US Patent & Trademark Office
Patent Public Search | Text View

United States Patent Application Publication	20250264358
Kind Code	A1
Publication Date	August 21, 2025
Inventor(s)	ASAKURA; Shinya

DETECTION DEVICE

Abstract

According to an aspect, a detection device includes: a light source device; an object placement member on which an object to be detected is placed; a liquid crystal shutter having divided regions; and an optical sensor having detection regions arranged in a plane. One of the detection regions includes one or more photodetection elements. The light source device includes a light-shielding wall disposed between two adjacent light-emitting elements out of the light-emitting elements. The divided regions in the liquid crystal shutter are each capable of being switched between a light-transmitting state and a non-light-transmitting state for each of the divided regions, and the light-emitting elements are each capable of being switched between a lit state and an unlit state for each of the light-emitting elements. The respective light-emitting elements, the respective divided regions of the liquid crystal shutter, and the respective detection regions overlap when viewed in the first direction.

Inventors: **ASAKURA; Shinya (Tokyo, JP)**

Applicant: **Japan Display Inc.** (Tokyo, JP)

Family ID: **1000008490749**

Appl. No.: **19/048053**

Filed: **February 07, 2025**

Foreign Application Priority Data

JP	2024-020777	Feb. 15, 2024

Publication Classification

Int. Cl.: **G01J1/04** (20060101); **G01J1/08** (20060101); **G01J1/16** (20060101)

U.S. Cl.:

CPC **G01J1/044** (20130101); **G01J1/08** (20130101); **G01J1/16** (20130101); G01J2001/1694 (20130101)

Background/Summary

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of priority from Japanese Patent Application No. 2024-020777 filed on Feb. 15, 2024, the entire contents of which are incorporated herein by reference.

BACKGROUND

1. Technical Field

[0002] What is disclosed herein relates to a detection device.

2. Description of the Related Art

[0003] Japanese Patent Publication No. 6830593 (JP-B-6830593) discloses a biosensor that includes an optical sensor including a photosensor (photodetection element), a culture vessel placed on the upper side of an imaging surface of the photosensor, and a point light source disposed above the culture vessel. The culture vessel accommodates therein a culture medium and a plurality of objects to be detected (microorganisms). In the biosensor of JP-B-6830593, light emitted from the point light source passes through the culture medium and the objects to be detected (microorganisms), and enters the photodiode. If a plurality of point light sources are provided to the biosensor according to JP-B-6830593, one object to be detected is irradiated with light rays in different directions from the point light sources, which may blur an image captured by the optical sensor.

[0004] Detection devices with higher accuracy of detection of the objects to be detected are required.

[0005] For the foregoing reasons, there is a need for a detection device that improves accuracy of detection of objects to be detected.

SUMMARY

[0006] According to an aspect, a detection device includes: a light source device including a plurality of light-emitting elements arranged in a plane; an object placement member with a light-transmitting property disposed overlapping the light source device on a first side in a first direction and on which an object to be detected is placed; a liquid crystal shutter that is disposed overlapping the object placement member on the first side in the first direction and has a plurality of divided regions arranged in a plane; and an optical sensor that is disposed overlapping the liquid crystal shutter on the first side in the first direction and has a plurality of detection regions arranged in a plane. One of the detection regions includes one or more photodetection elements. The light source device includes a light-shielding wall disposed between two adjacent light-emitting elements out of the light-emitting elements. The divided regions in the liquid crystal shutter are each capable of being switched between a light-transmitting state and a non-light-transmitting state for each of the divided regions, and the light-emitting elements are each capable of being switched between a lit state and an unlit state for each of the light-emitting elements. The respective light-emitting elements, the respective divided regions of the liquid crystal shutter, and the respective detection regions overlap when viewed in the first direction.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] FIG. **1** is a perspective view schematically illustrating a detection device according to an

embodiment of the present disclosure;
[0008] FIG. **2** is a perspective view of a state where a top plate is removed from FIG. **1**;
[0009] FIG. **3** is a schematic view of the detection device according to the embodiment;
[0010] FIG. **4** is a schematic view of a section of a liquid crystal shutter according to the embodiment;
[0011] FIG. **5** is a block diagram illustrating an example of the configuration of the detection device;
[0012] FIG. **6** is a schematic view illustrating projection regions of light emitted from light-emitting elements;
[0013] FIG. **7** is a schematic view of the detection device according to the embodiment viewed from the side;
[0014] FIG. **8** is a schematic view of a detection device according to a comparative example viewed from the side;
[0015] FIG. **9** is a schematic plan view of a light source device according to the embodiment;
[0016] FIG. **10** is a schematic plan view of the liquid crystal shutter according to the embodiment;
[0017] FIG. **11** is a schematic plan view of an optical sensor according to the embodiment;
[0018] FIG. **12**A is a schematic view illustrating a first process in which four divided regions included in a first divided region group are brought into a light-transmitting state;
[0019] FIG. **12**B is a schematic view illustrating a second process in which four divided regions included in a second divided region group are brought into the light-transmitting state;
[0020] FIG. **12**C is a schematic view illustrating a third process in which four divided regions included in a third divided region group are brought into the light-transmitting state;
[0021] FIG. **12**D is a schematic view illustrating a fourth process in which four divided regions included in a fourth divided region group are brought into the light-transmitting state;
[0022] FIG. **13** is a schematic diagram illustrating an operating state of two light-emitting elements and two divided regions of the liquid crystal shutter adjacent to each other in an X direction; and
[0023] FIG. **14** is a flowchart illustrating a detection operation example of the detection device according to the embodiment.

DETAILED DESCRIPTION

[0024] The following describes a mode (embodiment) for carrying out the present disclosure in detail with reference to the drawings. The present disclosure is not limited to the description of the embodiment given below. Components described below include those easily conceivable by those skilled in the art or those substantially identical thereto. In addition, the components described below can be combined as appropriate. What is disclosed herein is merely an example, and the present disclosure naturally encompasses appropriate modifications easily conceivable by those skilled in the art while maintaining the gist of the present disclosure.
[0025] To further clarify the description, the drawings may schematically illustrate, for example, widths, thicknesses, and shapes of various parts as compared with actual aspects thereof. However, they are merely examples, and interpretation of the present disclosure is not limited thereto. The same component as that described with reference to an already mentioned drawing is denoted by the same reference numeral through the present disclosure and the drawings, and detailed description thereof may not be repeated where appropriate.
[0026] In XYZ coordinates in the drawings, a Z direction (first direction) corresponds to the up-down direction; an X direction (second direction) corresponds to the right-left direction; and a Y direction (third direction) corresponds to the front-rear direction. The X direction intersects (at right angles) the Y and Z directions; the Y direction intersects (at right angles) the X and Z directions; and the Z direction intersects (at right angles) the X and Y directions. A Z**1** side is one side in the first direction, and a Z**2** side is the other side in the first direction. A plan view indicates a state viewed in the Z direction (first direction).
[0027] FIG. **1** is a perspective view schematically illustrating a detection device according to an

embodiment of the present disclosure. FIG. **2** is a perspective view of a state where a top plate is removed from FIG. **1**.

