(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 4 549 812 A1

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
07.05.2025 Bulletin 2025/19

(21) Application number: **23207052.4**

(22) Date of filing: **31.10.2023**

(51) International Patent Classification (IPC):
F21S 41/143 *(2018.01)* ***F21S 41/153*** *(2018.01)*
F21S 41/19 *(2018.01)* ***F21S 41/265*** *(2018.01)*
F21S 41/20 *(2018.01)* ***F21S 41/29*** *(2018.01)*
F21S 41/50 *(2018.01)* ***F21S 45/47*** *(2018.01)*

(52) Cooperative Patent Classification (CPC):
F21S 41/143; F21S 41/153; F21S 41/192; F21S 41/265; F21S 41/285; F21S 41/29; F21S 41/50; F21S 45/47

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC ME MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA
Designated Validation States:
KH MA MD TN

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(54) **VEHICLE LAMP AND VEHICLE HEADLIGHT COMPRISING THE LAMP**

(57) Vehicle lamp (1) and a headlight (23) which comprises the lamp (1). The lamp (1) comprises a light source (2), a primary optical element (3), a lens holder (4), and a secondary optical element (5). The primary optical element (3) is held between the light source (2) and the lens holder (4), and it contains at least two portions (6). Adjacent portions (6) are separated from each other by expansion joints (7) for limiting effects of thermal expansion of the adjacent portions (6) on each other. Each portion (6) comprises at least one alignment member for individual alignment of the portion (6) with respect to at least one other part of the lamp (1). Both optical elements can be segmented.

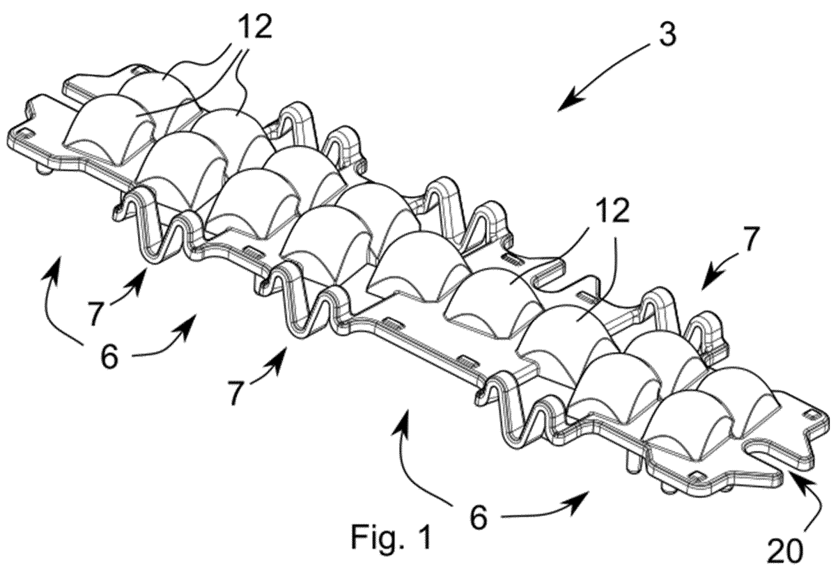

Fig. 1

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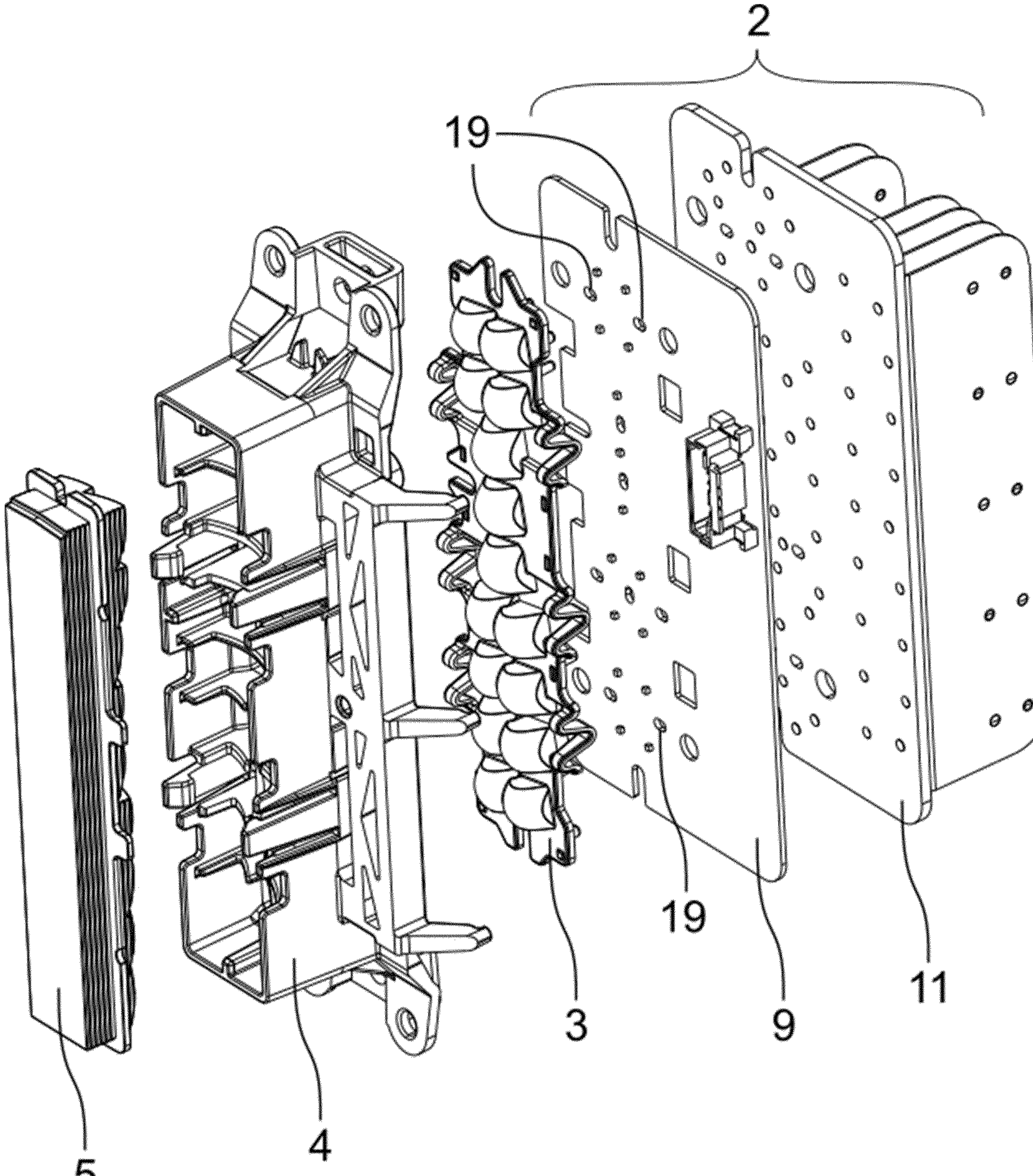

Fig. 5

Description

Technical field

[0001] The present invention relates to vehicle lighting. More specifically, it relates to a lamp with an improved optical element which is less affected by heat.

