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LIGHT SOURCE DEVICE AND HEATING SYSTEM INCLUDING LIGHT SOURCE DEVICE

Abstract

A light source device includes first to fourth laser light sources that emit first to fourth laser light, a condenser lens, first to fourth reflecting surfaces that reflect the first to fourth laser lights toward the condenser lens, and first to fourth afocal systems disposed such that the first to fourth laser lights exit the first to fourth afocal systems toward the first to fourth reflecting surfaces. When a plan view taken in a direction along the optical axis is divided into first to fourth quadrants with a position of the optical axis serving as an origin, the first to fourth reflecting surfaces are located in the first to fourth quadrants, respectively.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims priority under 35 U.S.C. § 119 to Japanese Patent Application No. 2024-020881, filed Feb. 15, 2024, the contents of which are incorporated herein by reference in their entirety.

BACKGROUND

Technical Field

[0002] The present disclosure relates to a light source device and a heating system including the light source device.

Background Art

[0003] Japanese Patent Application Publication No. 2017-134992 A describes a lighting device that evenly irradiates a projection surface with light and includes a transmissive diffusion plate that allows for reducing density of irradiation to an irradiation optical system. The lighting device includes a light-emitting portion that emits light, a light condenser portion that condenses light emitted from the light-emitting portion, a first diffuser that diffuses light condensed by the light condenser, a homogenizing optical component that homogenize the illuminance distribution and then allows the homogenized light to exit it, and a second diffusion portion that diffuses light exited the homogenizing optical component.

SUMMARY

[0004] Semiconductor lasers are used not only for illumination but also for various processes such as heating, drying, and pressurization. A system using a semiconductor laser for illumination, processing, or the like preferably includes a more compact light source device that can more uniformly emit light from a large number of semiconductor lasers in accordance with the application.

[0005] According to one aspect of the present disclosure, a light source device includes a first laser light source configured to emit a first laser light; a second laser light source configured to emit a second laser light; a third laser light source configured to emit a third laser light; a fourth laser light source configured to emit a fourth laser light; a condenser lens; a first reflecting surface located at a first distance along an optical axis of the condenser lens from the condenser lens such that a reflection direction of the first laser light is directed toward the condenser lens along the optical axis; a second reflecting surface located at a second distance along the optical axis from the condenser lens such that a reflection direction of the second laser light is directed toward the condenser lens along the optical axis; a third reflecting surface located at a third distance along the optical axis from the condenser lens such that a reflection direction of the third laser light is directed toward the condenser lens along the optical axis; a fourth reflecting surface located at a fourth distance along the optical axis from the condenser lens such that a reflection direction of the fourth laser light is directed toward the condenser lens along the optical axis; a first afocal system disposed on a first optical path from the first laser light source to the first reflecting surface such that the first laser light exits toward the first reflecting surface; a second afocal system disposed on a second optical path from the second laser light source to the second reflecting surface such that the second laser light exits toward the second reflecting surface; a third afocal system disposed on a third optical path from the third laser light source to the third reflecting surface such that the third laser light exits toward the third reflecting surface; and a fourth afocal system disposed on a fourth optical path from the fourth laser light source to the fourth reflecting surface such that the fourth laser light exits toward the fourth reflecting surface. When a plan view taken in a direction along the optical axis is divided into a first quadrant, a second quadrant, a third quadrant, and a fourth quadrant with a position of the optical axis serving as an origin, the first reflecting surface is located in the first quadrant, the second reflecting surface is located in the second quadrant, the third reflecting surface is located in the third quadrant, and the fourth reflecting surface is located in the fourth quadrant.

[0006] In the light source device, reflecting surfaces are respectively disposed in first to fourth quadrants to form light bundles along the optical axis of the condenser lens, so that first to fourth laser light sources can be disposed at positions away from the optical axis, for example, positions orthogonal to the optical axis, and each of the laser light sources and a corresponding one of the reflecting surfaces are connected by an optical path including an afocal system from which a collimated light bundle exits, so that the influence of the position (distance) of each of the reflecting surfaces on the condenser lens can be reduced. Consequently, a more compact light source device that can emit a laser light in which laser lights from a plurality of laser light sources are converged via the condenser lens can be provided.

Description

BRIEF DESCRIPTION OF DRAWINGS

[0007] FIG. **1** is a diagram illustrating a schematic configuration of a heating system.

[0008] FIG. **2** is a diagram illustrating a schematic configuration of a light source device.

[0009] FIG. **3** is a diagram illustrating an example of a laser module in an XY plane (plan view).

[0010] FIG. **4** is a top view of the laser module.

[0011] FIG. **5** is a diagram illustrating an example of a laser diode (LD) package.

[0012] FIG. **6** is an image showing a simulation result of an example of states of laser lights on a multiplexing surface.

[0013] FIG. **7** is a diagram illustrating another outline of a laser module.

[0014] FIG. **8** is a diagram illustrating the laser module in an XY plane (plan view).

[0015] FIG. **9** is a top view of the laser module.

[0016] FIG. **10** is an image showing an example of states of laser lights on a multiplexing surface.

[0017] FIG. **11**A is an image showing an example of a state of an irradiation area.

[0018] FIG. **11**B is an image showing an example of a state of an irradiation area.

DETAILED DESCRIPTION

[0019] FIG. **1** illustrates a schematic configuration of a heating system configured to heat an object, for example, an electrode material of a secondary battery, as an example of a processing apparatus that emits a plurality of laser beams. The heating system **1** includes a conveying device **4** that conveys a heating target **3** in a first direction (Y direction), and a heating device **2** that emits a laser light **7** for heating toward the conveying device **4**. The heating device **2** includes a plurality of heating modules **100** arranged in the conveyance direction (Y direction). Each of the heating modules **100** includes a plurality of light source devices **10** and an optical system **110** that is configured to bundle light emitted from the plurality of light source devices **10** and to cause the heating target **3** to be irradiated with the bundled light. An example of the optical system **110** is an optical system (optical axis adjustment optical system) including a plurality of projector optical axis adjustment mechanisms. Each of the light source devices **10** is arranged so as to be shorter in an X direction orthogonal to the conveyance direction and longer in a direction (Y direction) orthogonal to the X direction, and the plurality of light source devices **10** are included in the heating module **100**. These light source devices **10** are aligned in the X direction such that an axis (optical axis) along which the laser light **7** is emitted extends a direction (Z direction) orthogonal to the X and Y directions and such that a short-side direction of each light source device **10** coincides with the X direction. The laser light **7** emitted from each of the light source devices **10** is irradiated on a substantially rectangular irradiation area (projected region) **5** whose length in the X direction is longer than its length in the Y direction on the surface of the heating target **3** via the optical axis adjustment optical system **110**, and the inside of the irradiation area **5** is irradiated with substantially uniform intensity (illuminance). Accordingly, the heating target **3** can be heated substantially uniformly by the heating device **2**

