0313] Furthermore, in the fourth incident optical system **95a** and the fourth scanning optical system **95b** provided in the light scanning apparatus **910** according to the aspect of the embodiment, Inequalities (12) and (13) be satisfied.

[0314] Specifically, in the fourth incident optical system **95a** and the fourth scanning optical system **95b** provided in the light scanning apparatus **910** according to the aspect of the embodiment, β is -3.65 , D is 34.2 mm, L is 161.7 mm, and M is 0.103 .

[0315] Therefore, the value of each of Inequalities (11), (11a) and (11b) is calculated as 0.476 , so that Inequalities (11), (11a) and (11b) are satisfied.

[0316] Further, in the fourth incident optical system **95a** and the fourth scanning optical system **95b** provided in the light scanning apparatus **910** according to the aspect of the embodiment, M_{01} is 0.0393 .

[0317] Therefore, the value of Inequality (12) is calculated as 0.182 , so that Inequality (12) is satisfied.

[0318] Furthermore, in the fourth incident optical system **95a** and the fourth scanning optical system **95b** provided in

the light scanning apparatus **910** according to the aspect of the embodiment, L_s is 1.31 mm, and R is 20.586 mm.

[0319] Therefore, the value of Inequality (13) is calculated as 0.476 , and Inequality (13) is satisfied.

[0320] As described above, in the light scanning apparatus **910** according to the aspect of the embodiment, Inequality (11) is satisfied in the first incident optical system **65a** and the first scanning optical system **65b**, thereby it is possible to suppress a deterioration in the image quality due to the deviation of the arrival position of each light beam on the first scanned surface **308**.

[0321] In the light scanning apparatus **910** according to the aspect of the embodiment, Inequality (11) is satisfied in the second incident optical system **75a** and the second scanning optical system **75b**, thereby it is possible to suppress a deterioration in the image quality due to the deviation of the arrival position of each light beam on the second scanned surface **408**.

[0322] In the light scanning apparatus **910** according to the aspect of the embodiment, Inequality (11) is satisfied in the third incident optical system **85a** and the third scanning optical system **85b**, thereby it is possible to suppress a deterioration in the image quality due to the deviation of the arrival position of each light beam on the third scanned surface **508**.

[0323] In the light scanning apparatus **910** according to the aspect of the embodiment, Inequality (11) is satisfied in the fourth incident optical system **95a** and the fourth scanning optical system **95b**, thereby it is possible to suppress a deterioration in the image quality due to the deviation of the arrival position of each light beam on the fourth scanned surface **608**.

[0324] Numerical values of the respective Inequalities in each of the light scanning apparatuses according to the first to fifth embodiments described above are shown in the following Table 13.

TABLE 13

	First embodiment	Second embodiment	Third embodiment
β	-3.65	-3.65	-3.65
D [mm]	34.2	34.2	34.2
L [mm]	161.7	161.7	161.7
M	-0.127	-0.0385	-0.0735
M_{01}	-0.0918	-0.0385	-0.0212
L_s [mm]	-1.45	0	-1.31
R [mm]	41.166	76.858	25.004
Inequality (11): $0.05 < $	0.589	0.179	0.341
$(-\beta + (1 - \beta) \times D/L) \times M < 0.70$			
Inequality (11a): $0.10 < $			
$(-\beta + (1 - \beta) \times D/L) \times M < 0.65$			
Inequality (11b): $0.15 < $			
$(-\beta + (1 - \beta) \times D/L) \times M < 0.60$			
Inequality (12): $0 < (-\beta +$	0.426	0.179	0.098
$(1 - \beta) \times D/L) \times M_{01} < 0.185$			
Inequality (13): $0.05 < (-\beta +$	0.589	0.179	0.341
$(1 - \beta) \times D/L) \times (L_s/R +$			
$M_{01}) < 0.70$			
$1/R$ [1/mm]	0.0243	0.0130	0.0400

TABLE 13-continued

	Fourth embodiment		Fifth embodiment	
	First scanning system	Second scanning system	First and third scanning systems	Second and fourth scanning systems
β	-3.65	-3.65	-3.65	-3.65
D [mm]	34.2	34.2	34.2	34.2
L [mm]	161.7	161.7	161.7	161.7
M	0.100	0.0735	0.138	0.103
M01	0.0766	0.0212	0.114	0.0393
Ls [mm]	1.31	1.31	1.31	1.31
R [mm]	55.261	25.004	54.586	20.586
Inequality (11): $0.05 < (-\beta + (1 - \beta) \times D/L) \times M < 0.70$	0.465	0.341	0.638	0.476
Inequality (11a): $0.10 < (-\beta + (1 - \beta) \times D/L) \times M < 0.65$				
Inequality (11b): $0.15 < (-\beta + (1 - \beta) \times D/L) \times M < 0.60$				
Inequality (12): $0 < (-\beta + (1 - \beta) \times D/L) \times M01 < 0.185$	0.355	0.098	0.527	0.182
Inequality (13): $0.05 < (-\beta + (1 - \beta) \times D/L) \times (Ls/R + M01) < 0.70$	0.465	0.341	0.638	0.476
1/R [1/mm]	0.0181	0.0400	0.0183	0.0486

[0325] According to the aspect of the embodiments, a light scanning apparatus capable of easily reducing a deviation between scanning widths of multiple beams can be provided.