[0028] As illustrated in FIGS. **1** and **2**, a detection device **100** has a substantially box shape, for example. The detection device **100** includes a housing **3** and a holding member **4**. The housing **3** includes a top plate **31** and side plates **32** and **33**. The holding member **4** includes a plate **41** and a base plate **42**. An object placement member **110** is placed on the plate **41**. The four corners of the base plate **42** are provided with front-side holders **42***c* and rear-side holders **42***d*. The front-side holders **42***c* and the rear-side holders **42***d* are biased to the upper side (Z**1** side) by springs **5**. The object placement member **110** is placed on the plate **41**, whereby the plate **41** and the object placement member **110** are biased to the upper side (Z**1** side) by the springs **5**.

[0029] FIG. **3** is a schematic view of the detection device according to the embodiment. As illustrated in FIG. **3**, the detection device **100** includes a light source device **7**, the object placement member **110**, a liquid crystal shutter **82**, an optical sensor **81**, and the springs **5**.

[0030] The light source device **7** includes a light source substrate **72**, a plurality of light-emitting elements **71**, and a light-shielding wall **6**. The light-emitting element **71** is a light-emitting diode (LED), for example. The light-emitting elements **71** are provided on the light source substrate **72**. Thus, the light source device **7** includes a plurality of light-emitting elements **71** arranged in a plane. The light-shielding wall **6** separates the light-emitting elements **71** from each other.

[0031] The object placement member **110** includes a placement substrate **111** and a cover member **112**. The object placement member **110** is a Petri dish, for example. The object placement member **110** has a light-transmitting property. The placement substrate **111** is a light-transmitting substrate disposed overlapping the light source device **7** on the Z**1** side and on which objects to be detected **114** are placed.

[0032] The object placement member **110** according to the present embodiment is placed upside down with respect to a conventional object placement member. In other words, in the conventional object placement member, the placement substrate is placed on the lower side, and the cover member is placed on the upper side. By contrast, in the object placement member **110** according to the present embodiment, the placement substrate **111** is placed on the upper side, and the cover member **112** is placed on the lower side. The optical sensor **81** and the liquid crystal shutter **82** are provided on top of (on the Z**1** side of) the object placement member **110** placed upside down, and the light source device **7** is provided under (on the Z**2** side of) it. A culture medium **113** is provided under the placement substrate **111**, and the objects to be detected **114** are applied to the culture medium **113** (lower surface of the culture medium **113**). The object to be detected **114** is a microorganism, such as a bacterium, or a sample containing a microorganism and forms colonies on the culture medium **113** over time. The object to be detected **114** is not limited to the bacteria, and may be other micro-objects such as cells.

[0033] The optical sensor **81** includes an array substrate **811** and sensor pixels **812** (photodetection elements **813** or photodiodes). The optical sensor **81** is disposed overlapping the liquid crystal shutter **82** on the Z**1** side. The sensor pixels **812** are provided on the surface of the array substrate **811** on the Z**2** side. The liquid crystal shutter **82** will be described later.

[0034] Light L emitted from the light-emitting element **71** passes through the cover member **112**, the culture medium **113**, the placement substrate **111**, and a divided region of the liquid crystal shutter **82** in a light-transmitting state (open state) and travels toward the optical sensor **81**. The amount of light incident on the photodetection element **813** (photodiode) of the optical sensor **81** differs between a region overlapping the object to be detected **114** and a region not overlapping the object to be detected **114**. As a result, the optical sensor **81** can image the objects to be detected **114**. Thus, the detection device **100** is a device that monitors changes in the objects to be detected **114** by placing the objects to be detected **114** accommodated in the object placement member **110** between the light source device **7** and the optical sensor **81** and imaging the objects to be detected **114** by the optical sensor **81**.

[0035] FIG. **4** is a schematic view of a section of the liquid crystal shutter according to the embodiment. The twisting state of liquid crystal molecules of the liquid crystal shutter **82** is controlled by setting a voltage applied to electrodes to be on or off, whereby the liquid crystal shutter **82** can transmit or block light with a polarizing plate provided on the light emitting side of a liquid crystal layer LC**2** from which the light is emitted. FIG. **4** illustrates three divided regions **820** divided in the X direction.
[0036] The liquid crystal shutter **82** includes a first substrate **280***a*, a second substrate **280***b*, and the liquid crystal layer LC**2**. Specifically, the second substrate **280***b* is disposed on the Z**1** side of the first substrate **280***a* with a gap interposed therebetween, and the liquid crystal layer LC**2** is provided between the second substrate **280***b* and the first substrate **280***a*.
[0037] The first substrate **280***a* includes a first polarizing plate **289***a*, a first transparent substrate **283**, an insulating layer **287***a*, an insulating layer **287***b*, an insulating layer **287***c*, first electrodes **281**, and a first orientation film **290***a*. Specifically, the first polarizing plate **289***a*, the first transparent substrate **283**, the insulating layer **287***a*, the insulating layer **287***b*, the insulating layer **287***c*, the first electrodes **281**, and the first orientation film **290***a* are stacked in this order from the Z**2** side to the Z**1** side.
[0038] The second substrate **280***b* includes a second polarizing plate **289***b*, a second transparent substrate **288**, a second electrode **282**, and a second orientation film **290***b*. Specifically, the second polarizing plate **289***b*, the second transparent substrate **288**, the second electrode **282**, and the second orientation film **290***b* are stacked in this order from the Z**1** side to the Z**2** side.
[0039] The first polarizing plate **289***a* and the second polarizing plate **289***b* are polarizing plates that transmit light of the component in incident light that oscillates in a predetermined direction and block light of the component that oscillates in any direction other than the predetermined direction.
[0040] The first transparent substrate **283** and the second transparent substrate **288** are glass substrates, for example. The first electrode **281** and the second electrode **282** are light-transmitting electrodes made of indium tin oxide (ITO), for example. The first orientation film **290***a* and the second orientation film **290***b* are made of polyimide (PI), for example. The orientation film is provided to control the orientation of liquid crystal molecules when the liquid crystal molecules are required to be aligned in one direction over a certain large area.
[0041] The liquid crystal shutter **82** includes a switch SW composed of a thin-film transistor (TFT), for example. The switch SW includes a channel **284**, a source **285***a*, a drain **285***b*, and a gate **285***c* mounted on the first transparent substrate **283** of the first substrate **280***a*. The source **285***a* is supplied with a potential based on a local dimming signal. The drain **285***b* is electrically coupled to wiring **286**. The switch SW switches between a state in which a drain current flows to the first electrode **281** and a state in which the drain current does not flow thereto, depending on the presence or absence of a signal supplied to the gate **285***c*. Each divided region **820** is provided with the first electrode **281**, the second electrode **282**, and one switch SW.
[0042] FIG. **5** is a block diagram illustrating an example of the configuration of the detection device. As illustrated in FIG. **5**, the detection device **100** includes the optical sensor **81**, the liquid crystal shutter **82**, the light source device **7**, and a host IC **75**. The optical sensor **81** includes the array substrate **811**, the sensor pixels **812** (photodetection elements **813** or photodiodes) formed on the array substrate **811**, gate line drive circuits **814**A and **814**B, a signal line drive circuit **815**A, and a detection control circuit (ROIC) **816**.
[0043] The array substrate **811** is formed using a substrate as a base. Each of the sensor pixels **812** is configured with a corresponding one of the photodetection elements **813**, a plurality of transistors, and various types of wiring.
[0044] The array substrate **811** has a detection region AA and a peripheral region GA. The detection region AA is a region provided with the sensor pixels **812** (photodetection elements **813**). The peripheral region GA is a region between the outer periphery of the detection region AA and the outer ends of the array substrate **811** and is a region not provided with the sensor pixels **812**.