Background of the Invention

[0002] LED headlights or headlight modules in the state of the art generally comprise a PCB with LEDs attached to a heat sink, a primary optics, secondary optics (often simply called lens or projection lens) and support elements such as casings and lens holders. The primary optics is closer to the LEDs and pre-processes the light, and the secondary optics then directs the light in a desired pattern on the road ahead. An example of such an LED headlight is disclosed in document US11028987 B2 or in document WO2022242783 A1. The latter document also discloses an assembly kit and method for a headlight module.

[0003] The optical elements are nowadays commonly made from clear polymer, such as polycarbonate or PMMA, because these are lighter and easier to manufacture than optics made from glass. However, one disadvantage of polymer optics is in its thermal expansivity. Light sources, even LEDs, produce a significant amount of heat during their operation and since the primary optics is very close the light source, it gets heated. The optical element thus thermally expands, and the illumination pattern provided by the lamp is slightly distorted by this expansion. This distortion is more noticeable in details of the illumination pattern such as a cut-off line. For more complex headlight optical elements, this distortion becomes more significant. Thermal expansion of optical elements and its unwanted effects on the optical function of the elements is thus one of hindrances in development of more complex optical elements and illumination modules, especially for use in vehicle headlights. More complex elements and modules could for example improve design, increase energy efficiency, save space, etc.

[0004] It would therefore be desirable to provide a way of reducing the effect of thermal expansion on the optical elements in vehicle lamps.

Summary of the Invention

[0005] The shortcomings of the solutions known in the prior art are to some extent eliminated by a vehicle lamp comprising at least a light source, a primary optical element, a lens holder, and a secondary optical element. The primary optical element is held between the light source and the lens holder. The light source is preferably an LED light source. All the LEDs then preferably share a common PCB. The primary optical element is closer to the light source than the secondary optical element and receives light from the light source, while the secondary optical element receives light from the primary one. The lens holder can be one or more components which carry one or both of the optical elements. Preferably, one lens holder (which can however be from multiple parts) carries, supports, pushes onto or otherwise holds both the optical elements and attaches them to another part of the lamp, for example to the light source.

[0006] The primary optical element contains at least two portions, and it further contains at least one expansion joint. An expansion joint is a component which holds the portions together but at the same time reduces effects of thermal expansion of adjacent portions on each other. The portions are held together preferably at least to the extent that they can easily be assembled all at once, e.g., the whole primary optical element is gripped and mounted to the light source at once. Some movement between the portions is however allowed by the joints in order to limit the effects of the thermal expansion.

[0007] Since polymers used for optics generally expand when their temperature rises, if one portion of the primary optical element is heated, it increases its volume or area. If the portions were connected to each other fixedly (by screws, gluing, welding etc.), the expansion of the one portion would necessarily press on adjacent portions and would move the portions. Since it is important in vehicle lamps to have optical elements centred with respect to light sources, this movement caused by the expansion is undesirable.

[0008] Therefore, adjacent portions of the primary optical element are separated from each other by at least one expansion joint. Further, each portion comprises at least one alignment member for individual alignment of the portion with respect to at least one other part of the lamp. The alignment member can especially be a pin or other protrusion, or a hole or recess. Using pins and oval holes for alignment of lamp components is known in the art. For the present invention, the significant aspect is that each portion has at least one alignment member of its own. As a result, each portion is aligned/centred by itself. I.e., the alignment of one portion is at least to some extent independent of other portions. Combined with the expansion joints, this means that the portions are centred individually and are unaffected (or at least less affected) by expansions of other portions. As a result, temperature changes have a much lesser impact on functioning of the lamp or on the resulting illumination pattern the lamp provides, e.g., on the road ahead if the lamp is a headlight.

[0009] As an example, polycarbonate (PC) has a coefficient of thermal expansion of 0,065 mm/m °C. This means that an optical element with a length of 150 mm, which is roughly a standard size of headlight optical elements, which gets heated by an LED light source by 30 °C when it reaches its standard operating temperature of 50 °C, expands by almost 0,3 mm. This expansion would shift the optical element with respect to the light source which would deform the shape of the lamp's illumination pattern on the road. By isolating the expansion to the individual segments, if there were four segments of the same size, the expansion of each segment is less than 0,1 mm. Movement of a portion of the optical element by less than one tenth of millimetre generally does not significantly affect the lamp's performance.

[0010] The above exemplary calculation is fairly simplified, since it for example assumes that the optical element is heated evenly and that the portions have the same size, but it demonstrates how the division of the primary optical element can help reducing the overall thermal deformation of the primary optical element and can thus help with maintaining the lamp's illumination performance regardless of temperature of the LEDs and the optical element.

[0011] The lamp according to the invention can especially be an exterior lamp, e.g., a headlight or a taillight or a module for them. It can also be an illuminated front grille or bumper or similar illumination device. It is however also possible to use the lamp in the interior, even though distortion of lamp's illumination pattern due to thermal expansion has much smaller significance in the interior.

[0012] The optical element can be made from a polymeric material, such as PMMA or polycarbonate. The lens holder and/or the primary optical element itself preferably keep the primary optical element at a specified distance from the light source, or especially from its LED sub-sources. For example, the lens holder can push the element towards the light source, while there are protrusions on the back side of the element which function as stops for the backwards movement and keep a minimum distance between the optical parts of the primary optical element and the LEDs. These stops can be braced against the surface of the light source (e.g., of a PCB). The surface than comprises no other components (e.g., parts soldered to the PCB) at the locations corresponding to the stops. There can also be depression complementary to the shape of the stops provided on the light source. The stops can then limit the distance between the primary optical element and the light source and can also help centring these two components.

[0013] The portions are thus sub-parts of the primary optical element which are separated from each other, and at the same time held together, by the expansion joint(s). The function of the expansion joints which allows the limiting of effects of thermal expansion can be provided by their material (e.g., by using a more flexible/elastic material than the material of the portions), by shape of the material (e.g., making the joints thinner, porous, perforated or curved, such that they are more flexible/elastic than the portions), by their construction (e.g., by providing multiple mutually telescopic or otherwise linearly movable parts of the joint) etc. The effects of the expansion, which are to be limited, are thus mainly forces/pressures/pulls caused by expansion of one portion acting on the neighbouring portion(s), and the corresponding movement of these neighbouring portion(s).