[0326] Although preferred embodiments have been described above, the disclosure is not limited to these embodiments, and various modifications and changes can be made within the scope of the gist of the disclosure.

[Image Forming Apparatus]

[0327] FIG. 16 shows a sub-scanning cross sectional view of a main part of an image forming apparatus 90 in which the light scanning apparatus 910 according to the fifth embodiment of the disclosure is mounted.

[0328] The image forming apparatus 90 is a tandem-type color image forming apparatus that records image information on a surface of each photosensitive drum serving as an image carrier by using the light scanning apparatus 910 according to the fifth embodiment.

[0329] The image forming apparatus 90 includes the light scanning apparatus 910 according to the fifth embodiment, developing units 15, 16, 17 and 18, photosensitive drums (photosensitive bodies) 23, 24, 25 and 26, a conveying belt 91, a printer controller 93 and a fixing unit 94.

[0330] Color signals (code data) of R (red), G (green) and B (blue) output from an external apparatus 92 such as a personal computer are input to the image forming apparatus 90.

[0331] The input color signals are converted into image data (dot data) of C (cyan), M (magenta), Y (yellow), and K (black) by the printer controller 93 in the image forming apparatus 90.

[0332] The converted image data is input to the light scanning apparatus 910 according to the fifth embodiment.

[0333] Light beams 19, 20, 21, and 22 modulated in accordance with respective image data are emitted from the light scanning apparatus 910 according to the fifth embodi-

ment, and photosensitive surfaces of photosensitive drums 23, 24, 25 and 26 are exposed to the light beams 19 to 22.

[0334] In the image forming apparatus 90, charging rollers (not shown) for uniformly charging the surfaces of the photosensitive drums 23 to 26 are provided so as to abut on the surfaces.

[0335] The surfaces of the photosensitive drums 23 to 26 charged by the charging rollers are irradiated with the light beams 19 to 22 from the light scanning apparatus 910 according to the fifth embodiment.

[0336] As described above, the light beams 19 to 22 are modulated on the basis of the image data of the respective colors, and electrostatic latent images are formed on the surfaces of the photosensitive drums 23 to 26 by the irradiation with the light beams 19 to 22.

[0337] The formed electrostatic latent images are developed as toner images by developing units 15, 16, 17 and 18 arranged so as to abut on the photosensitive drums 23 to 26.

[0338] The toner images developed by the developing units 15 to 18 are multi-transferred onto a sheet (transferred material) (not shown) conveyed on the conveying belt 91 by a transferring roller (transferring unit) (not shown) arranged so as to face the photosensitive drums 23 to 26, thereby forming one full-color image.

[0339] Then, the sheet on which the unfixed toner image is transferred is further conveyed to the fixing unit 94 arranged behind the photosensitive drums 23 to 26 (on the left side in FIG. 16).

[0340] The fixing unit 94 is formed by a fixing roller having a fixing heater (not shown) therein and a pressurizing roller arranged so as to be in pressure contact with the fixing roller.

[0341] Then, the sheet conveyed from the transferring portion is heated while being pressed at the pressure-contact portion between the fixing roller and the pressurizing roller, thereby the unfixed toner image on the sheet is fixed.

[0342] Further, a sheet discharging roller (not shown) is arranged behind the fixing roller, and the sheet discharging

roller discharges the sheet on which the toner image is fixed to the outside of the image forming apparatus **90**.

[0343] The image forming apparatus **90** records image signals (image information) on the photosensitive surfaces of the photosensitive drums **23** to **26** corresponding to the respective colors of C, M, Y and K by using the light scanning apparatus **910** according to the fifth embodiment, and prints a color image at high speed.

[0344] As the external apparatus **92**, for example, a color image reading apparatus including a CCD sensor may be used. In this case, the color image reading apparatus and the image forming apparatus **90** form a color digital copying machine.

[0345] The image forming apparatus **90** may be provided with four light scanning apparatuses according to any one of the first to third embodiments or two light scanning apparatuses **710** according to the fourth embodiment instead of the light scanning apparatus **910** according to the fifth embodiment.