The gate line drive circuits **814**A and **814**B, the signal line drive circuit **815**A, and the detection control circuit **816** are provided in the peripheral region GA.

[0045] Each of the sensor pixels **812** is an optical sensor that includes the photodetection element (photodiode) **813** as a sensor element. Each of the photodetection elements **813** outputs an electrical signal corresponding to light emitted thereto.

[0046] The detection control circuit **816** is a circuit that supplies control signals Sa, Sb, and Sc to the gate line drive circuits **814**A and **814**B and the signal line drive circuit **815**A, respectively, to control operations of these circuits. The detection control circuit **816** includes a signal processing circuit that performs signal processing on detection signals Vdet from the photodetection elements **813**.

[0047] The detection control circuit **816** performs signal processing on the detection signals Vdet from the photodetection elements **813** and outputs sensor values So based on the detection signals Vdet to the host IC **75**. Thus, the detection device **100** detects information on the object to be detected **114**.

[0048] The liquid crystal shutter **82** includes a plurality of divided regions **820** and a second light-emitting element control circuit (DDIC-**2**) **822**. Each of the divided regions **820** is arranged overlapping a plurality of (e.g., four) photodetection elements **813**. The second light-emitting element control circuit **822** supplies control signals Sg to the respective divided regions **820** and controls operations of these regions. The divided region **820** of the liquid crystal shutter **82** overlaps the photodetection elements **813** when viewed in the Z direction. In the present embodiment, the number of the light-emitting elements **71** overlapping one divided region **820** of the liquid crystal shutter **82** may be two or more.

[0049] The light source device **7** includes the light source substrate **72**, the light-emitting elements **71** formed on the light source substrate **72**, gate line drive circuits **814**C and **814**D, a signal line drive circuit **815**B, and a first light-emitting element control circuit (DDIC-**1**) **74**.

[0050] The light-emitting elements **71** are arranged in a matrix (row-column configuration) in a region of the light source substrate **72** overlapping the detection region AA. The light source substrate **72** is a drive circuit substrate that drives each of the light-emitting elements **71** so as to switch the state of the element between on (lit state) and off (unlit state). The light-emitting elements **71** are disposed overlapping the respective divided regions **820** of the liquid crystal shutter **82**. In other words, the respective light-emitting elements **71**, the respective divided regions **820** of the liquid crystal shutter **82**, and respective detection regions **810** overlap when viewed in the Z direction.

[0051] The first light-emitting element control circuit **74** supplies control signals Sd, Se, and Sf to the gate line drive circuits **814**C and **814**D and the signal line drive circuit **815**B, respectively, to control operations of these circuits.

[0052] The host IC **75** includes, as a control circuit for the optical sensor **81**, a sensor value storage circuit **751**, a sensor value calculation circuit **752**, a light intensity setting circuit **753**, and a target value storage circuit **759**. The sensor value storage circuit **751** stores therein the sensor values So output from the detection control circuit **816** of the optical sensor **81**. The sensor value calculation circuit **752** performs a predetermined calculation process on the sensor values So of the photodetection elements **813**.

[0053] In a light intensity setting mode, the light intensity setting circuit **753** compares the sensor values So detected by the photodetection elements **813** with a preset target sensor value So-t acquired from the target value storage circuit **759** to set light intensities of the light-emitting elements **71** for detection. The target value storage circuit **759** stores therein the preset target sensor value So-t.

[0054] The host IC **75** includes, as a control circuit for the light source device **7**, a lighting pattern generation circuit **754** and a lighting pattern storage circuit **755**. The lighting pattern storage circuit **755** stores therein information on the light intensity of each of the light-emitting elements **71** in the light intensity setting mode.

[0055] The lighting pattern generation circuit **754** generates various control signals based on the information on the light intensity in the lighting pattern storage circuit **755**.

[0056] The host IC **75** includes an image generation circuit **756** and a storage circuit **757**. In a detection mode, the image generation circuit **756** generates an image of the object to be detected **114**, based on the sensor values So output from the photodetection elements **813**. The storage circuit **757** stores therein image data generated by the image generation circuit **756**. The host IC **75** is coupled to a host computer (PC) **758** and transfers the image data to the host PC **758**.

[0057] FIG. **6** is a schematic view illustrating projection regions of light emitted from the light-emitting elements.

[0058] As illustrated in FIG. **6**, a total of 16 light-emitting elements **71** according to the present embodiment are provided. The **16** light-emitting elements **71** are arranged in a matrix (row-column configuration) at regular intervals in the X direction (second direction) and the Y direction (third direction). In the **16** light-emitting elements **71**, the distance between the light-emitting elements **71** adjacent to each other in the X direction is a distance d, and the distance between the light-emitting elements **71** adjacent to each other in the Y direction is also the distance d.

[0059] Light emitted from one light-emitting element **71** spreads radially as the light travels toward the upper side (Z**1** side). Therefore, as illustrated in FIG. **6**, a projection region IA of light projected onto the optical sensor **81** without the liquid crystal shutter **82** is a circle with a radius r centered on the light-emitting element **71**. As illustrated in FIG. **6**, the projection regions IA adjacent in the X or Y direction have an overlapping portion P indicated by hatching. This overlapping portion P causes the image of the object to be detected **114** to be blurred or hazy.

[0060] FIG. **7** is a schematic view of the detection device according to the embodiment viewed from the side. FIG. **8** is a schematic view of a detection device according to a comparative example viewed from the side.