[0014] The at least one other part of the lamp, which is a counterpart for the alignment of the portions, can be any component, e.g., the lens holder, a casing or frame of the lamp, or the light source. It is preferable to use a counterpart which is from a material with smaller thermal expansivity coefficient than that of the primary optical segment. The light source is thus a preferable counterpart for the alignment because it usually contains a PCB. Standard PCB materials, such as fiberglass or other composites, have a low thermal expansivity and can thus keep the portions aligned as needed. It is however also possible to e.g., make the lens holder from fiberglass and then use it as the alignment counterpart. The counterpart can comprise complementary alignment members, e.g., if there are pins on the optical element, the counterpart can contain holes, and vice versa.

[0015] It is possible to connect two adjacent portions with multiple expansion joints. The portions can all be in one row or column, i.e., there are two end portions which have a single adjacent portion on one of their sides, and any potential further portions are between the two end portions and have an adjacent portion on both sides. It is also possible to have the portions in multiple rows or columns etc. E.g., four portions can be in two rows and columns, i.e., they can form a square formation. The rows or columns of the portions can then have different numbers of portions, e.g., there can be four rows of portions, first and last row having two portions next to each other each, and the second and third rows only having one portion. Any configuration of any number of portions can be used in the presented lamp.

[0016] Preferably, the portions of the primary optical element and the at least one expansion joint are made from a single piece of material. This significantly simplifies manufacturing of the element. It can be e.g., injection moulded in a single mould. There is thus no need to provide multiple moulds, to assemble the primary optical element from multiple pieces etc.

[0017] Preferably, each expansion joint is formed as a curved section of the primary optical element and/or a section of the primary optical element having a reduced cross-section. This form of the joints can be combined with making the whole element from one piece of material. The whole primary optical element is thus cheaper, lighter, less prone to wear etc.

[0018] Each expansion joint can then have a cross-section having three curved parts, wherein one of the curved parts which is located between the other two curved parts has curvature in opposite direction than the other two curved parts. The joint can thus have for example a shape of a rounded letter M or W. This wave with multiple different curvature directions, i.e., with centres of curvature at different sides of the cross-section, can allow bigger range of movement of each portion without affecting the other portions. With multiple curved parts, i.e., at least two, each of the curved parts is also bent less during the thermal expansion and is thus less likely to break over time.

[0019] The lens holder can be pressed against the primary optical element at each portion. E.g., the lens holder can have at least one pressing protrusion for each portion and via this protrusion, the lens holder forces the primary optical element towards the light source. The optical element is thus prevented from bending or from detaching from the light source. Since the lens holder presses against each portion, the individual alignment or positioning of the portions is further supported.

[0020] The primary optical element can have a substantially planar light entry surface and/or the secondary optical element can have a substantially planar light exit surface. These shapes of the surfaces can have aesthetical effects but can also have technical impact. E.g., flat entry surfaces allow the primary optical element to be closer to the light source and substantially flat surfaces, e.g., planar with micro-optics, in general can lead to smaller lamps with the same illumination functions.

[0021] Both entry and exit surfaces of both optical elements can generally have almost any shape, e.g., can be protruding, can be flat, can have continuous freeform shape, can have micro-optics etc.

[0022] The light source can comprise a printed circuit board with LED sub-sources and a heat sink. The light source can then comprise the complementary alignment members for the alignment members of the primary optical element, e.g., it can comprise holes passing through the PCB into the heat sink.

[0023] Each portion of the primary optical element can comprise at least one primary segment, wherein each primary segment is individually shaped and oriented for processing and directing light from the light source. The primary segments are thus the parts of the element which provide the desired optical function. Each sub-source of the light source can then have its own segment which processes and directs light for this sub-source individually. This allows obtaining much more complex illumination functions than when the optical element has its optical surfaces common for all the sub-sources.

[0024] The secondary optical element can also be segmented, i.e., it can comprise multiple secondary segments, wherein each secondary segment is aligned with a corresponding primary segment. Each secondary segment is individually shaped and oriented for processing and directing light from the corresponding primary segment. Each secondary segment thus receives light from the corresponding primary segment and directs it to a prescribed location which is to be illuminated by this segment. The primary and secondary segments thus cooperate to process the light from the light source, especially from a corresponding sub-source of the light source, and to direct the processed light to a certain part of the road ahead. The processing for example includes homogenization and stretching of the light beam over the prescribed area, e.g., from a first distance in front of the vehicle to a second distance in front of the vehicle.

[0025] Having both the primary and secondary optical elements segmented increases the versatility of the lamp. By shaping the segments, i.e., by shaping the entry and exit surfaces of both types of segments, the light can be shaped and oriented as needed. The shape of the exit surface of the secondary segments can be visible from the outside, so its shape can also be affected by design considerations. For each corresponding primary and secondary segments, the four surfaces can all be designed together by a computer simulation. The simulation can be inputted with some parameters such as the location (area) which is supposed to be illuminated by the specific segments, and can output the shape of all four surfaces. Designing other corresponding segments can be done in the same way independently (i.e., each sub-module as defined below can be designed separately and then their segments are put at the common optical elements).

[0026] The lens holder can comprise a shielding grille for separating light beams passing between corresponding primary segments and secondary segments. The lens holder is thus located between the elements and the grille ensures that the light beams from different primary segments do not influence each other and do not reach any other secondary segment than the corresponding one. The grille thus further ensures that the sub-modules do not influence each other - that the light from one does not spill into the other.

[0027] The shielding grille can have at least one roughened or matted surface for reducing glare. Glare occurring on smooth surfaces of the grille could be a source of locally increased brightness in the resulting illumination pattern. This would lower the homogeneity, and it could be distracting to the driver or to drivers of other vehicles. Some or all surfaces can thus be treated or created such they are less reflective. The choice of surface for this treatment, i.e., the roughening or matting, can also be a computer simulation. E.g., the simulation can show which surfaces reflect high amount of light, which than creates the inhomogeneities, and these selected surfaces can then be treated. The treatment can comprise altering the mould for making the lens holder, e.g., roughening its corresponding walls; it can comprise coating the surface with a less reflective coating; it can comprise grinding/-sanding the surfaces etc. For simplicity, the whole lens holder can be e.g., coated, so that there is no need for identifying the surfaces which are prone to creating glares.

[0028] Each primary segment with its corresponding secondary segment can have a corresponding light sub-source on the light source, wherein the mutually corresponding primary segment, secondary segment and sub-source form an illumination sub-module for illuminating a given area for illumination in front of the lamp. The corresponding passage in the shielding grille can also be considered a part of each sub-module. These sub-modules are basically independent in their illumination function, e.g., each can be directed independently on other sub-modules, but they share the optical elements and the light source. Therefore, the lamp is very versatile (each sub-module provides its own illumination so a plurality of sub-modules can be combined into a lamp providing any desired illumination pattern designed by a skilled person) but is also relatively cheap and easy to assemble, because number of components of the lamps is much lower than it would be if the sub-modules didn't share the optical elements. There are preferably at least five, more preferably at least ten sub-modules. This number of sub-modules can provide reasonable illumination, e.g., for a low beam function etc., and can take fuller advantage of the advantages of the present invention (improved resistance to thermal expansion, easier assembly etc.).