[0020] FIG. **2** illustrates an example of the light source device **10**. FIG. **2** is a plan view perpendicular to an X-axis. The light source device **10** includes a laser module **20** including a plurality of laser light sources, a homogenizing optical system **11** that further homogenizes the laser light **7** exited a condenser lens **28** of the laser module **20** and causes the homogenized laser light to exit it, and a projection optical system **13** that projects the laser light **7** exited the homogenizing optical system **11** toward the irradiation area **5** via the optical axis adjustment optical system **110**. Examples of the homogenizing optical system **11** include a component including a rod integrator **11***a*. The rod integrator **11***a* has a cylindrical shape, and propagates a laser light incident on the incident surface thereof toward an emission surface while totally reflecting the laser light at the inner wall thereof. Thus, a laser light having a uniform light amount over the entire area of the emission surface is emitted from the emission surface of the homogenizing optical system **11**. In another example, in the homogenizing optical system **11**, reflection of the laser light by the rod integrator **11***a* is not a total reflection. The homogenizing optical system **11** can be combined with other optical elements such as a scattering plate and a fly-eye lens, and can be configured satisfying desired homogenization requirements. The projection optical system **13** can be a lens system including one or more lenses and can include other optical elements such as mirrors or prisms to bend an optical axis **8**.

[0021] FIG. **3** illustrates a configuration of the laser module **20** viewed from a plane perpendicular to the optical axis **8** (XY plane in plan view), and FIG. **4** illustrates a configuration of the laser module **20** viewed from a plane perpendicular to a Y axis (ZX plane in plan view). The laser module **20** includes a first laser light source **31***a* that emits a first laser light **37***a*, a second laser light source **31***b* that emits a second laser light **37***b*, a third laser light source **31***c* that emits a third laser light **37***c*, a fourth laser light source **31***d* that emits a fourth laser light **37***d*, and a condenser lens (condenser lens) **28**. The condenser lens **28** can be constituted by one lens or a plurality of lenses.

[0022] The laser module **20** further includes a first reflective element **33***a*, a second reflective element **33***b*, a third reflective element **33***c*, and a fourth reflective element **33***d*.

When a plan view (XY plane) of the laser module **20** taken in a direction along the optical axis **8** of the condenser lens **28** is divided into a first quadrant **41**, a second quadrant **42**, a third quadrant **43**, and a fourth quadrant **44** with the position of the optical axis **8** serving as the origin of the quadrants, the first reflective element **33***a* is disposed in a range of the first quadrant **41**, the second reflective element **33***b* is disposed in a range of the second quadrant **42**, the third reflective element **33***c* is disposed in a range of the third quadrant **43**, and the fourth reflective element **33***d* is disposed in a range of the fourth quadrant **44**. An example of the reflective elements **33***a* to **33***d* is a prism or a mirror. As illustrated in FIG. **2**, the first reflective element **33***a* has a first reflecting surface **32***a* located at a first distance L**1** along the optical axis **8** from the condenser lens **28** such that the reflection direction of the first laser light **37***a* is directed toward the condenser lens **28** along the optical axis **8**. The second reflective element **33***b* has a second reflecting surface **32***b* located at a second distance L**2** along the optical axis **8** from the condenser lens **28** such that the reflection direction of the second laser light **37***b* is directed toward the condenser lens **28** along the optical axis **8**. Similarly, the third reflective element **33***c* has a third reflecting surface **32***c* located at a third distance L**3** along the optical axis **8** from the condenser lens **28** such that the reflection direction of the third laser light **37***c* is directed toward the condenser lens **28** along the optical axis **8**. The fourth reflective element **33***d* has a fourth reflecting surface **32***d* disposed at a fourth distance L**4** along the optical axis **8** from the condenser lens **28** such that the reflection direction of the fourth laser light **37***d* is directed toward the condenser lens **28** along the optical axis **8**.

[0023] As illustrated in FIG. **2**, the first distance L**1** is typically a distance along the optical axis **8** from the center of the first reflecting surface **32***a* to a surface **28***a* of the condenser lens **28** on the first reflecting surface **32***a* side (hereinafter referred to as an "inner surface **28***a*"). Similarly, the second distance L**2** is typically a distance along the optical axis **8** from the center of the second reflecting surface **32***b* to the inner surface **28***a* of the condenser lens **28**. The third distance L**3** is typically a distance along the optical axis **8** from the center of the third reflecting surface **32***c* to the inner surface **28***a* of the condenser lens **28**. The fourth distance L**4** is typically a distance along the optical axis **8** from the center of the fourth reflecting surface **32***d* to the inner surface **28***a* of the condenser lens **28**. In this example, the first distance L**1** and the third distance L**3** are equal to each other, and the second distance L**2** and the fourth distance L**4** are equal to each other. The second distance L**2** is set longer than the first distance L**1**, and the fourth distance L**4** is set longer than the third distance L**3**. The relationship among these distances L**1** to L**4** is not limited to the above, but the relationship described above is a preferable example for providing a compact laser module **20**.

[0024] The laser module **20** further includes a first afocal system **35***a* disposed on a first optical path **34***a* between the first laser light source **31***a* and the first reflecting surface **32***a* such that the first laser light **37***a* exits it toward the first reflecting surface **32***a*. Similarly, the laser module **20** includes a second afocal system **35***b* disposed on a second optical path **34***b* from the second laser light source **31***b* to the second reflecting surface **32***b* such that the second laser light **37***b* exits it toward the second reflecting surface **32***b*. The laser module **20** includes a third afocal system **35***c* disposed on a third optical path **34***c* from the third laser light source **31***c* to the third reflecting surface **32***c* such that the third laser light **37***c* exits it toward the third reflecting surface **32***c*. The laser module **20** includes a fourth afocal system **35***d* disposed on a fourth optical path **34***d* from the fourth laser light source **31***d* to the fourth reflecting surface **32***d* such that the fourth laser light **37***d* exits it toward the fourth reflecting surface **32***d*.

[0025] The first to fourth afocal systems **35***a* to **35***d* can have a common configuration and include, for example, lenses **51** having a positive power and disposed on the sides of the laser light sources **31***a* to **31***d*, respectively, and lenses **52** having a negative power and disposed on the sides of the reflecting surfaces **32***a* to **32***d*, respectively.