[0061] First, the comparative example illustrated in FIG. **8** is described. In the comparative example illustrated in FIG. **8**, the light-shielding wall **6** illustrated in FIG. **7** is not provided. As illustrated in FIG. **8**, a divided region **82-1** overlaps a light-emitting element **71-1**, a divided region **82-2** overlaps a light-emitting element **71-2**, a divided region **82-3** overlaps a light-emitting element **71-3**, and a divided region **82-4** overlaps a light-emitting element **71-4** when viewed in the Z direction. Light L**1** is emitted from the light-emitting element **71-1**, light L**2** is emitted from the light-emitting element **71-2**, light L**3** is emitted from the light-emitting element **71-3**, and light L**4** is emitted from the light-emitting element **71-4**. As illustrated in FIG. **8**, the light L**1** is incident on the entire area of the divided region **82-1**, the entire area of the divided region **82-2**, and part of the divided region **82-3** in the comparative example. Similarly, the light L**2** is incident on the entire area of the divided region **82-2**, the entire area of the divided region **82-1**, the entire area of the divided region **82-3**, and part of the divided region **82-4**. In the comparative example not provided with the light-shielding wall **6**, the irradiation angle of light emitted from the light-emitting element **71** is an angle θ**2**.

[0062] By contrast, the configuration according to the embodiment illustrated in FIG. **7** includes the light-shielding wall **6**. The light-shielding wall **6** is a partition that separates the light-emitting elements **71** adjacent to each other in the X direction and the light-emitting elements **71** adjacent to each other in the Y direction. The light-shielding wall **6** has a grid shape when viewed from the Z direction. The light-shielding wall **6** protrudes toward the Z**1** side. The height of the light-shielding wall **6** is higher than that of the light-emitting element **71**. The light-shielding wall **6** has a visible light absorbing property of absorbing at least part of visible light. As illustrated in FIG. **7**, the light L**1** is incident on the entire area of the divided region **82-1** and part of the divided region **82-2** in the embodiment. In other words, the light L**1** illustrated in FIG. **8** reaches the divided region **82-3**, but in the embodiment, the light L**1** is blocked by the light-shielding wall **6** and does not reach the divided region **82-3**. Similarly, the light L**3** is incident on the entire area of the divided region **82-3**, part of the divided region **82-2**, and part of the divided region **82-4**.

[0063] In the embodiment provided with the light-shielding wall **6**, the irradiation angle of light emitted from the light-emitting element **71** is an angle θ**1**. The angle θ**1** is smaller than the angle θ**2**. Thus, the light L emitted from one light-emitting element **71** is incident on one divided region **820** overlapping the one light-emitting element **71** in the X direction and another divided region **820** adjacent to the one divided region **820**, and does not reach the other divided regions **820** because the light is blocked by the light-shielding wall **6**. In other words, the angle θ**2** is an angle of light incident on the region beyond the divided region **820** adjacent to a certain divided region **820**, and the angle θ**1** is an angle of light not incident on the region beyond the divided region **820** adjacent to the certain divided region **820**.

[0064] FIG. **9** is a schematic plan view of the light source device according to the embodiment. FIG. **10** is a schematic plan view of the liquid crystal shutter according to the embodiment. FIG. **11** is a schematic plan view of the optical sensor according to the embodiment.

[0065] As illustrated in FIG. **9**, a total of 16 light-emitting elements **71** according to the present embodiment are provided. The **16** light-emitting elements **71** can be switched between the lit state and the unlit state for each of the light-emitting elements **71**. The **16** light-emitting elements **71** are arranged in a matrix (row-column configuration) at regular intervals in the X and Y directions as described above. Specifically, four rows along the X direction are arranged, and four columns along the Y direction are arranged. As for the rows, for example, the first row is positioned on the most Y2 side. In the first row, four light-emitting elements **71** are arranged at regular intervals from the X2 side to the X1 side. Specifically, light-emitting elements **71-1**, **71-2**, **71-3**, and **71-4** are arranged from the X2 side to the X1 side. In the second row, four light-emitting elements **71** are arranged at regular intervals from the X2 side to the X1 side.

[0066] Specifically, light-emitting elements **71-5**, **71-6**, **71-7**, and **71-8** are arranged from the X2 side to the X1 side. In the third row, four light-emitting elements **71** are arranged at regular intervals from the X2 side to the X1 side. Specifically, light-emitting elements **71-9**, **71-10**, **71-11**, and **71-12** are arranged from the X2 side to the X1 side. In the fourth row, four light-emitting elements **71** are arranged at regular intervals from the X2 side to the X1 side. Specifically, light-emitting elements **71-13**, **71-14**, **71-15**, and **71-16** are arranged from the X2 side to the X1 side.

[0067] As for the columns, for example, the first column is positioned on the most X2 side. In the first column, four light-emitting elements **71** are arranged at regular intervals from the Y2 side to the Y1 side. Similarly, in the second, the third, and the fourth columns, four light-emitting elements **71** are arranged at regular intervals from the Y2 side to the Y1 side.

[0068] As illustrated in FIG. **10**, the liquid crystal shutter **82** according to the present embodiment is divided into a total of 16 parts in plan view seen in the Z direction. In other words, the liquid crystal shutter **82** has 16 divided regions **820** divided in the X and Y directions.

[0069] The light-emitting elements **71** can be switched between the lit state and the unlit state for each of the light-emitting elements **71**. The divided region **820** overlapping the light-emitting element **71** in the lit state when viewed in the Z direction is brought into the light-transmitting state, and the divided region **820** overlapping the light-emitting element **71** in the unlit state when viewed in the Z direction is brought into the non-light-transmitting state.

[0070] The divided regions **820** adjacent to each other in the X or Y direction are arranged without a gap or with a slight gap interposed therebetween. All the divided regions **820** each have a square shape when viewed in the Z direction. The divided regions **820** are arranged in a matrix (row-column configuration) at regular intervals in the X and Y directions when viewed in the Z direction. The **16** divided regions **820** are arranged in a lattice pattern at regular intervals in the X and Y directions. Specifically, in the same manner as the arrangement of the light-emitting elements, four rows along the X direction are arranged, and four columns along the Y direction are arranged. As for the rows, for example, the first row is positioned on the most Y2 side. In the first row, four divided regions **820** are arranged at regular intervals from the X2 side to the X1 side.

Specifically, divided regions **82-1**, **82-2**, **82-3**, and **82-4** are arranged from the X2 side to the X1 side. In the second row, four divided regions **820** are arranged at regular intervals from the X2 side to the X1 side.

[0071] Specifically, divided regions **82-5**, **82-6**, **82-7**, and **82-8** are arranged from the X2 side to the X1 side. In the third row, four divided regions **820** are arranged at regular intervals from the X2 side to the X1 side. Specifically, divided regions **82-9**, **82-10**, **82-11**, and **82-12** are arranged from the X2 side to the X1 side. In the fourth row, four divided regions **820** are arranged at regular intervals from the X2 side to the X1 side. Specifically, divided regions **82-13**, **82-14**, **82-15**, and **82-16** are arranged from the X2 side to the X1 side.