[0029] Light output directions (e.g., given by vectors connecting a centre of secondary segment with a centre of the illuminated area on the road or on a vertical surface in front of the lamp) of at least some sub-modules can be mutually nonparallel wherein arrangement of sub-modules on the lamp is different than arrangement of their corresponding areas for illumination.

[0030] This means that the sub-modules, when looking at the lamp from the front, are arranged differently, then the corresponding areas for illumination, when looking at an illuminated vertical surface from the back or looking at an illuminated road from above. The arrangements define how the sub-modules/areas are located with respect to each other. E.g., it defines which sub-module/area is adjacent to which, how far they are from each other etc. For example, the arrangement of sub-modules can be that they are in a single row which is oriented vertically, horizontally or diagonally. Or they can be in a grid formation with a certain number of rows and columns, each with a certain number of sub-segments. The arrangement of areas, especially for headlights, is to some extent given by legal requirements. For example, it is given, how bright the illumination pattern of a low-beam light must be at certain distances from the automobile. It is given, that for right-hand traffic, the right side is illuminated more (to illuminate traffic signs) while the left side is illuminated less (so that oncoming traffic is not blinded). The present invention thus makes it possible to obtain the prescribed road illumination for given light function while the sub-modules of the lamp have any arbitrary arrangement. The arrangement of sub-modules can for example be given by design requirements of customers, by technical requirements etc.

[0031] On vehicle lamps known in the state of the art, the arrangement of sub-modules (e.g., LEDs of a matrix headlight with primary optics and projection lens - the known headlights do not have sub-modules with the same parts and construction as described above) is the same as the arrangement of the areas for illumination. Therefore, the sub-modules are in a substantially vertical row and the leftmost sub-module illuminates the leftmost part of the road, the sub-module next to it illuminates the adjacent part of the road, etc., until the rightmost sub-module which illuminates the rightmost part of the road (or more precisely the rightmost submodule usually illuminates the area next to the road on the right side, not the road itself).

[0032] Having a different arrangement of sub-modules while maintaining the required illumination pattern on the road is not possible in the state of the art. The sub-modules would have to be completely separated, i.e., they would be individual modules with individual and thus expensive assembly and with very demanding alignment. One reason for this is that the individual directing/orienting of sub-modules in the present invention is relatively sensitive to heat expansion. Since the light beams are rearranged on their way from the secondary segment to the corresponding area for illumination, movement of the primary segments with respect to the light sub-sources can easily distort the illumination pattern. The improved resistance to thermal expansion achieved by the individually aligned portions connected by expansion joints is thus especially important for the lamp having sub-modules arranged differently that the areas for illumination.

[0033] For at least some of the sub-modules, the arrangement of sub-modules on the lamp can be rotated with respect to the arrangement of their corresponding areas for illumination. Some of the sub-modules can be arranged vertically one above another and when the lamp illuminates a flat vertical surface from a pre-defined distance, the corresponding areas for illumination by the vertically arranged sub-modules are then arranged on the surface at substantially the same height.

[0034] Substantially the same height means e.g., that there can be a vertical line passing through all the areas. In layman's terms, this just means that the road is illuminated from left to right (which is required) even though not all the sub-modules are arranged from left to right. The sub-modules can be arranged in rows, e.g., at least five rows, each having from 1 to 3 sub-modules. Each row is at different height, i.e., they are one above another. This can enable creation of headlights with modules appearing as substantially vertical bright lines, which is a desired look difficult to achieve by lamps known in the art.

[0035] The predefined distance is commonly 25 meters - at this distance, the illumination pattern of a headlight should fulfil the legal requirements, i.e., it should look substantially the same as the pattern on the road during actual use of the headlight.

[0036] The sub-modules can be arranged in the lamp based at least partially on their operating temperature, i.e., based on how hot they or their sub-sources are expected to get when used for a longer period, e.g., half an hour. The operating temperature can e.g., be the temperature reached by the corresponding sub-source. Some sub-modules with a higher operating temperature can then be separated from each other by at least one sub-module with a lower operating temperature. At the same time, the areas for illumination by the sub-modules with the higher operating temperature are directly adjacent or overlapping.

[0037] Commonly, the middle of the road needs to be the brightest, while the illumination pattern gets dimmer towards the side and farther from the vehicle. The sub-modules directed to the middle areas can thus provide brighter illumination which naturally means they produce more heat and thus have higher operating temperatures. The areas for illumination of these brighter sub-modules are next to each other or even overlap to make the areas even brighter, as needed. In the state of the art, these hotter sub-modules are adjacent to each other, because the arrangement of sub-modules or sub-sources is the same as the arrangement of the areas for illumination, as described above. The present invention, on the other hand, can have different arrangement of the sub-modules. It can thus be advantageous to put the hotter sub-modules away from each other so that their heat can be more effectively dissipated. The colder sub-modules can then be adjacent to the hotter ones. The temperature across the light source is then more uniform and the highest temperature is lower than when the hottest sub-modules are directly next to each other.

[0038] The shortcomings of the solutions known in the prior art are to some extent also eliminated by a vehicle headlight which comprises multiple illumination modules, wherein at least two of the illumination modules are vehicle lamps according to the invention. For example, a headlight with multiple modules, each having the substantially vertical sub-module arrangement as described in more detail above, can be especially advantageous because it provides a very attractive and original appearance to the vehicle.

Description of drawings

[0039] A summary of the invention is further described by means of exemplary embodiments thereof, which are described with reference to the accompanying drawings, in which:

Fig 1. Shows a perspective view of a primary optical element from an exemplary vehicle lamp according to the present invention, wherein division of the primary optical element into four portions separated by expansion joints can be seen, as well as its division into fifteen optical primary segments.

Fig 2. Shows a side view of the primary optical element from fig. 1, wherein cross-sections of the expansion joints can be seen in the figure as well as alignment pins for centring the portions of the primary optical elements.

Fig 3. Shows a detail of one of the expansion joints from fig. 2. The crosssection of this joint with its three curved parts can be seen.

Fig 4. Shows a front view of the primary optical element from figs. 1 to 3. It can be seen that some of the primary segments extend above openings between the portions and that each expansion joint has two arms delimiting this opening from left and right sides.

Fig 5. Shows an exploded view of the exemplary vehicle lamp comprising a heat sink, PCB, primary optical element, lens holder and a secondary optical element.

Fig 6. Shows a back view of the lens holder from fig. 5, wherein the lens holder comprises a shielding grille which separates light beams originating from LEDs on the PCB and traveling between the two optical elements.

Fig 7. Shows a side view of the lens holder from fig. 6.