The lens **51** having a positive power can have a configuration of one lens having a positive power, a configuration of a plurality of lenses, or a combination of a lens having a positive power and a lens having a negative power. The lens **52** having a negative power can have a configuration of one lens having a negative power, a configuration of a plurality of lenses, or a combination of a lens having a negative power and a lens having a positive power. The afocal system including the lens **51** having a positive power and the lens **52** having a negative power has a relatively short overall length and is one example of a system suitable for providing a compact laser module **20**. The configurations of the first to fourth afocal systems **35***a* to **35***d* are not limited to a lens system and can be a combination of mirror surfaces or a combination of a mirror surface and a lens, or can be a configuration including other optical elements such as a prism, as long as the configurations serve as non-focus optical systems from which the respective laser lights (each being a substantially parallel laser light bundle) **37***a* to **37***d*, incident from the respective laser light sources **31***a* to **31***d*, exit as substantially parallel light bundles.

[0026] Each of the first to fourth laser light sources **31***a* to **31***d* can contain a single semiconductor laser element (laser diode) or a plurality of semiconductor laser elements (laser diodes). Each of the first to fourth laser light sources **31***a* to **31***d* of this example includes, for example, an LD assembly **56** containing four LD packages **55**, in each of which a plurality of semiconductor laser elements are arranged in four rows and seven columns and packaged. Accordingly, each of the first to fourth afocal systems **35***a* to **35***d* causes a respective one of the first laser light (laser light bundle) **37***a* to the fourth laser light (laser light bundle) **37***d*, in each of which the laser beams emitted from the **112** semiconductor laser elements are concentrated and collimated, to be incident on a corresponding one of the reflecting surfaces **32***a* to **32***d*. Therefore, the laser module **20** can concentrate laser beams emitted from the **448** semiconductor laser elements via the condenser lens **28** and emit the concentrated laser beams as the laser light **7**.

[0027] FIG. **5** illustrates an example of the LD package **55**. The LD package **55** includes a base **58** and a collimating lens **57** illustrated in FIG. **5**.

[0028] The base **58** can be formed using, for example, a metal material such as iron, an iron alloy, or copper. The substrate **58** can also be formed using a ceramic material such as AIN, SiC, or SiN. The base **58** can also be formed by forming a base portion **58***b* and a sidewall portion **58***a* using different materials and then bonding the base portion **58***b* and the sidewall portion **58***a* together. A metal lead pin can be provided on the sidewall portion **58***a* to be used as a part of a wiring. An insulating member can be provided between the sidewall portion **58***a* and the lead pin to prevent short-circuits.

[0029] The collimating lens **57** includes a plurality of lens surfaces arranged in a matrix of M rows and N columns (M is a natural number and M≥2 and N is a natural number and N≥3). The lens portion corresponds to the number of semiconductor laser elements to be mounted. The collimating lens **57** can be formed using a material having transmissivity such as glass or synthetic quartz.

[0030] The semiconductor laser elements are disposed in a matrix of M rows N columns. In the example of FIG. **5**, the semiconductor laser elements are disposed in a matrix of four rows and seven columns. The emission peak wavelength of the semiconductor laser elements can be, for example, in a range from 420 nm to 750 nm. The semiconductor laser elements can emit a blue laser light and have an emission peak wavelength in a range from 420 nm to 490 nm. The semiconductor laser elements can be multimode lasers to increase output. The semiconductor laser element can include a first semiconductor laser element having an emission peak wavelength of a first wavelength, and a second semiconductor laser element having an emission peak wavelength of a second wavelength different from the first wavelength. In the processing apparatus illustrated in FIG. **1**, when two or more kinds of substances are included in the heating target **3**, an absorption coefficient can be different for each substance. In this case, by appropriately adjusting the first wavelength and the second wavelength, the heating target **3** can be efficiently heated.

[0031] The light source device **10** includes the laser module **20** in which the first reflecting surface **32***a* to the fourth reflecting surface **32***d* are disposed respectively corresponding to the first quadrant **41** to the fourth quadrant **44** around the optical axis **8** of the condenser lens **28**. At the first reflecting surface **32***a* to the fourth reflecting surface **32***d*, the laser beams emitted from the plurality of semiconductor laser elements through each of the first afocal system **35***a* to the fourth afocal system **35**d are concentrated (bundled). Thus, the first laser light **37***a* to the fourth laser light **37***d* collimated to a small diameter are reflected toward the condenser lens **28** along the optical axis **8**. Accordingly, the plurality of laser lights **37***a* to **37***d* dispersed in a narrow range (range in which a beam diameter is small) around the optical axis **8** can be incident on the condenser lens **28**. The plurality of laser lights **37***a* to **37***d* via the condenser lens **28** have a high energy density. When the laser lights **37***a* to **37***d* pass through the homogenizing optical system **11**, the laser light **7** having high energy density and high homogeneity is emitted.

[0032] In the laser module **20**, with the first reflecting surface **32***a* to the fourth reflecting surface **32***d* disposed in the first quadrant **41** to the fourth quadrant **44**, respectively, with the position of the optical axis **8** in the plan view (XY plane) serving as the origin, the laser lights **37***a* to **37***d* input to the condenser lens **28** can be distributed to the first quadrant **41** to the fourth quadrant **44**, respectively, and the coherent laser lights **37***a* to **37***d* can be incident on the condenser lens **28** while avoiding overlapping thereof. Moreover, the first reflecting surface **32***a* to the fourth reflecting surface **32***d* are located in the first quadrant **41** to the fourth quadrant **44**, respectively, so that respective optical systems can be disposed in each of the first quadrant **41** to the fourth quadrant **44**. Therefore, the flexibility of the arrangement of the optical systems that cause the first laser light

37*a* to the fourth laser light **37***d* to be incident on the first reflecting surface **32***a* to the fourth reflecting surface **32***d*, respectively, is increased, and the laser module **20** including the optical system for integrating laser beams from a large number of laser elements and emitting the laser lights **37***a* to **37***d* with high density can be made compact.