[0346] While the embodiments of the disclosure have been described with reference to exemplary embodiments, it is to be understood that the disclosure is not limited to the disclosed exemplary embodiments. The scope of the following claims is to be accorded the broadest interpretation so as to encompass all such modifications and equivalent structures and functions.

[0347] This application claims the benefit of Japanese Patent Application No. 2024-019123, filed Feb. 13, 2024, which is hereby incorporated by reference herein in its entirety.

What is claimed is:

1. An apparatus comprising:

- a deflecting unit configured to deflect a plurality of light fluxes from a first light source with a plurality of light emitting points to scan a first scanned surface in a main scanning direction;
- a first element having a first surface and configured to guide the plurality of light fluxes deflected by a first deflecting surface of the deflecting unit to the first scanned surface; and
- a first incident system configured to cause the plurality of light fluxes from the first light source to be incident on the first deflecting surface,

wherein, a following condition is satisfied:

$$0.05 < \left| M_{1i} \left[-\beta_1 + \frac{(1 - \beta_1)D_1}{L_1} \right] \right| < 0.70,$$

where L_1 represents a distance between the first light source and the first deflecting surface on an optical axis of the first incident system, D_1 represents a distance between the first deflecting surface and the first surface on an optical axis of the first element, β_1 represents a lateral magnification in a sub-scanning cross section of the first incident system, and M_{1i} represents an inclination of the first surface at a position at which the light flux from an i -th light emitting point of the first light source arrives on the first surface.

2. The apparatus according to claim **1**, wherein a following condition is satisfied:

$$0 < \left| M_{01} \left[-\beta_1 + \frac{(1 - \beta_1)D_1}{L_1} \right] \right| < 0.185,$$

where M_{01} represents a sagittal line tilt amount of the first surface on the optical axis of the first element.

3. The apparatus according to claim **1**, wherein a following condition is satisfied:

$$0.05 < \left[\frac{L_s}{R} + M_{01} \right] \times \left[-\beta_1 + \frac{(1 - \beta_1)D_1}{L_1} \right] < 0.70,$$

where R represents a curvature radius in the sub-scanning cross section of the first surface on the optical axis of the first element, L_s represents an eccentricity amount in a sub-scanning direction of the first element, and M_{01} represents a sagittal line tilt amount of the first surface on the optical axis of the first element.

4. The apparatus according to claim **1**, wherein a sagittal line tilt amount of the first surface varies in accordance with a position in the main scanning direction.

5. The apparatus according to claim **4**, wherein an absolute value of a sagittal line tilt amount of the first surface is largest on the optical axis of the first element.

6. The apparatus according to claim **1**, wherein the first element has a positive power in the sub-scanning cross section.

7. The apparatus according to claim **1**, further comprising a first imaging system including the first element and configured to guide the plurality of light fluxes deflected by the first deflecting surface to the first scanned surface,

wherein an element closest to the deflecting unit on the paths of the plurality of light fluxes among at least one element included in the first imaging system is an element having the strongest power in a main scanning cross section among the at least one element.

8. The apparatus according to claim **1**, further comprising: a second element having a second surface and configured to guide a plurality of light fluxes of a second light source with a plurality of light emitting points deflected by the first deflecting surface to a second scanned surface; and

a second incident system configured to cause the plurality of light fluxes from the second light source to be incident on the first deflecting surface,

wherein the deflecting unit is configured to deflect the plurality of light fluxes from the second light source to scan the second scanned surface in the main scanning direction, and

wherein, a following condition is satisfied:

$$0.05 < \left| M_{2j} \left[-\beta_2 + \frac{(1 - \beta_2)D_2}{L_2} \right] \right| < 0.70,$$

where L_2 represents a distance between the second light source and the first deflecting surface on an optical axis of the second incident system, D_2 represents a distance between the first deflecting surface and the second

surface on an optical axis of the second element, β_2 represents a lateral magnification in the sub-scanning cross section of the second incident system, and M_{2j} represents an inclination of the second surface at a position at which the light flux from a j-th light emitting point of the second light source arrives on the second surface.

9. The apparatus according to claim 8, wherein an absolute value of a sagittal line tilt amount of the first surface on the optical axis of the first element and an absolute value of a sagittal line tilt amount of the second surface on the optical axis of the second element are different from each other.