[0072] As for the columns, for example, the first column is positioned on the most X2 side. In the first column, four divided regions **820** are arranged at regular intervals from the Y2 side to the Y1 side. Similarly, in the second, the third, and the fourth columns, four divided regions **820** are arranged at regular intervals from the Y2 side to the Y1 side.

[0073] The divided region **820** according to the present disclosure does not necessarily have a square shape in plan view. Thus, the divided region **820** may have, for example, an equilateral triangular shape or a polygonal shape with five or more sides in plan view. The divided regions **820** that are simultaneously brought into the light-transmitting state are not adjacent to each other.

[0074] As illustrated in FIG. **11**, one detection region **810** includes one or more photodetection elements **813** (photodiodes). While one detection region **810** according to the present embodiment includes four photodetection elements **813**, the present disclosure is not limited thereto, and one detection region **810** may include three or less or five or more photodetection elements **813**. The detection region **810** is arranged correspondingly to the divided region **820** of the liquid crystal shutter **82**. Specifically, the outline of the detection region **810** overlaps the outline of the divided region **820** of the liquid crystal shutter **82** when viewed in the Z direction. Therefore, four photodetection elements **813** are disposed overlapping one divided region **820** of the liquid crystal shutter **82** when viewed in the Z direction.

[0075] The detection regions **810** are arranged in a matrix (row-column configuration) at regular intervals in the X and Y directions when viewed in the Z direction. The **16** detection regions **810** are arranged in a lattice pattern at regular intervals in the X and Y directions. Specifically, in the same manner as the arrangement of the light-emitting elements **71** and the divided regions **820** of the liquid crystal shutter **82**, four rows along the X direction are arranged, and four columns along the Y direction are arranged. As for the rows, for example, the first row is positioned on the most Y2 side. In the first row, four detection regions **810** are arranged at regular intervals from the X2 side to the X1 side. In the second row, four detection regions **810** are arranged at regular intervals from the X2 side to the X1 side. In the third row, four detection regions **810** are arranged at regular intervals from the X2 side to the X1 side. In the fourth row, four detection regions **810** are arranged at regular intervals from the X2 side to the X1 side.

[0076] The following describes the operating timing of the liquid crystal shutter **82** and the timings of the turning-on and -off of the light-emitting elements. FIG. **12**A is a schematic view illustrating a first process in which four divided regions included in a first divided region group are brought into the light-transmitting state. FIG. **12**B is a schematic view illustrating a second process in which four divided regions included in a second divided region group are brought into the light-transmitting state. FIG. **12**C is a schematic view illustrating a third process in which four divided regions included in a third divided region group are brought into the light-transmitting state. FIG. **12**D is a schematic view illustrating a fourth process in which four divided regions included in a fourth divided region group are brought into the light-transmitting state. The light-emitting elements **71** in the lit state are represented by hollow circles, while the light-emitting elements **71** in the unlit state are represented by hatched circles. The divided regions **820** in the light-transmitting state are represented by hollow squares, while the divided regions **820** in the non-light-transmitting state are represented by hatched squares.

[0077] The divided regions **820** of the liquid crystal shutter **82** and the light-emitting elements **71** are arranged in a matrix (row-column configuration) at regular intervals in the X and Y directions as described above. In the embodiment, the following process is performed four times (a plurality of times): four (predetermined number of 2 or more) divided regions **820** are brought into the light-transmitting state, and **12** (the number of remaining divided regions) divided regions **820** are brought into the non-light-transmitting state, wherein the number of **12** (the number of remaining divided regions) is calculated by subtracting 4 (predetermined number of 2 or more) from **16** (total number of divided regions). The above process is performed by changing the divided regions **820** to be brought into the light-transmitting state until all the **16** (total number of divided regions) divided regions **820** are brought into the light-transmitting state at least once. Specifically, the process is composed of the first process illustrated in FIG. **12**A, the second process illustrated in FIG. **12**B, the third process illustrated in FIG. **12**C, and the fourth process illustrated in FIG. **12**D.
[0078] As illustrated in FIG. **12**A, the four divided regions included in the first divided region group are brought into the light-transmitting state in the first process. The four divided regions are the divided regions **82-1**, **82-3**, **82-9**, and **82-11**, and the other divided regions **820** are brought into the non-light-transmitting state. The light-emitting elements **71-1**, **71-3**, **71-9**, and **71-10** are brought into the lit state, and the other light-emitting elements **71** are brought into the unlit state. As illustrated in FIG. **12**A, the divided regions **820** that are simultaneously brought into the light-transmitting state are not adjacent to each other.
[0079] As illustrated in FIG. **12**B, the four divided regions included in the second divided region group are brought into the light-transmitting state in the second process. The four divided regions are the divided regions **82-2**, **82-4**, **82-10**, and **82-12**, and the other divided regions **820** are brought into the non-light-transmitting state. The light-emitting elements **71-2**, **71-4**, **71-10**, and **71-12** are brought into the lit state, and the other light-emitting elements **71** are brought into the unlit state. As illustrated in FIG. **12**B, the divided regions **820** that are simultaneously brought into the light-transmitting state are not adjacent to each other.
[0080] As illustrated in FIG. **12**C, the four divided regions included in the third divided region group are brought into the light-transmitting state in the third process. The four divided regions are the divided regions **82-5**, **82-7**, **82-13**, and **82-15**, and the other divided regions **820** are brought into the non-light-transmitting state. The light-emitting elements **71-5**, **71-7**, **71-13**, and **71-15** are brought into the lit state, and the other light-emitting elements **71** are brought into the unlit state. As illustrated in FIG. **12**C, the divided regions **820** that are simultaneously brought into the light-transmitting state are not adjacent to each other.
[0081] As illustrated in FIG. **12**D, the four divided regions included in the fourth divided region group are brought into the light-transmitting state in the fourth process. The four divided regions are the divided regions **82-6**, **82-8**, **82-14**, and **82-16**, and the other divided regions **820** are brought into the non-light-transmitting state. The light-emitting elements **71-6**, **71-8**, **71-14**, and **71-16** are brought into the lit state, and the other light-emitting elements **71** are brought into the unlit state. As illustrated in FIG. **12**D, the divided regions **820** that are simultaneously brought into the light-transmitting state are not adjacent to each other.
[0082] FIG. **13** is a schematic diagram illustrating an operating state of two light-emitting elements and two divided regions of the liquid crystal shutter adjacent to each other in the X direction. In FIG. **13**, the upper left diagram illustrates the turning-on and -off timings of the light-emitting element **71-1** (refer to FIG. **9**) and the operating state of the divided region **82-1** (refer to FIG. **10**) of the liquid crystal shutter **82**. The light-emitting element **71-1** and the divided region **82-1** overlap when viewed in the Z direction. In FIG. **13**, the lower right diagram illustrates the turning-on and -off timings of the light-emitting element **71-2** (refer to FIG. **9**) and the operating state of the divided region **82-2** (refer to FIG. **10**) of the liquid crystal shutter **82**. The light-emitting element **71-2** and the divided region **82-2** overlap when viewed in the Z direction.
[0083] The control signal Sg (refer to FIG. **5**) for instructing the shutter to open and close is

indicated by a solid line, and the transmittance of the shutter is indicated by a dashed line. The highest transmittance of the liquid crystal shutter **82** is 100%, and the lowest transmittance is 0%. In the present embodiment, a transmittance of 95% is indicated by an alternate long and two short dashes line because a predetermined transmittance at which satisfactory detection accuracy can be obtained is 95% or higher.