[0033] For example, the first reflecting surface **32***a* to the fourth reflecting surface **32***d* allow the first laser light source **31***a* to the fourth laser light source **31***d* to be disposed at positions away from the optical axis **8**, typically, at positions orthogonal to the optical axis **8**. Specifically, the optical axis **8** is orthogonal to the surface of a first substrate **25** to be described below on which the first laser light source **31***a* and the second laser light source **31***b* are disposed. The optical axis **8** is orthogonal to the surface of a second substrate **26** on which the third laser light source **31***c* and the fourth laser light source **31***d* are disposed. Moreover, the optical paths **34***a* to **34***d* respectively including the afocal systems **35***a* to **35***d*, which respectively causes laser lights from the laser light sources **31***a* to **31***d* to be collimated and to be incident on the reflecting surfaces **32***a* to **32***d*, can be orthogonal to the optical axis **8**. Accordingly, the laser module **20**, which is configured to concentrate light beams from a large number of laser elements and to emit the concentrated light beams, can be reduced in length in the direction (Z direction) of the optical axis **8**.

[0034] In addition, the laser lights **37***a* to **37***d* are collimated by the afocal systems **35***a* to **35***d*, respectively, whereby, even if the distance L**1** to L**4** from the condenser lens **28** to the respective reflecting surfaces **32***a* to **32***d* are changed, the laser lights **37***a* to **37***d* can be incident on the condenser lens **28** without substantial change in the areas of the light bundles that reach the condenser lens **28**. Accordingly, the positions (distances) L**1** to L**4** of the reflecting surfaces **32***a* to **32***d* can have less influence on the condenser lens **28**, and the selectivity of the positions (distances) L**1** to L**4** of the reflecting surfaces **32***a* to **32***d* can be improved. Consequently, when the clearance in the direction (Z direction) of the optical axis **8** is secured, as illustrated in FIG. **3**, in plan view (XY plane), at least some of the optical paths **34***a* to **34***d* including the afocal systems **35***a* to **35***d* from the plurality of laser light sources **31***a* to **31***d* respectively to the reflecting surfaces **32***a* to **32***d* can overlap each other. Even when at least some of the optical paths **34***a* and **34***b* or at least some of the optical paths **34***c* and **34***d* overlap each other, the laser lights **37***a* to **37***d* are reduced in size and collimated by the afocal systems **35***a* to **35***d*, respectively, and are incident on the condenser lens **28**. This makes it possible to provide the laser module **20** and the light source device **10** that are more compact and can emit a laser light in which the plurality of laser lights **37***a* to **37***d* are concentrated (bundled) via the condenser lens **28**.

[0035] The laser module **20** of this example includes an upper module **21** disposed on an upper side (+ direction on Y-axis) of the optical axis (Z-axis) **8** including the first optical path **34***a* and the second optical path **34***b* respectively including the first afocal system **35***a* and the second afocal system **35***b*, and a lower module **22** disposed on a lower side (− direction on the Y-axis) of the optical axis **8** including the third optical path **34***c* and the fourth optical path **34***d* respectively including the third afocal system **35***c* and the fourth afocal system **35***d*. With first optical path **34***a* to the fourth optical path **34***d* established separately in the upper and lower sides, the length of the laser module **20** in the direction (Z direction) of the optical axis **8** can be reduced. The optical paths **34***a* to **34***d* respectively including the afocal systems **35***a* to **35***d* can also be concentrated on one side, for example, the upper side (for example, + direction on the Y-axis) with respect to the optical axis **8**.

[0036] Moreover, by changing the first distance L**1** of the first reflecting surface **32***a* and the second distance L**2** of the second reflecting surface **32***c*, optical elements such as lenses included in the first optical path **34***a* and the second optical path **34***b* and the laser light sources **31***a* and **31***b* can overlap each other in plan view (XY plane) as illustrated in FIG. **3**. As an example, as illustrated in FIGS. **3** and **4**, when the second distance L**2** is longer than the first distance L**1**, the largest lenses **51** of the afocal systems **35***a* and **35***b* can partially overlap each other in the XY plane. Alternatively, the largest lenses **51** of the afocal systems **35***a* and **35***b* can partially overlap each other in the YZ plane. The laser light sources **31***a* and **31***b* can also partially overlap each other in the XY plane and/or the YZ plane. Similarly, the third distance L**3** of the third reflecting surface **32***c* and the fourth distance L**4** of the fourth reflecting surface **32***d* can be changed. For example, with the fourth distance L**4** is longer than the third distance L**3**, the laser light source **31***c* and the laser light source **31***d* and optical elements such as lenses included in the third optical path **34***c* and the fourth optical path **34***d* can overlap each other in plan view (XY plane). Therefore, the distances of the laser module **20** in the Z direction and the X direction can be reduced, and the laser module **20** that is more compact and the light source device **10** including the laser module **20** can be provided.

[0037] As described above, the distances L**1** to L**4** between the condenser lens **28** and the first reflecting surface **32***a* to the fourth reflecting surface **32***d*, respectively, can be flexibly set. An example of the laser module **20** having a compact and highly symmetric arrangement is the laser module **20** in which the first distance L**1** between the first reflecting surface **32***a* of the upper module **21**, which is disposed in the first quadrant **41**, and the condenser lens **28** is equal to the third distance L**3** between the third reflecting surface **32***c* of the lower module **22**, which is disposed in the third quadrant **43**, and the condenser lens. Further, in this laser module **20**, the second distance L**2** between the second reflecting surface **32***b* of the upper module **21**, which is disposed in the second quadrant **42**, and the condenser lens **28** is equal to the fourth distance L**4** between the fourth reflecting surface **32***d* of the lower module **22**, which is disposed in the fourth quadrant **44**, and the condenser lens. In the laser module **20**, an optical path length of the first optical path **34***a*, including the first afocal system **35***a*, from the first reflecting surface **32***a* to the first laser light source **31***a* can be equal to an optical path length of the third optical path **34***c*, including the third afocal system **35***c*, from the third reflecting surface **32***c* to the third laser light source **31***c*. In addition, an optical path length of the second optical path **34***b*, including the second afocal system **35***b*, from the second reflecting surface **32***b* to the second laser light source **31***b* can be equal to an optical path length of the fourth optical path **34***d* including the fourth afocal system **35***d* from the fourth reflecting surface **32***d* to the fourth laser light source **31***d*.

[0038] Moreover, in the laser module **20**, in a plan view (XY plane), the first reflecting surface **32***a* and the third reflecting surface **32***c* can be disposed at positions of point symmetry (first point symmetry) about the optical axis **8**, and the second reflecting surface **32***b* and the fourth reflecting surface **32***d* can be disposed at positions of point symmetry (second point symmetry) about the optical axis **8**. In the laser module **20**, a configuration of a first optical system **61** of a path from the first laser light source **31***a* to the condenser lens **28**, including the optical path length, is the same as (that is, identical to) a configuration of a third optical system **63** of a path from the third laser light source **31***c* to the condenser lens **28**, and the first laser light **37***a* and the third laser light **37***c* emitted from them are incident on the condenser lens **28** in point symmetry about the optical axis **8**. In addition, a configuration of a second optical system **62** of a path from the second laser light source **31***b* to the condenser lens **28**, including the optical path length, is the same as (that is, identical to) a configuration of a fourth optical system **64** of a path from the fourth laser light source **31***d* to the condenser lens **28**, and the second laser light **37***b* and the fourth laser light **37***d* emitted from them are incident on the condenser lens **28** in point symmetry about the optical axis **8**. This facilitates the homogenization by the homogenizing optical system **11**. This will be described in detail below.