10. The apparatus according to claim 8, further comprising:

- a third element having a third surface and configured to guide a plurality of light fluxes of a third light source with a plurality of light emitting points deflected by a second deflecting surface of the deflecting unit to a third scanned surface;
- a fourth element having a fourth surface and configured to guide a plurality of light fluxes of a fourth light source with a plurality of light emitting points deflected by the second deflecting surface to a fourth scanned surface;
- a third incident system configured to cause the plurality of light fluxes from the third light source to be incident on the second deflecting surface; and
- a fourth incident system configured to cause the plurality of light fluxes from the fourth light source to be incident on the second deflecting surface,

wherein the deflecting unit is configured to deflect the plurality of light fluxes from the third light source and the plurality of light fluxes from the fourth light source to scan the third and fourth scanned surfaces in the main scanning direction, respectively,

wherein, a following condition is satisfied:

$$0.05 < \left| M_{3k} \left[-\beta_3 + \frac{(1 - \beta_3)D_3}{L_3} \right] \right| < 0.70,$$

where L_3 represents a distance between the third light source and the second deflecting surface on an optical axis of the third incident system, D_3 represents a distance between the second deflecting surface and the third surface on an optical axis of the third element, β_3 represents a lateral magnification in the sub-scanning cross section of the third incident system, and M_{3k} represents an inclination of the third surface at a position at which the light flux from a k-th light emitting point of the third light source arrives on the third surface, and

wherein, a following condition is satisfied:

$$0.05 < \left| M_{4i} \left[-\beta_4 + \frac{(1 - \beta_4)D_4}{L_4} \right] \right| < 0.70,$$

where L_4 represents a distance between the fourth light source and the second deflecting surface on an optical axis of the fourth incident system, D_4 represents a distance between the second deflecting surface and the fourth surface on an optical axis of the fourth element, β_4 represents a lateral magnification in the sub-scanning cross section of the fourth incident system, and

M_{4i} represents an inclination of the fourth surface at a position at which the light flux from an i-th light emitting point of the fourth light source arrives on the fourth surface.

11. An apparatus comprising:

- a deflecting unit configured to deflect a plurality of light fluxes from a first light source with a plurality of light emitting points to scan a first scanned surface in a main scanning direction;
- a first element having a first surface and configured to guide the plurality of light fluxes deflected by a first deflecting surface of the deflecting unit to the first scanned surface; and
- a first incident system configured to cause the plurality of light fluxes from the first light source to be incident on the first deflecting surface,

wherein a normal of the first surface on an optical axis of the first element is inclined with respect to the optical axis.

12. A forming apparatus comprising:

the apparatus according to claim 1; and

a developing unit configured to develop an electrostatic latent image formed on the first scanned surface by the apparatus.

13. The forming apparatus according to claim 12, wherein, in the apparatus, a following condition is satisfied:

$$0 < \left| M_{01} \left[-\beta_1 + \frac{(1 - \beta_1)D_1}{L_1} \right] \right| < 0.185,$$

where M_{01} represents a sagittal line tilt amount of the first surface on the optical axis of the first element.

14. The forming apparatus according to claim 12, wherein, in the apparatus, a following condition is satisfied:

$$0.05 < \left| \left[\frac{L_s}{R} + M_{01} \right] \times \left[-\beta_1 + \frac{(1 - \beta_1)D_1}{L_1} \right] \right| < 0.70,$$

where R represents a curvature radius in the sub-scanning cross section of the first surface on the optical axis of the first element, L_s represents an eccentricity amount in a sub-scanning direction of the first element, and M_{01} represents a sagittal line tilt amount of the first surface on the optical axis of the first element.

15. The forming apparatus according to claim 12, wherein, in the apparatus, a sagittal line tilt amount of the first surface varies in accordance with a position in the main scanning direction.

16. The forming apparatus according to claim 15, wherein, in the apparatus, an absolute value of a sagittal line tilt amount of the first surface is largest on the optical axis of the first element.

17. A forming apparatus comprising:

the apparatus according to claim 1; and

a controller configured to convert a signal output from an external apparatus into image data to input the image data to the apparatus.

18. The forming apparatus according to claim **17**, wherein, in the apparatus, a following condition is satisfied:

$$0 < \left| M_{01} \left[-\beta_1 + \frac{(1 - \beta_1)D_1}{L_1} \right] \right| < 0.185,$$

where M_{01} represents a sagittal line tilt amount of the first surface on the optical axis of the first element.

19. The forming apparatus according to claim **17**, wherein, in the apparatus, a following condition is satisfied:

$$0.05 < \left| \left[\frac{L_g}{R} + M_{01} \right] \times \left[-\beta_1 + \frac{(1 - \beta_1)D_1}{L_1} \right] \right| < 0.70,$$

where R represents a curvature radius in the sub-scanning cross section of the first surface on the optical axis of the first element, L_g represents an eccentricity amount in a sub-scanning direction of the first element, and M_{01} represents a sagittal line tilt amount of the first surface on the optical axis of the first element.

20. The forming apparatus according to claim **17**, wherein, in the apparatus, a sagittal line tilt amount of the first surface varies in accordance with a position in the main scanning direction.

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