[0084] First, the divided region **82-1** of the liquid crystal shutter **82** receives the control signal Sg (refer to FIG. **5**) to open (turn on) the shutter at time T**1** as indicated by the solid line. After the control signal Sg is received, the transmittance of the divided region **82-1** of the liquid crystal shutter **82** gradually increases. The transmittance reaches 95% at time T**2** and is saturated near 100% at time T**3**. In the embodiment, a state where the transmittance is 95% or higher is the state where the liquid crystal shutter **82** is in the light-transmitting state (open state), and a state where the transmittance is lower than 58, for example, is the non-light-transmitting state (closed state). Therefore, the divided region **82-1** of the liquid crystal shutter **82** is brought into the light-transmitting state (open state) at time T**2**. The time length from time T**1** to time T**2** is determined in advance by experiment, for example. Thus, it is determined that the transmittance of the liquid crystal shutter **82** reaches 95% at the time when (time T**2**-time T**1**) has elapsed since time T**1**.

[0085] At time T**3**, the light-emitting element **71-1** shifts from the unlit state (off state) to the lit state. The light-emitting element **71-1** remains in the lit state from time T**3** to time T**4**. At time T**4**, the light-emitting element **71-1** shifts to the unlit state.

[0086] When the control signal Sg to close (turn off) the shutter is received at time T**5** after time T**4**, the transmittance of the divided region **82-1** of the liquid crystal shutter **82** gradually decreases from time T**5**. The transmittance of the divided region **82-1** reaches 95% at time T**6** and is saturated near 0% at time T**7**. The transmittance reaches 95% at time T**6**, whereby the divided region **82-1** of the liquid crystal shutter **82** comes into the closed state at time T**6**. Time T**7** is a timing at which all the divided regions **820** are in the non-light-transmitting state.

[0087] After time T**7**, the light-emitting element **71-2** is brought into the lit and unlit states, and the divided region **82-2** of the liquid crystal shutter **82** is brought into the open state. The changes between the lit and unlit states of the light-emitting element **71-2** are the same as those in the light-emitting element **71-1**, and the open and closed states of the divided region **82-2** of the liquid crystal shutter **82** are the same as those in the divided region **82-1**.

[0088] Specifically, the divided region **82-2** of the liquid crystal shutter **82** first receives the control signal Sg to open (turn on) the shutter at time T**8** as indicated by the solid line. After the control signal Sg is received, the transmittance of the divided region **82-2** of the liquid crystal shutter **82** gradually increases. The transmittance reaches 95% at time T**9** and is saturated near 100% at time T**10**.

[0089] At time T**10**, the light-emitting element **71-2** shifts from the unlit state (off state) to the lit state. The light-emitting element **71-2** remains in the lit state from time T**10** to time T**11**. At time T**11**, the light-emitting element **71-2** shifts to the unlit state.

[0090] When the control signal Sg to close (turn off) the shutter is received at time T**12** after time T**11**, the transmittance of the divided region **82-2** gradually decreases from time T**12**. The transmittance reaches 95% at time T**13** and is saturated near 0% at time T**14**.

[0091] The divided region **82-1** is brought into the light-transmitting state in the first process illustrated in FIG. **12**A, and the divided region **82-2** is brought into the light-transmitting state in the second process illustrated in FIG. **12**B. The divided regions **82-1** and **82-2** are adjacent to each other in the X direction. Time T**7** is the timing at which all the divided regions **820** are in the non-light-transmitting state. Thus, the divided region **82-1** that is brought into the light-transmitting state in the first process (certain process) out of the four times (a plurality of times) is adjacent to the divided region **82-2** that is brought into the light-transmitting state in the second process (next process following the certain process) in the present embodiment, and the timing at which all the divided regions **820** are in the non-light-transmitting state is provided between the first process and the second process.

[0092] The following describes a detection operation example of the detection device. FIG. **14** is a flowchart illustrating the detection operation example of the detection device according to the embodiment.

[0093] First, the lighting pattern generation circuit **754** (refer to FIG. **5**) brings all the light-emitting elements **71** into the unlit (off) state and turns off (closes) all the divided regions **820** of the liquid crystal shutter **82** at Step S**101**. As a result, all the **16** light-emitting elements **71** illustrated in FIG. **9** are in the unlit state, and all the **16** divided regions **820** illustrated in FIG. **10** are in the off state.

[0094] Subsequently, the host IC **75** (refer to FIG. **5**) sets the number n of the light-emitting element **71** to **1** (n=1) (Step S**102**).

[0095] Then, the lighting pattern generation circuit **754** turns on the control signals for all the divided regions **820** included in the divided region group corresponding to the number n (Step S**103**). Specifically, as described with reference to FIG. **12**A, the lighting pattern generation circuit **754** turns on the control signals for the four divided regions (divided regions **82-1**, **82-3**, **82-9**, and **82-11**) included in the first divided region group in the first process. As a result, the divided region **82-1**, for example, receives the control signal Sg to open (turn on) the shutter at time T**1** as described with reference to FIG. **13**.

[0096] Subsequently, after the transmittance of all the divided regions included in the first divided region group subjected to the process at Step S**103** reaches 95% or higher, the lighting pattern generation circuit **754** turns on the light-emitting elements **71** corresponding to the number n (Step S**104**). All the divided regions included in the first divided region group subjected to the process at Step S**103** are specifically the divided regions **82-1**, **82-3**, **82-9**, and **82-11**. As a result, the light-emitting element **71-1**, for example, shifts from the unlit state (off state) to the lit state at time T**3** as described with reference to FIG. **13**.

[0097] Then, the image generation circuit **756** (refer to FIG. **5**) generates a plurality of pieces of divided image data of the divided regions **820** included in the divided region group corresponding to the number n and stores the generated data in the storage circuit **757** (Step S**105**). As a result, the divided image data corresponding to all the divided regions **820** included in the first divided region group, for example, are generated and stored.