[0039] FIG. **6** is a simulation result showing an example of the illuminance distribution of the laser lights **37***a* to **37***d* on a multiplexing surface **29**. As shown in FIG. **6**, on the multiplexing surface **29** on an upstream side of the condenser lens **28**, the first laser light **37***a* and the third laser light **37***c* that are incident from the optical paths having a common configuration including the optical path length are at the same magnification. Therefore, laser beams from a large number of laser diodes have a common intensity distribution as a bundle of laser beams. In addition, the second laser light **37***b* and the fourth laser light **37***d* that are incident from the optical paths having a common configuration including the optical path length are at the same magnification. Therefore, laser beams from a large number of laser diodes have a common intensity distribution as a bundle of light beams. On the other hand, the distances L**1** and L**3** are different from the distances L**2** and L**4**, so that the spread of the first laser light **37***a* and the third laser light **37***c* is different from the spread of the second laser light **37***b* and the fourth laser light **37***d*. By combining light bundles in which two sets of laser lights having different distributions, that is, a set of the laser lights **37***a* and **37***c* and a set of the laser lights **37***b* and **37***d* are arranged in point symmetry, by the condenser lens **28**, the laser light **7** having higher homogeneity can be emitted from the laser module **20**.

[0040] For example, a state in which the illuminance distributions of the first laser light **37***a* and the fourth laser light **37***d* are reversed from those described above would be considered. In that case, due to the asymmetry of the illuminances on the multiplexing surface **29**, even though the first laser light **37***a* to the fourth laser light **37***d* pass through the homogenizing optical system **11**, there would be unevenness in the illuminance distribution.

[0041] Moreover, locations of the first reflecting surface **32***a* and the third reflecting surface **32***c* at the first point-symmetrical positions about the optical axis **8** and locations of the second reflecting surface **32***b* and the fourth reflecting surface **32***d* at the second point-symmetrical positions about the optical axis **8** can be respectively interchangeable with each other in the plan view (XY plane). That is, the position of the first reflecting surface **32***a* and the position of the second reflecting surface **32***b* around the optical axis **8** can be interchangeable (replaceable) with each other, and the position of the third reflecting surface **32***c* and the position of the fourth reflecting surface **32***d* can be interchangeable (replaceable) with each other. In one typical example, the arrangement of the first reflecting surface **32***a* and the third reflecting surface **32***c* can be symmetrical to the arrangement of the second reflecting surface **32***b* and the fourth reflecting surface **32***d* with respect to the X-axis, and the arrangement of the first reflecting surface **32***a* and the second reflecting surface **32***b* can be symmetrical to the arrangement of the third reflecting surface **32***c* and the fourth reflecting surface **32***d* with respect to the Y-axis. When the first to fourth laser lights **37***a* to **37***d* enters the condenser lens **28** in a state of high symmetry around the optical axis **8** and are combined (multiplexed), the laser light **7** with higher homogeneity can be emitted from the laser module **20**.

[0042] With these reflecting surfaces **32***a* to **32***d* located close to the optical axis **8** in a state of high symmetry, the laser lights **37***a* to **37***d* can be incident on the condenser lens **28** in a state of high density. Therefore, these laser lights **37***a* to **37***d* can be combined by the more compact condenser lens **28**, and the more compact laser module **20** can be provided.

[0043] As illustrated in FIG. **3**, in a plan view (XY plane), a distance W**12** between the center of a use region of the first reflecting surface **32***a* and the center of a use region of the second reflecting surface **32***b* can be larger than the maximum diameter of each of the use region of the first reflecting surface and the use region of the second reflecting surface, for example, a diagonal distance W**1** of each of these reflecting surfaces, and can be smaller than the maximum value of a maximum effective diameter of the first afocal system **35***a* and a maximum effective diameter of the second afocal system, for example, a diameter D**1** of the lens **51** having a positive power. In addition, a distance W**34** between the center of a use region of the third reflecting surface **32***c* and the center of a use region of the fourth reflecting surface **32***d* can be larger than the maximum diameter of each of the use region of the third reflecting surface **32***c* and the use region of the fourth reflecting surface **32***d*, for example, a diagonal distance W**2** of each of these reflecting surfaces, and can be smaller than the maximum value of a maximum effective diameter of the third afocal system **35***c* and a maximum effective diameter of the fourth afocal system **35***d*, for example, the diameter D**1** of the lens **51** having a positive power. Thus, even when the laser lights **37***a* to **37***d* are emitted at a high density, unintended interferences of the members are less likely to occur.

[0044] In the laser module **20**, the first laser light source **31***a* and the second laser light source **31***b* can be equidistantly disposed along the Y-axis with respect to the first reflecting surface **32***a* and the second reflecting surface **32***b*, respectively, of the upper module **21**. In addition, the third laser light source **31***c* and the fourth laser light source **31**d can be equidistantly disposed along the Y-axis with respect to the third reflecting surface **32***c* and the fourth reflecting surface **32***d*, respectively, of the lower module **22**. Therefore, the laser module **20** can further include the first substrate **25**, which supports the first laser light source **31**a and the second laser light source **31***b* of the upper module **21**, and the second substrate **26**, which supports the third laser light source **31***c* and the fourth laser light source **31***d* of the lower module **22**, on the side opposite to the first substrate **25** with respect to the optical axis **8**. The first substrate **25** and the second substrate **26** can be flat plates. The first laser light source **31***a* and the second laser light source **31***b* can be disposed on both sides of a first center line **25***a* of the first substrate **25** parallel to the optical axis **8**. The third laser light source **31***c* and the fourth laser light source **31***d* can be disposed on both sides of a second center line **26***a* of the second substrate **26** parallel to the optical axis **8**.

[0045] The first substrate **25** and the second substrate **26** can be heat dissipation substrates, substrates having high thermal conductivity such as aluminum, substrates provided with a heat sink, or substrates including a mechanism for forced cooling such as water cooling or air cooling.