Fig 8. Shows a schematic perspective view of the secondary optical element, wherein fifteen optical secondary segments with different shapes and inclinations can be seen in the figure.

Fig 9. Shows a side view of the secondary optical element from fig. 8.

Fig 10. Schematically shows a front view of two headlights, each comprising four exemplary vehicle lamps according to the invention, wherein each of the lamps has a substantially vertical arrangement of sub-modules and thus its width is much smaller than its height.

Fig 11. Shows a perspective view of a partially assembled lamp from fig. 5, wherein there is a mounting support with three pins, and the heat sink is mounted on the mounting support.

Fig 12. Schematically shows a front view of partially mounted lamp from fig. 5, wherein there is a mounting support with three pins, and the heat sink, the PCB and the primary optical element are mounted on the mounting support and centred by the pins of the mounting support.

Fig 13. Shows another schematical view of the partially mounted lamp from fig. 12, wherein the lens holder in mounted on the mounting support as well.

Fig 14. Shows a schematical diagram of one sub-module of an exemplary lamp according to the invention and its area for illumination projected onto a vertical surface placed in front of the lamp.

Fig 15. Shows a schematical diagram depicting an arrangement of areas for illumination by individual sub-modules of the exemplary lamp.

Fig 16. Shows two schematical diagrams of arrangements of sub-modules of an exemplary lamp, wherein fig. 16A shows an ordered vertical arrangement and fig. 16B shows a vertical arrangement of the sub-modules where three sub-modules with the highest expected temperature are separated from each other by several colder sub-modules. However, as can be seen in fig. 15, these three sub-modules illuminate overlapping areas, so it's apparent that their light beams cross the light beams of the colder sub-modules. Both diagrams in fig. 16 also schematically show temperature of the sub-modules along the lamp to show impact of the rearrangement of the sub-modules on the overall temperature.

Fig 17. Shows the diagram from fig. 15.

Fig 18. Shows two more schematical diagrams of arrangements of sub-modules of an exemplary lamp, wherein in fig. 18A the sub-modules are arranged in a circle and in fig. 18B the sub-modules are in a V-shaped arrangement.

Exemplary Embodiments of the Invention

[0040] The invention will be further described by means of exemplary embodiments with reference to the respective drawings.

[0041] The vehicle lamp 1 according to the first exemplary embodiment is shown in figs. 1 to 13 and in the diagrams in figs. 14, 15 and 16A. The lamp 1 is a matrix module in this embodiment, and its individual components can be seen in fig. 5. The lamp 1 comprises a light source 2, a primary optical element 3, a secondary optical element 5 and a lens holder 4. It also comprises a casing which encapsulates the other components and facilitates mounting of the matrix module into a headlight 23 (see fig. 10 showing two headlights 23, each with four modules; only the outlines of the module's casings and of the secondary optical elements 5 are shown in fig. 10).

[0042] For the description of the lamp 1 given below, an X, Y, Z coordinate system standard for vehicle lamps 1 is used. The X axis goes from front to rear. Frontwards direction herein is the general direction in which light is emitted from the lamp 1; for a headlight 23, this direction corresponds to the forward movement of the vehicle. The rearwards direction is thus opposite to the frontwards direction. The Z direction goes up and down and the Y direction goes from left to right.

[0043] The light source 2 comprises a heat sink 11, a printed circuit board 9 (PCB) glued to the heat sink 11, and an array of LED sub-sources 10 carried by the PCB 9 (not shown in fig. 5). There are fifteen LEDs in the exemplary embodiment. The heat sink 11 comprises an aluminium plate and a number of aluminium fins. It also comprises several kinds of mounting and alignment members which will be described in more detail below with reference to figs. 11 to 13. The PCB 9 comprises the same mounting and alignment members overlapping with the members of the heat sink 11 such that complementary mounting and alignment members, located on the primary optical element 3 and the lens holder 4, can pass through.

Primary optical element 3:

[0044] The primary optical element 3 is made from a clear polymer, such a PMMA or polycarbonate. It is made from one piece of the material, e.g., by injection moulding. It has a body, which is substantially plate shaped, and the body carries multiple optical segments and expansion joints 7, which will be described further below. Details of the primary optical element 3 can be seen in figs. 1 to 4. The primary optical element 3 is divided into four portions 6 aligned in a row, which are separated from each other by expansion joints 7. The expansion joints 7 allow adjacent portions 6 to slightly move relative to each other without affecting each other, or at least without affecting each other as much as they would if they the portions 6 were not separated. As a result, thermal expansion of the primary optical element 3 does not affect the element as a whole but only the individual portions 6.

[0045] The expansion joints 7 in the depicted embodiment are created as a thinner and curved section of the body. Each of the joints has three curved parts 8, as can be seen in fig. 3. The side curved parts 8, which are each attached to one portion 6, are curved upwards, i.e., are concave, and the middle curved part 8, which attaches the side curved parts 8 to each other, is curved downwards, i.e., is convex. This triple curvature allows enough movement between the portions 6 during their thermal expansion.

[0046] Each portion 6 of the primary optical element 3 has multiple conical alignment pins 18 (see fig. 2 and 3) which extend rearwards from the element. In the depicted embodiment, there are nine alignment pins 18 in total - their arrangement can be deduced from the arrangement of the corresponding oval-shaped alignment holes 19 visible on the PCB 9 in fig. 9.

[0047] When the lamp 1 is assembled, the alignment pins 18 pass through the alignment holes 19 in the PCB 9 and in the heat sink 11. The oval shape is for allowing assembly despite any potential manufacturing imprecisions, and the alignment members align each of the portions 6 individually with respect to the PCB 9, and thus also the LEDs, in Y a Z directions of the headlight 23. For a correct alignment of the primary optical element 3 relative to the PCB 9 and the LEDs in the X direction, there are further provided shorter pins on the back side of the primary optical element 3 (see fig. 2). These shorter pins do not have corresponding holes, but they contact the PCB 9 with their free ends and thus keep the primary optical element 3 at a desired distance from the LEDs.

[0048] As a result of the above-described individual alignment of the portions 6 with respect to the PCB 9, each portion 6 remains centred regardless of expansion of other portions 6. Each portion 6 is only affected by its own expansion, at a much smaller scale than the whole primary optical element 3 would be. The PCB 9 is made from a material with a very small thermal expansion coefficient and it's thus suitable for keeping the primary optical element 3 properly centred.

[0049] The optical function of the primary optical element 3 is provided by the primary segments 12. Each primary segment 12 serves for preprocessing light from one of the LEDs before the secondary optical element 5 processes the light further and directs it towards the road to illuminate its corresponding area 15 for illumination. Each primary segment 12 has its own shape, which is designed in relation to a corresponding secondary segment 13 on the secondary optical element 5 (further described below). Each segment has an entry surface for receiving light form the corresponding LED and an exit surface for outputting light towards the secondary optical element 5. The entry surfaces of the primary segments 12 are substantially planar, while the exit surfaces have a protruding pillow-like shape. This shape is a freeform lens shape in the exemplary embodiment. Simulation software for modelling lens shapes according to a desired optical function or parameters is known in the art and can be used to obtain the shape of the optical elements of the vehicle lamp 1.