[0098] Subsequently, the lighting pattern generation circuit **754** brings the light-emitting elements **71** corresponding to the number n into the unlit state (Step S**106**). Specifically, the light-emitting elements that overlaps the divided regions **820** included in the first divided region group when viewed in the Z direction are changed from the lit state to the unlit state at time T**4** described with reference to FIG. **13**.

[0099] After the light-emitting elements **71** are brought into the unlit state at Step S**106**, the lighting pattern generation circuit **754** turns off the control signals for all the divided regions **820** included in the divided region group corresponding to the number n (Step S**107**). Specifically, when the control signals Sg to close (turn off) the shutters of all the divided regions **820** included in the first divided region group are received at time T**5** after time T**4** described with reference to FIG. **13**, the transmittance of all the divided regions **820** gradually decreases from time T**5**.

[0100] The host IC **75** determines whether the number n is the final value (Step S**108**). If the number n is not determined to be the final value, the host IC updates the number n of the light-emitting element to n+1 (n=n+1) (Step S**109**). For example, the host IC **75** updates n=1 to n=2, and the lighting pattern generation circuit **754** performs the processing at Step S**103** again. The case of n=2 corresponds to the second process according to the present embodiment.

[0101] Then, the processing from Step S**103** to Step S**107** is performed, and the host IC **75** determines whether the number n is the final value again (Step S**108**), and the processing is repeated until the number n is determined to be the final value. In the present embodiment, the third process and the fourth process are performed after the second process. In other words, the process is performed by changing the divided regions **820** to be brought into the light-transmitting state until all the **16** divided regions **820** are brought into the light-transmitting state at least once.

[0102] If the host IC **75** determines that the number n is the final value (Step S**108**), the image generation circuit **756** combines all the divided image data to generate composite image data (Step S**110**). As a result, the composite image data corresponding to all the divided regions **820** of the liquid crystal shutter **82** is generated. The image generation circuit **756** transfers the composite image data to the host PC **758** (Step S**111**).

[0103] As described above, the detection device **100** includes the light source device **7**, the object placement member **110** with a light-transmitting property, the liquid crystal shutter **82** having a plurality of divided regions **820**, and the optical sensor **81** having a plurality of detection regions **810**. The divided regions **820** in the liquid crystal shutter **82** can be switched between the light-transmitting state and the non-light-transmitting state for each of the divided regions **820**, and the light-emitting elements **71** can be switched between the lit state and the unlit state for each of the light-emitting elements **71**. The respective light-emitting elements **71**, the respective divided regions **820** of the liquid crystal shutter **82**, and the respective detection regions **810** overlap when viewed in the Z direction. The light source device **7** includes the light-shielding wall **6** disposed between two adjacent light-emitting elements **71** out of the light-emitting elements **71**.

[0104] As described above, if a plurality of light-emitting elements **71** are provided, one object to be detected **114** is irradiated with light rays in different directions emitted from the light-emitting elements **71**, which may blur an image captured by the optical sensor **81**.

[0105] By contrast, in the present embodiment, the respective light-emitting elements **71**, the respective divided regions **820** of the liquid crystal shutter **82**, and the respective detection regions **810** of the optical sensor **81** overlap when viewed in the Z direction. In addition, the light-shielding wall **6** is provided between two adjacent light-emitting elements **71**. Therefore, by turning on one light-emitting element **71** and bringing the divided region **820** arranged overlapping the one light-emitting element **71** into the light-transmitting state, the detection device **100** prevents a plurality of light rays L from being incident on the detection region **810** arranged overlapping the divided region **820** in the light-transmitting state.

[0106] By providing the light-shielding wall **6** between two adjacent light-emitting elements **71**, part of the light L emitted from one light-emitting element **71** is blocked by the light-shielding wall **6**. This configuration further prevents a plurality of light rays L from being incident on the divided region **820** and the detection region **810** arranged overlapping the one light-emitting element **71**. Therefore, the detection device **100** can further reduce blurring of the image captured by the optical sensor **81**.

[0107] The divided region **820** that overlaps the light-emitting element **71** in the lit state when viewed in the Z direction is brought into the light-transmitting state, and the divided region **820** that overlaps the light-emitting element **71** in the unlit state when viewed in the Z direction is brought into the non-light-transmitting state.

[0108] This configuration can turn on one light-emitting element **71**, bring one divided region **820** arranged overlapping the one light-emitting element **71** into the light-transmitting state, and bring the divided regions **820** adjacent to the one divided region **820** into the non-light-transmitting state. Therefore, the light L transmitted through the divided region **820** in the light-transmitting state and reaching the detection region **810** is limited to the light L emitted from the one light-emitting element **71**. With this configuration, the detection device **100** can further reduce blurring of the image captured by the optical sensor **81**.

[0109] Four (predetermined number of 2 or more) divided regions **820** are brought into the light-transmitting state, and the remaining 12 divided regions **820** are brought into the non-light-transmitting state, wherein the number of **12** (the number of remaining regions) is calculated by subtracting 4 (predetermined number of 2 or more) from **16** (total number of divided regions **820**).

[0110] In other words, a process is performed in which four divided regions **820** out of the **16** divided regions **820** are simultaneously brought into the light-transmitting state. Thus, all the (**16**) divided regions **820** can be brought into the light-transmitting state by four processes. Therefore, the detection device **100** can bring all the (**16**) divided regions **820** into the light-transmitting state in a smaller number of processes than in a case where only one divided region **820** is brought into the light-transmitting state in one process, for example.

[0111] The divided regions **820** that are simultaneously brought into the light-transmitting state are not adjacent to each other.

[0112] Therefore, when one light-emitting element **71** is turned on, and the divided region **820** arranged overlapping the one light-emitting element **71** is brought into the light-transmitting state, the light L transmitted through the divided region **820** in the light-transmitting state and reaching the detection region **810** is limited to the light L emitted from the one light-emitting element **71**. With this configuration, the detection device **100** can further reduce blurring of the image captured by the optical sensor **81**.

[0113] The light L emitted from one light-emitting element **71** is incident on one divided region **820** overlapping the one light-emitting element **71** when viewed in the Z direction and another divided region **820** adjacent to the one divided region **820**, and is blocked by the light-shielding wall **6** such that the light does not reach the other divided regions **820**.

[0114] Thus, part of the light L emitted from one light-emitting element **71** is blocked by the light-shielding wall **6**. This configuration further prevents a plurality of light rays L from being incident on the divided region **820** and the detection region **810** overlapping the one light-emitting element **71** when viewed in the Z direction. Therefore, the detection device **100** can further reduce blurring of the image captured by the optical sensor **81**. Examples of being adjacent herein include being adjacent in the X direction, adjacent in the Y direction, and adjacent in the XY direction (i.e., adjacent diagonally). For example, the divided regions adjacent to the divided region **82-6** in the X direction are the divided regions **82-5** and **82-7**. The divided regions adjacent to the divided region **82-6** in the Y direction are the divided regions **82-2** and **82-10**. The divided regions adjacent to the divided region **82-6** in the XY direction are the divided regions **82-1**, **82-3**, **82-9**, and **82-11**.