[0046] In this way, the laser module **20** of this example is compact and can output the laser light **7** with high homogeneity in which laser beams from a large number of laser elements are concentrated (bundled). Consequently, the light source device **10** including the laser module **20** is not only suitable for illumination of a projector but also suitable as a light source device of the heating system **1** for a process such as drying and heat generation in which a laser light having an increased energy density is required. The laser module **20** of this example is relatively compact, in particular, in the X direction. Thus, for example, the width of the light source device **10** in the X direction as illustrated in FIG. **1** can be made equal to or less than the width of the conveying device **4** in the X direction. Thus, the heating system **1** is reduced in size.

[0047] Moreover, in the laser module **20** of this example, the first optical path **34***a* including the first afocal system **35***a* of the upper module **21** and the second optical path **34***b* including the second afocal system **35***b* partially overlap in + direction on the Y-axis, and the third optical path **34***c* including the third afocal system **35***c* of the lower module **22** and the fourth optical path **34***d* including the fourth afocal system **35***d* partially overlap in-direction on the Y-axis. Therefore, both the first substrate **25** on which the first laser light source **31***a* and the second laser light source **31***b* are mounted and the second substrate **26** on which the third laser light source **31***c* and the fourth laser light source **31***d* are mounted can have a rectangular shape which is shorter in the X direction and longer in the Z direction.

[0048] The laser module **20** including the upper module **21** and the lower module **22** has a rectangular shape which is shorter in the X direction and longer in the Y direction in the XY plane (plan view) and extends in the Z direction, and can have a rectangular parallelepiped shape which is short in the X direction as a whole. Therefore, the light source device **10** including the laser module **20** can be compactly disposed such that the X direction thereof is a short-side direction (short side). Consequently, as illustrated in FIG. **1**, with the plurality of light source devices **10** disposed such that the short-side directions of the first substrate **25** and the second substrate **26** coincide with a direction perpendicular to the optical axis **8** in plan view (that is, the XZ plane) in which the X direction of the light source devices **10** is typically perpendicular to the conveyance direction (that is, the first direction), the heating module **100**, which includes the plurality of light source devices **10** and can be disposed short and compact in the conveyance direction, can be provided. This allows for providing the heating device **2** that continuously irradiates the heating target **3** conveyed by the conveying device **4** with a plurality of laser lights **7** having high homogeneity.

[0049] FIGS. **7** to **9** illustrate an example of a different laser module **20***a* of certain embodiments of the present disclosure. Like the laser module **20** illustrated in FIG. **2**, the laser module **20***a* is also a module that can be included in the light source device **10** together with the homogenizing optical system **11** and the like. FIG. **7** illustrates a configuration of the laser module **20***a* viewed from a lateral side (X direction), FIG. **8** illustrates a configuration of the laser module **20***a* viewed from a rear side in a plane (Z direction, plan view, XY plane) perpendicular to the optical axis **8**, and FIG. **9** illustrates a configuration of the laser module **20***a* viewed from above (Y direction). Configurations of the laser module **20***a* that are different from those of the laser module **20** will be described below. Configurations of the laser module **20***a* that are the same as that of the laser module **20** will not be specifically described below.

[0050] The laser module **20***a* differs from the laser module **20** in that the laser module **20***a* further has the following configuration. The laser module **20***a* includes a fifth laser light source **31***e* that emits a fifth laser light **37***e*, a sixth laser light source **31***f* that emits a sixth laser light **37***f*, a seventh laser light source **31***g* that emits a seventh laser light **37***g*, and an eighth laser light source **31***h* that emits an eighth laser light **37***h*. The laser module **20***a* further includes a fifth reflecting surface **32***e* located between the first reflecting surface **32***a* and the second reflecting surface **32***b* in plan view (XY plane) such that the reflection direction of the fifth laser light **37***e* is directed toward the condenser lens **28** along the optical axis **8**, and a sixth reflecting surface **32***f* located between the third reflecting surface **32***c* and the fourth reflecting surface **32***d* in plan view (XY plane) such that the reflection direction of the sixth laser light **37***f* is directed toward the condenser lens **28** along the optical axis **8**. The fifth reflecting surface **32***e* is one of surfaces of a fifth reflective element **33***e*. The sixth reflecting surface **32***f* is one of surfaces of a sixth reflective element **33***f*. Moreover, the laser module **20***a* includes a fifth afocal system **35***e* disposed on a fifth optical path **34***e* from the fifth laser light source **31***e* to the condenser lens **28** such that the fifth laser light **37***e* exits toward the fifth reflecting surface **32***e*, and a sixth afocal system **35***f* disposed on a sixth optical path **34***f* from the sixth laser light source **31***f* to the condenser lens **28** such that the sixth laser light **37***f* exits toward the sixth reflecting surface **32***f*.

[0051] The fifth laser light source **31***e* constitutes the upper module **21** together with the first laser light source **3***a* and the second laser light source **31***b*, and the fifth afocal system **35***e* from the fifth laser light source **31***e* to the fifth reflecting surface **32***e* is included in the upper module **21**. In the laser module **20***a* of this example, the fifth reflecting surface **32***e* is disposed at a position that allows a distance (fifth distance) L**5** along the optical axis **8** is equal to or longer than the first distance L**1** and equal to or shorter than the second distance L**2**. The distance L**5** between the fifth reflecting surface **32***e* and the condenser lens **28** can be shorter than the first distance L**1** or longer than the second distance L**2**.

[0052] The sixth laser light source **31***f* constitutes the lower module **22** together with the third laser light source **31***c* and the fourth laser light source **31***d*, and the sixth afocal system **35***f* from the sixth laser light source **31***f* to the sixth reflecting surface **32***f* is included in the lower module **22**. In the laser module **20***a* of this example, the sixth reflecting surface **32***f* is disposed at a position where a distance (sixth distance) L**6** along the optical axis **8** is equal to the fifth distance L**5**, and is equal to or longer than the third distance L**3** and equal to or shorter than the fourth distance L**4**. The distance L**6** between the sixth reflecting surface **32***f* and the condenser lens **28** can be shorter than the third distance L**3** or longer than the fourth distance L**4**. Although the fifth distance L**5** and the sixth distance L**6** need not be equal to each other, an optical path from the fifth laser light source **31***e* to the fifth reflecting surface **32***e* and an optical path from the sixth laser light source **31***f* to the sixth reflecting surface **32***f* are disposed at corresponding positions in the upper module **21** and the lower module **22**, so that the laser module **20***a* that is more compact in the direction of the optical axis **8** (Z direction) can be provided.

[0053] The optical element **33***g* can be a mirror or a prism.