[0050] As can best be seen in fig. 4, which shows the primary optical element 3 from the front, there are three portions 6 with four segments in two rows, and one portion 6 with three segments in a single row. The portions 6 with four segments have the segments partially overlapping. The primary segments 12 also partially overlap the expansion joints 7 - there are openings in the joints behind the overhanging segments so that the segments don't have any impact on function of the expansion joints 7. Each expansion joint 7 in this embodiment is formed by two curved arms which are separated by the rectangular opening.

[0051] The arrangement of the primary segments 12 is affected by expected operating temperature of individual LEDs. The LEDs corresponding to the primary segments 12 which are in the single row illuminate the area directly in front of the automobile. This area 15 (marked as "I, J, K" in the schematic diagram in fig. 15) needs the highest intensity of illumination and so the LEDs directed here are stronger and produce more heat. It is therefore advantageous to give these LEDs more space to prevent overheating and that's why these three LEDs and their corresponding primary segments 12 are in the single row with no neighbouring LEDs/segments next to them.

Lens holder 4:

[0052] The lens holder 4 is made from non-transparent plastic. It has several purposes. Firstly, it carries the secondary optical element 5. There are four snapping arms on the front side of the lens holder 4 and the secondary optical element 5 has a flange (see fig. 8) which can be caught be the arms. The arms can be seen in fig. 7 - two of them are visible, the other two are hidden behind the first two - they are the parts of the lens holder 4 extending the farthest to right in fig. 7. Each of the arms has an inclined protrusion at its free end, which enables the secondary optical element 5 to be inserted into the lens holder 4 but prevent its removal from the lens holder 4.

[0053] Secondly, the lens holder 4 presses on the primary optical element 3. The lamp 1 is held together by screws and these screws force the lens holder 4 towards the PCB 9 and heat sink 11, such that the primary optical element 3 is squeezed in-between. There are pressing protrusions 22 provided on the back side of the lens holder 4 (see fig. 6) which are in contact with the primary optical element 3. This helps keeping the primary optical element 3 straight and steady during use.

[0054] Thirdly, the lens holder 4 comprises mounting pins 21 (see fig. 7) which keep the lamp 1 components centred in Y and Z directions. The mounting pins 21 pass through the mounting recesses 20 in the primary optical element 3 and also through the similarly shaped recesses in the PCB 9 and the heat sink 11. These recesses also serve for aligning the components during mounting, as will be described in more detail further below. The lens holder 4 also has another kind of pressing elements - these further pressing elements are pushing the PCB 9 towards the heat sink 11 to keep it from bulging. They are the right-most elements in fig. 6.

[0055] Another function of the lens holder 4 is in shielding the light exiting individual primary segments 12 from any stray light from the other primary segments 12. This stray light might cause inhomogeneities in the illumination pattern on the road, it could blind oncoming traffic etc. The lens holder 4 thus has a shielding grille which creates a tunnel for each primary segment 12 (see fig. 6 or 13). The walls of the tunnel enclose the respective light beam and prevent mixing of the light beams from different LEDs.

[0056] The lens holder 4 has number of matted surfaces in order to reduce glare. All the surfaces of the grille can be matted. These surfaces absorb light, instead of reflecting it, which again prevents creation of inhomogeneities in the illumination pattern on the road. The matting in the exemplary embodiment is done by increasing roughness of these surface - e.g., an injection mould for creating the lens holder 4 has corresponding surfaces with an increased roughness.

Secondary optical element 5:

[0057] The secondary optical element 5 can be from the same material as the primary optical element 3, e.g., it is from one piece of polycarbonate. The secondary optical element 5 has fifteen secondary segments 13, similarly to the primary segments 12 on the primary optical element 3. Each secondary segment 13 has its individual shape, provided by the computer simulation together with the shape of the corresponding primary segment 12. This shape is modelled such that the segment sends the light passing through into a desired direction to a desired area 15 for illumination. The position and size of this area 15, which can be a part of the road ahead or a part of a vertical surface in front of the lamp 1, is one of the parameters given to the simulation software.

[0058] Each secondary segment 13 has an entry surface for receiving light from the corresponding primary segment 12. The entry surfaces in the illustrated embodiment protrude rearwards from the secondary optical element 5 (see figs. 5 and 8 and 9). It can be seen in fig. 8 that the secondary segments 13 corresponding to the three primary segments 12 in the single row have larger width the other secondary segments 13 - they extend through the whole width of the secondary optical element 5 while the other secondary segments 13 extend through a half of the width.

[0059] The left and right sides of the secondary optical element 5 comprise grooves or teeth which improve homogeneity of the outputted light by preventing or breaking up glares, similarly to the matted surface of the lens holder 4.

[0060] Each secondary segment 13 further has an exit surface for outputting light. These surfaces are substantially planar in the depicted embodiment, but they comprise micro-optical elements for increasing homogeneity. These elements can be grooves, scratches, micro-lens, mutually inclined sub-surfaces etc. Their sizes can be e.g., up to 0.5 mm in at least two of their dimensions.

[0061] Each of the LED sub-sources 10 of the light source 2 thus has a corresponding primary segment 12, corresponding tunnel in the shielding grille and a corresponding secondary segment 13. These mutually corresponding parts together form a sub-module 14. The sub-modules 14 have basically independent illumination functions - they do not influence each other, share light between themselves etc. They however share the optical elements which significantly simplifies assembly of the lamp 1 and decreases production costs. In other words, the sub-modules 14 can be optically/luminously independent, but mechanically dependent by sharing the optical elements. As a result, they can each be designed individually but are manufactured and assembled together. On the illuminated surface, each module illuminates a certain area 15 for illumination - these areas 15 together partially overlap and form the whole illumination pattern of the lamp 1, e.g., a high-beam light function. The desired shape and intensity of the pattern is known in the art and usually is to some extent prescribed by traffic laws. A diagram of a sub-module 14 is depicted in fig. 14, together with an image of the resulting area 15 for illumination.

[0062] Thanks to the mutual independence of the sub-modules 14, each sub-module 14 can direct light to any desired part of the road, i.e., its corresponding area 15 for illumination can be located anywhere in the lamp's 1 "field of vision". In the first exemplary embodiment, the sub-modules 14 have a substantially vertical arrangement illustrated in fig. 16A. The sub-modules 14 are thus placed in rows where each row only has one or two sub-modules 14. In the resulting headlight 23 (see fig. 10), the lamp 1 thus appears as a substantially vertical bright line with height much larger than width. On the road / on a vertical surface in front of the lamp 1 however, the corresponding areas 15 for illumination are placed next to each other at the same height / distance from the automobile. Some of the areas 15 are stretched more or less up and down or left and right, in accordance with the overall desired shape and intensity of the resulting illumination pattern of the lamp 1 The arrangement of the areas 15 is thus rotated by approximately 90° with respect to the arrangement 16 of sub-modules 14.