[0115] The light-emitting elements **71**, the divided regions **820**, and the detection regions **810** are arranged in a matrix (row-column configuration) along the X direction (second direction) intersecting the Z direction (first direction) and the Y direction (third direction) intersecting the Z and X directions. The following process is performed four times: four divided regions **820** are brought into the light-transmitting state, and the remaining 12 divided regions **820** are brought into the non-light-transmitting state, wherein the number of **12** (the number of remaining divided regions) is calculated by subtracting 4 (predetermined number of 2 or more) from **16** (total number of divided regions). The process is performed by changing the divided regions **820** to be brought into the light-transmitting state until all of the **16** divided regions **820** are brought into the light-transmitting state at least once.

[0116] Therefore, in the present embodiment, all the (**16**) divided regions **820** can be brought into the light-transmitting state in four processes. By contrast, in an aspect where only one divided region **820** is brought into the light-transmitting state in one process, for example, 16 processes are required to bring the **16** divided regions **820** into the light-transmitting state.

[0117] Therefore, in the present embodiment, all the (**16**) divided regions **820** can be brought into the light-transmitting state in a smaller number of processes.

[0118] The divided region **82-1** that is brought into the light-transmitting state in the first process (certain process) out of the processes of the four times (a plurality of times) described above and the divided region **82-2** that is brought into the light-transmitting state in the second process (next process) are adjacent to each other in the X direction. The timing (time T**7** and time T**8**) at which all the divided regions **820** are in the non-light-transmitting state is provided between the first process and the second process.

[0119] In other words, the divided region **82-1** is brought into the non-light-transmitting state before the divided region **82-2** is brought into the light-transmitting state. Therefore, the light L that reaches the divided region **82-2** is limited to the light L emitted from the light-emitting element **71-2**, thereby further reducing blurring of the image captured by the optical sensor **81**.

[0120] The light-emitting element **71** is brought into the lit state when the transmittance of the divided region **820** in the light-transmitting state is equal to or higher than a predetermined value with respect to the maximum transmittance. The predetermined value is, for example, 95%.

[0121] Specifically, as described with reference to FIG. **13**, the period during which the transmittance of the divided region **82-1** is equal to or higher than a predetermined value of 95% is from time T**2** to time T**6**. In the period from time T**2** to time T**6**, the light-emitting element **71-1** is in the lit state. In other words, when the light-emitting element **71-1** is in the lit state, the divided region **82-1** is in the light-transmitting state, and the divided regions **820** adjacent to the divided region **82-1** are in the non-light-transmitting state. This configuration prevents a plurality of light rays from being incident on one detection region **810**, thereby further reducing blurring of the image captured by the optical sensor **81**.

[0122] After one light-emitting element **71** is brought into the unlit state, the transmittance of one divided region **820** overlapping the one light-emitting element **71** when viewed in the Z direction starts to decrease.

[0123] Specifically, referring to FIG. **13**, the time at which the light-emitting element **71-1** is brought into the unlit state is time T**4**. The time at which the transmittance of the divided region **82-1** starts to decrease is time T**5**. Time T**5** comes after time T**4**. In other words, whenever the light-emitting element **71-1** is in the unlit state, the divided region **82-1** is in the non-light-transmitting state. This configuration prevents a plurality of light rays from being incident on one detection region **810**, thereby further reducing blurring of the image captured by the optical sensor **81**.

Claims

1. A detection device comprising: a light source device comprising a plurality of light-emitting elements arranged in a plane; an object placement member with a light-transmitting property disposed overlapping the light source device on a first side in a first direction and on which an object to be detected is placed; a liquid crystal shutter that is disposed overlapping the object placement member on the first side in the first direction and has a plurality of divided regions arranged in a plane; and an optical sensor that is disposed overlapping the liquid crystal shutter on the first side in the first direction and has a plurality of detection regions arranged in a plane, wherein one of the detection regions includes one or more photodetection elements, the light source device comprises a light-shielding wall disposed between two adjacent light-emitting elements out of the light-emitting elements, the divided regions in the liquid crystal shutter are each capable of being switched between a light-transmitting state and a non-light-transmitting state for each of the divided regions, and the light-emitting elements are each capable of being switched between a lit state and an unlit state for each of the light-emitting elements, and the respective light-emitting elements, the respective divided regions of the liquid crystal shutter, and the respective detection regions overlap when viewed in the first direction.

2. The detection device according to claim 1, wherein the divided region overlapping the light-emitting element in the lit state when viewed in the first direction out of the divided regions is brought into the light-transmitting state, and the divided region overlapping the light-emitting element in the unlit state when viewed in the first direction is brought into the non-light-transmitting state.

3. The detection device according to claim 2, wherein a predetermined number of 2 or more of divided regions are brought into the light-transmitting state, and the remaining divided regions are brought into the non-light-transmitting state, the number of the remaining divided regions being calculated by subtracting the predetermined number from the total number of the divided regions.

4. The detection device according to claim 3, wherein the divided regions that are simultaneously

brought into the light-transmitting state are not adjacent to each other.
5. The detection device according to claim 4, wherein light emitted from one light-emitting element is incident on one divided region overlapping in the first direction with the one light-emitting element and another divided region adjacent to the one divided region, and is blocked by the light-shielding wall such that the light does not reach the other divided regions.
6. The detection device according to claim 3, wherein the light-emitting elements, the divided regions, and the detection regions are arranged in a matrix having a row-column configuration along a second direction intersecting the first direction and a third direction intersecting the first direction and the second direction, a process is performed a plurality of times, in which the predetermined number of 2 or more of the divided regions are brought into the light-transmitting state and the remaining divided regions are brought into the non-light-transmitting state, the number of the remaining divided regions being calculated by subtracting the predetermined number from the total number of the divided regions, and the process is performed by changing the divided regions to be brought into the light-transmitting state until all of the divided regions are brought into the light-transmitting state at least once.
7. The detection device according to claim 6, wherein the divided region that is brought into the light-transmitting state in a certain process out of the processes of the plurality of times is adjacent to the divided region that is brought into the light-transmitting state in a next process following the certain process, and a timing at which all the divided regions are in the non-light-transmitting state is provided between the certain process and the next process.
8. The detection device according to claim 5, wherein the one light-emitting element is brought into the lit state when the transmittance of the one divided region in the light-transmitting state is equal to or higher than a predetermined value with respect to a maximum transmittance.
9. The detection device according to claim 8, wherein the transmittance of the one divided region starts to decrease after the one light-emitting element is brought into the unlit state.
10. The detection device according to claim 8, wherein the predetermined value is 95%.