[0054] The laser module **20***a* includes a middle module **23** provided behind the upper module **21** and the lower module **22** (at a position away from the condenser lens **28**). The middle module **23** includes a seventh laser light source **31***g* disposed at a seventh distance L**7** on the upper side (+ side in the Y direction), and a seventh afocal system **35***g* disposed on a seventh optical path **34***g* from the seventh laser light source **31***g* to the condenser lens **28** such that a seventh laser light **37***g* exits toward a seventh reflecting surface **32***g*. The middle module **23** includes an eighth afocal system **35***h* disposed on an eighth optical path **34***h* from the eighth laser light source **31***h* disposed at an eighth distance L**8** to the condenser lens **28** such that an eighth laser light **37***h* exits toward an eighth reflecting surface **32***h*. Each of the fifth afocal system **35***e* to the eighth afocal system **35***h* can include the lens **51** having a positive power and the lens **52** having a negative power similarly to the first afocal system **35***a* to the fourth afocal system **35***d*.

[0055] Similarly to the first laser light source **31***a* to the fourth laser light source **31***d*, each of the fifth laser light source **31***e* to the eighth laser light source **31***h* can include the LD assembly **56** containing four LD packages **55**. The LD package **55** of this example includes a plurality of semiconductor laser elements arranged in four rows and seven columns. Consequently, in the laser module **20***a* of this example, laser beams emitted from a total of 896 semiconductor laser elements included in a total of 32 LD packages **55** can be concentrated (bundled) by the condenser lens **28** and emitted as the laser light **7**.

[0056] FIG. **10** illustrates an example of the illuminance distribution of the laser lights **37***a* to **37***h* projected (input) onto the multiplexing surface **29** on the upstream side of the condenser lens **28**. The first laser light **37***a* and the third laser light **37***c* are incident on the multiplexing surface **29** in point symmetry, the second laser light **37***b* and the fourth laser light **37***d* are incident on the multiplexing surface **29** in point symmetry, the fifth laser light **37***e* is incident on a position between (intermediate position between) the position on which the first laser light **37***a* is incident and the position on which the second laser light **37***b* is incident, the sixth laser light **37***f* is incident on a position between (intermediate position between) the position on which the third laser light **37***c* is incident and the position on which the fourth laser light **37***d* is incident, the seventh laser light **37***g* is incident on a position between the position on which the first laser light **37***a* is incident and the position on which the second laser light **37***b* is incident, and the eighth laser light **37***h* is incident on a position between the position on which the second laser light **37***b* is incident and the position on which the fourth laser light **37***d* is incident. Consequently, the first laser light **37***a* to the eighth laser light **37***h* enter the condenser lens **28** in an arrangement with high density (in a dense state) and high symmetry. Therefore, the laser light **7** with high density and high homogeneity can be emitted through the condenser lens **28**.

[0057] In the laser module **20***a*, the first laser light source **31***a*, the fifth laser light source **31***e*, and the second laser light source **31***b* of the upper module **21** and the seventh laser light source **31***g* on the upper side of the middle module **23** can be aligned in the Z direction along the optical axis **8** so as to be concentrated in a narrow range in the X direction. Therefore, the laser light sources **31***a*, **31***e*, **31***b*, and **31***g* can be mounted on the common first substrate **25** that is long in the Z direction and short in the X direction, as in the laser module **20**. Similarly, in the laser module **20***a*, the third laser light source **31***c*, the sixth laser light source **31***f*, and the fourth laser light source **31***d* of the lower module **22** and the eighth laser light source **31***h* on the lower side of the middle module **23** can be aligned in the Z direction along the optical axis **8** so as to be concentrated in a narrow range in the X direction. Therefore, these laser light sources **31***c*, **31***f*, **31***d*, and **31***h* can be mounted on the common second substrate **26** that is long in the Z direction and short in the X direction. The first substrate **25** and the second substrate **26** can have a heat dissipation function or a cooling function.

[0058] In the laser module **20***a*, 32 LD packages **55** can be disposed such that the array of 32 LD packages **55** is longer in the Z direction and shorter in the X direction. Therefore, the light source device **10** including the laser module **20***a* is compact in the X direction as a whole, includes a large number of LD packages **55**, and can emit the laser light **7** with high density and higher homogeneity obtained by bundling laser beams from a large number of semiconductor laser elements.

[0059] FIG. **11**A is a simulation result of an example of the illuminance distribution of a laser light emitted from the light source device **10** when the illuminance distribution of the laser lights **37***a* to

37*h* on the multiplexing surface **29** is as shown in FIG. **10**. FIG. **11**A is an example of an irradiation area **5** exhibited by the laser light **7** emitted from the light source device **10** including the laser module **20** in which the first reflecting surface **32***a* and the third reflecting surface **32***c* are arranged rotationally symmetrically and the second reflecting surface **32***b* and the fourth reflecting surface **32***d* are arranged rotationally symmetrically.

[0060] FIG. **11**B is an example of an irradiation area **5***a* exhibited by a laser light emitted from a light source device including a laser module in which the first reflecting surface **32***a* and the third reflecting surface **32***c* are arranged line-symmetrically and the second reflecting surface **32***b* and the fourth reflecting surface **32***d* are arranged line-symmetrically. That is, with respect to the illuminance distribution of FIG. **10**, the first laser light **37***a* and the fourth laser light **37***d* are replaced with each other, and the illuminance distribution of FIG. **10** is horizontally inverted.

[0061] As shown in FIG. **11**B, even in an example in which the first reflecting surface **32***a* and the third reflecting surface **32***c* are not disposed rotationally symmetrically and the second reflecting surface **32***b* and the fourth reflecting surface **32***d* are not disposed rotationally symmetrically, a laser light having a high uniformity ratio of about 92% can be emitted. However, by employing the rotational symmetry, as shown in FIG. **11**A, a laser light having a higher uniformity ratio of about 98% can be emitted, and the heating target **3** can be more uniformly heated without unevenness. The uniformity ratio is obtained by measuring the illuminance distribution using an illuminance meter and calculating a minimum value/a maximum value of the obtained illuminance distribution×100 (%).