[0063] Figs. 15 and 16A show each sub-module 14 and area 15 marked by a letter so that corresponding sub-modules 14 and areas 15 are easily discernible. The light beams from different sub-modules 14 can cross each other and can have totally independent directions. The desired illumination pattern, which is always almost the same for specific illumination functions, can thus be provided by any arbitrary arrangement 16 of sub-modules 14, e.g., given by customer requirements for design of the lamp 1. The shape and inclination of the primary and secondary segments 13 of each sub-module 14 can be obtained by a simulation software, but the resulting optical elements are very complex and thus very sensitive to precision of assembly. Thermal expansion generally disrupts the precision. Therefore, the limited impact of thermal expansion achieved by the expansion joints 7 connecting the individually centred portions 6 of the primary optical element 3 is very advantageous.

[0064] For example, the perceived rotation of the arrangements between the sub-modules 14 and the areas 15 is sensitive to the thermal expansion - without the expansion joints 7, the amount of rotation changes with temperature of the primary optical element 3. The pattern on the road would thus have different inclination with respect to the Y direction (from left to right) when the lamp 1 is just turned on than when the lamp 1 reaches its higher operating temperature. This change in inclination is of course undesirable and such a headlight 23 would not meet legal requirements.

Assembly:

[0065] The assembly of the lamp 1 according to the first embodiment basically follows the method described in

WO2022242783 A1. A mounting support 24 with three pins is used as a base for the assembly and the mounting recesses 20 on the light source 2, the primary optical element 3 and the lens holder 4 receive these pins. The recesses on the light source 2 and the primary optical element 3 also receive the corresponding mounting pins 21 of the lens holder 4 once the lens holder 4 is mounted on the mounting support 24.

[0066] In fig. 11, only the heat sink 11 is placed on the mounting support 24. The pins of the support protrude above the heat sink 11. In fig. 12, the PCB 9 as well as the primary optical element 3 are added to the pins of the support. The lens holder 4 is then added in fig. 13. The secondary optical element 5 can also be added to the lens holder 4, but it does not come into contact with the mounting support 24. The mounting support 24 thus keeps the components together and mutually aligned so that they can be screwed together. The lamp 1 is then removed from the mounting support 24.

[0067] In a second exemplary embodiment, the construction of the lamp 1 is the same as in the first embodiment. The only difference is in the arrangement of the sub-modules 14, which is shown in fig. 16B, and thus in the shape of the primary segments 12 and secondary segments 13. The arrangement 17 of areas 15 is the same as in the first embodiment, i.e., it's shown in fig. 15, but since the arrangement of the sub-modules 14 is different, the sub-modules 14 need to have differently shaped optics in order to direct the light to the corresponding areas 15.

[0068] While in the first embodiment the arrangement 16 of sub-modules 14 was inspired mostly be design reasons, e.g., a customer wanted headlight 23 with vertically extending modules, in the second embodiment, the sub-modules 14 are arranged according to their operating temperature. Since some parts of the road need to be illuminated with higher intensity, some LEDs of the light source 2 need to have higher power. As a result, these LEDs produce more heat. Fig. 16A schematically shows the temperature of the sub-modules 14 along the lamp 1 - it can be seen that the three LEDs for illumination of areas 15 I, J, K, where the road needs to be the brightest, heat their respective sub-modules 14 to higher temperatures. The highest temperature is at sub-module 14 J, since it is placed between sub-modules 14 K and I which are also more powerful and thus heat sub-module 14 J even more.

[0069] The arrangement 16 of sub-modules 14 in the second embodiment in fig. 16B has the three hottest LEDs separated by groups of colder LEDs. Each sub-module 14 still illuminates the same area 15 at the same position on the road / on the vertical surface, so from the outside, there is no visible difference between the first embodiment and the second embodiment. However, as can be seen in fig. 16B, since the three hottest LEDs / sub-modules 14 are not grouped together, they don't heat each other as much and their individual operation temperatures are thus lower. Three peaks can stell be seen in temperature graph in fig. 16B, but these peaks are smaller than the one in fig. 16A. The highest temperature in the lamp 1 is thus lowered by the arrangement 16 of sum-modules 14 according to the second embodiment. The temperatures along the lamp 1 are also more uniform.

[0070] Since a skilled person knows beforehand which LEDs are expected to have higher temperature when the lamp 1 is on, the expected operating temperature or the expected amount of heat produced by each LED or sub-module 14 can be taken into account when designing the lamp 1. The skilled person can design the arrangement 16 of sub-modules 14 themselves or the operating temperature can be input into a simulation software which outputs the arrangement as well as the shape of each segment.

[0071] It is apparent that the sub-modules 14 can be arranged in many more different ways, based on design requirements, heat outputs of the LEDs, available space in a headlight etc. Cooling intensity of the heat sink 11 can also be considered, as well as the fact that hotter air tends to go upwards. E.g., the heat sink 11 might have the highest cooling intensity at its lower portion, so one of the hotter sub-modules 14 can be the downmost sub-module 14. Another of the modules can be the upmost sub-module 14, since the heat from this sub-module 14 won't have any higher located sub-module 14 to heat.

[0072] Two more examples of sub-module 14 arrangement are shown in fig. 18. In fig. 18A, the sub-modules 14 have a circular arrangement. This can for example be a result of customer requirement on lamp 1 design. The primary and secondary segments 13 are then again shaped and oriented such that they individually illuminat their corresponding areas 15 for illumination and the illumination pattern on the road thus looks the same as for the first embodiment. In fig. 18B, the arrangement 16 of sub-modules 14 is in the shape of "V", which again can be required by design, but can also provide three sub-module 14 locations where the sub-module 14 is not surrounded by other sub-modules 14 on both sides. These locations thus contain sub-modules 14 I, J, a K. The heat from these three sub-modules 14 thus dissipates more freely.

[0073] Many more further configurations will be apparent to a skilled person. In some embodiments, the arrangement 16 of sub-modules 14 can be horizontal, as is typical for matrix headlights 23, but the individual LEDs can again be arranged such that the hotter LEDs are apart from each other. The number of sub-modules 14 can be different than fifteen, there can e.g., be additional sub-modules 14 for illumination of traffic signs etc.

[0074] In other alternative embodiments, the primary optical element 3 can have protruding entry surfaces and substantially flat exit surfaces and/or the secondary optical element 5 can have substantially flat entry surfaces and protruding exit surfaces.