Claims

1. A light source device comprising: a first laser light source configured to emit a first laser light; a second laser light source configured to emit a second laser light; a third laser light source configured to emit a third laser light; a fourth laser light source configured to emit a fourth laser light; a condenser lens; a first reflecting surface located at a first distance along an optical axis of the condenser lens from the condenser lens such that a reflection direction of the first laser light is directed toward the condenser lens along the optical axis; a second reflecting surface located at a second distance along the optical axis from the condenser lens such that a reflection direction of the second laser light is directed toward the condenser lens along the optical axis; a third reflecting surface located at a third distance along the optical axis from the condenser lens such that a reflection direction of the third laser light is directed toward the condenser lens along the optical axis; a fourth reflecting surface located at a fourth distance along the optical axis from the condenser lens such that a reflection direction of the fourth laser light is directed toward the condenser lens along the optical axis; a first afocal system disposed on a first optical path from the first laser light source to the first reflecting surface such that the first laser light exits toward the first reflecting surface; a second afocal system disposed on a second optical path from the second laser light source to the second reflecting surface such that the second laser light exits toward the second reflecting surface; a third afocal system disposed on a third optical path from the third laser light source to the third reflecting surface such that the third laser light exits toward the third reflecting surface; and a fourth afocal system disposed on a fourth optical path from the fourth laser light source to the fourth reflecting surface such that the fourth laser light exits toward the fourth reflecting surface, wherein, when a plan view taken in a direction along the optical axis is divided into a first quadrant, a second quadrant, a third quadrant, and a fourth quadrant with a position of the optical axis serving as an origin, the first reflecting surface is located in the first quadrant, the second reflecting surface is located in the second quadrant, the third reflecting surface is located in the third quadrant, and the fourth reflecting surface is located in the fourth quadrant.

2. The light source device according to claim 1, wherein the second distance is longer than the first distance, the fourth distance is longer than the third distance, at least a part of the first optical path and at least a part of the second optical path overlap each other in the plan view, and at least a part of the third optical path and at least a part of the fourth optical path overlap each other in the plan view.

3. The light source device according to claim 2, wherein the first distance and the third distance are equal to each other, the second distance and the fourth distance are equal to each other, an optical path length of the first optical path and an optical path length of the third optical path are equal to each other, an optical path length of the second optical path and an optical path length of the fourth optical path are equal to each other, the first reflecting surface and the third reflecting surface are located at first point-symmetrical positions about the optical axis in the plan view, and the second reflecting surface and the fourth reflecting surface are located at second point-symmetrical positions about the optical axis in the plan view.

4. The light source device according to claim 3, wherein the first point-symmetrical positions and the second point-symmetrical positions are interchangeable with each other in the plan view.

5. The light source device according to claim 1, wherein at least one of the first afocal system, the second afocal system, the third afocal system, or the fourth afocal system comprises at least one lens having a positive refractive power and at least one lens having a negative refractive power.

6. The light source device according to claim 1, wherein in the plan view, a distance between a center of a use region of the first reflecting surface and a center of a use region of the second reflecting surface is larger than a maximum diameter of each of the use region of the first reflecting surface and the use region of the second reflecting surface, and is smaller than a maximum value of a maximum effective diameter of the first afocal system and a maximum effective diameter of the second afocal system, and a distance between a center of a use region of the third reflecting surface and a center of a use region of the fourth reflecting surface is larger than a maximum diameter of each of the use region of the third reflecting surface and the use region of the fourth reflecting surface, and is smaller than a maximum value of a maximum effective diameter of the third afocal system and a maximum effective diameter of the fourth afocal system.

7. The light source device according to claim 1, further comprising: a fifth laser light source configured to emit a fifth laser light; a sixth laser light source configured to emit a sixth laser light; a fifth reflecting surface located between the first reflecting surface and the second reflecting surface in the plan view such that a reflection direction of the fifth laser light is directed toward the condenser lens along the optical axis; a sixth reflecting surface located between the third reflecting surface and the fourth reflecting surface in the plan view such that a reflection direction of the sixth laser light is directed toward the condenser lens along the optical axis; a fifth afocal system disposed on a fifth optical path from the fifth laser light source to the condenser lens such that the fifth laser light exits toward the fifth reflecting surface; and a sixth afocal system disposed on a sixth optical path from the sixth laser light source to the condenser lens such that the sixth laser light exits toward the sixth reflecting surface.

8. The light source device according to claim 1, further comprising: a seventh laser light source configured to emit a seventh laser light; a seventh reflecting surface located between the first reflecting surface and the third reflecting surface in the plan view at a position farthest from the condenser lens such that a reflection direction of the seventh laser light is directed toward the condenser lens along the optical axis; and a seventh afocal system disposed on a seventh optical path from the seventh laser light source to the condenser lens such that the seventh laser light exits toward the seventh reflecting surface.

9. The light source device according to claim 8, further comprising: an eighth laser light source configured to emit an eighth laser light; an optical element comprising: the seventh reflecting surface, and an eighth reflecting surface on a side opposite to the seventh reflecting surface such that a reflection direction of the eighth laser light is directed toward the condenser lens along the optical axis; and an eighth afocal system disposed on an eighth optical path from the eighth laser light source to the condenser lens such that the eighth laser light exits toward the eighth reflecting surface.

10. The light source device according to claim 1, further comprising: a first substrate supporting the first laser light source and the second laser light source; and a second substrate supporting the third laser light source and the fourth laser light source on a side opposite to the first substrate with respect to the optical axis.

11. The light source device according to claim 10, wherein the first substrate and the second substrate are flat plates, the first laser light source and the second laser light source are disposed on both sides of a first center line of the first substrate, the first center line being parallel to the optical axis, and the third laser light source and the fourth laser light source are disposed on both sides of a second center line of the second substrate, the second center line being parallel to the optical axis.

12. The light source device according to claim 10, wherein the first substrate and the second substrate are heat dissipation substrates.

13. The light source device according to claim 1, further comprising a homogenizing optical system disposed on an exiting side of the condenser lens.

14. The light source device according to claim 1, wherein each of the first laser light source, the second laser light source, the third laser light source, and the fourth laser light source comprises a plurality of semiconductor laser elements.

15. A heating system comprising: a conveying device configured to convey a heating target in a first direction; and a heating module configured to emit a heating laser light toward the conveying device, wherein the heating module comprises a plurality of the light source devices according to claim 10, the heating module is disposed in the first direction, and the plurality of light source devices are arranged in the first direction such that short- side directions of the first substrate and the second substrate coincide with a direction perpendicular to a direction of the optical axis in a plan view perpendicular to the first direction.

16. The heating system according to claim 15, wherein the first substrate and the second substrate are flat plates, the first laser light source and the second laser light source are disposed on both sides of a first center line of the first substrate, the first center line being parallel to the optical axis, and the third laser light source and the fourth laser light source are disposed on both sides of a second center line of the second substrate, the second center line being parallel to the optical axis.

17. The heating system according to claim 15, wherein the first substrate and the second substrate are heat dissipation substrates.