[0075] The number of portions 6 of the primary optical element 3 can be different as well. At least two portions 6 are needed, but at least three portions 6 are preferable for fully utilizing the advantages of the expansion joints 7. The number of primary segments 12 on each portion 6 can also be different - there can be portions 6 with only a single primary segment 12 on them, there can be portions 6 carrying five or more segments etc. The expected operating temperature can be considered when choosing the number of segments for the portions 6.

[0076] The complexity of the optics can also be considered when choosing the number of portions 6 or the numbers of segments for each portion 6. For example, for a less complicated optical element geometries, e.g., when the arrangement 16 of submodules is horizontal and the sub-modules 14 have the same order as the areas 15, two portions 6 on the primary optical element 3 can be sufficient. On the other hand, for more complex geometries, e.g., when the segments have micro-optics on their entry and/or exit surfaces and the arrangement 16 of sub-segments is significantly different from the arrangement 17 of areas 15 (e.g., as depicted in fig. 18), more portions 6 with less segments per portion 6 can be advantageous. In some embodiments, there can even be only a single segment on some or all portions 6.

[0077] The expansion joints 7 can have different shapes than in the depicted embodiments. E.g., there can be only one or only two curved parts 8 on the joint. Or the shape of the joint can be such that the curve lies in the plane of the body of the element. I.e., when viewed from the side, the expansion joints 7 can be undiscernible, but when viewed from the front, each joint can be seen as a section of the element with cutouts and curved arms connecting the portions 6. For example, the two lateral arms forming the expansion joints 7 in fig. 1 can be rotated be 90° and thus can be fully placed between the portions 6 without protruding forwards or backwards.

[0078] Instead of the two curved arms separated by an opening, an expansion joint 7 can e.g., have only one arm which extends across the whole width of the primary optical element 3. The primary segments 12 then preferably do not overhang their respective portions 6.

[0079] The mounting and assembly members and elements can also be different. Any way of assembling lamps 1 and aligning their component known to a skilled person can be used as a part of the lamp 1.

Reference list

[0080]

1. Lamp
2. Light source
3. Primary optical element
4. Lens holder
5. Secondary optical element
6. Portion
7. Expansion joint
8. Curved part
9. Printed circuit board
10. Sub-source
11. Heat sink
12. Primary segment
13. Secondary segment
14. Sub-module
15. Area for illumination
16. Arrangement of sub-modules
17. Arrangement of areas
18. Alignment pin
19. Alignment hole
20. Mounting recess
21. Mounting pin
22. Pressing protrusion
23. Headlight
24. Mounting support

Claims

1. Vehicle lamp (1) comprising a light source (2), a primary optical element (3), a lens holder (4) and a secondary optical element (5), wherein the primary optical element (3) is held between the light source (2) and the lens holder (4), **characterized in that** the primary optical element (3) contains at least two portions (6) and it further contains at least one expansion joint (7) for limiting effects of thermal expansion of adjacent portions (6) on each other, wherein adjacent portions (6) are separated from each other by at least one expansion joint (7), wherein each portion (6) comprises at least one alignment member for individual alignment of the portion (6) with respect to at least one other part of the lamp (1).

2. The vehicle lamp (1) according to claim 1 **wherein** the portions (6) of the primary optical element (3) and the at least one expansion joint (7) are made from a single piece of material.

3. The vehicle lamp (1) according to any of the preceding claims **wherein** each expansion joint (7) is formed as a curved section of the primary optical element (3) and/or a section of the primary optical element (3) having a reduced cross-section.

4. The vehicle lamp (1) according to claim 3 **wherein** each expansion joint (7) has a cross-section having three curved parts (8), wherein one of the curved parts (8) which is located between the other two curved parts (8) is curved in opposite direction than the other two curved parts (8).

5. The vehicle lamp (1) according to any of the preceding claims **wherein** the lens holder (4) is pressed against the primary optical element (3) at each portion (6).

6. The vehicle lamp (1) according to any of the preceding claims **wherein** the primary optical element (3) has a substantially planar light entry surface and/or

the secondary optical element (5) has a substantially planar light exit surface.

7. The vehicle lamp (1) according to any of the preceding claims **wherein** the light source (2) comprises a printed circuit board (9) with LED sub-sources (10) and a heat sink (11), wherein the light source (2) comprises complementary alignment members for the alignment members of the primary optical element (3).

8. The vehicle lamp (1) according to any of the preceding claims **wherein** each portion (6) of the primary optical element (3) comprises at least one primary segment (12), wherein each primary segment (12) is individually shaped and oriented for processing and directing light from the light source (2).

9. The vehicle lamp (1) according to claim 8 **wherein** the secondary optical element (5) comprises multiple secondary segments (13), wherein each secondary segment (13) is aligned with a corresponding primary segment (12), wherein each secondary segment (13) is individually shaped and oriented for processing and directing light from the corresponding primary segment (12).

10. The vehicle lamp (1) according to claim 9 **wherein** the lens holder (4) comprises a shielding grille for separating light beams passing between corresponding primary segments (12) and secondary segments (13).

11. The vehicle lamp (1) according to claim 10 **wherein** the shielding grille has at least one roughened or matted surface for reducing glare.

12. The vehicle lamp (1) according to any of claims 8 to 11 **wherein** each primary segment (12) with its corresponding secondary segment (13) have a corresponding light sub-source (10) on the light source (2), wherein the mutually corresponding primary segment (12), secondary segment (13) and sub-source (10) form an illumination sub-module (14) for illuminating an area (15) in front of the lamp (1), wherein light output directions of at least some sub-modules (14) are mutually nonparallel wherein arrangement (16) of sub-modules (14) on the lamp (1) is different than arrangement (17) of their corresponding areas (15) for illumination.

13. The vehicle lamp (1) according to claim 12 **wherein** for at least some of the sub-modules (14), the arrangement (16) of sub-modules (14) on the lamp (1) is rotated with respect to the arrangement (17) of their corresponding areas (15) for illumination, wherein some of the sub-modules (14) are arranged vertically one above another and when the lamp (1) illuminates a flat vertical surface from a pre-defined distance, the corresponding areas (15) for illumination by the vertically arranged sub-modules (14) are arranged on the surface at substantially the same height.

14. The vehicle lamp (1) according to any of claims 12 to 13 **wherein** the sub-modules (14) are arranged in the lamp (1) based at least partially on their operating temperature, wherein some sub-modules (14) with a higher operating temperature are separated from each other by at least one sub-module (14) with a lower operating temperature, wherein the areas (15) for illumination by the sub-modules (14) with the higher operating temperature are directly adjacent or overlapping.

15. Vehicle headlight (23) **characterized in that** it comprises multiple illumination modules, wherein at least two of the illumination modules are vehicle lamps (1) according to any of claims 12 to 14.

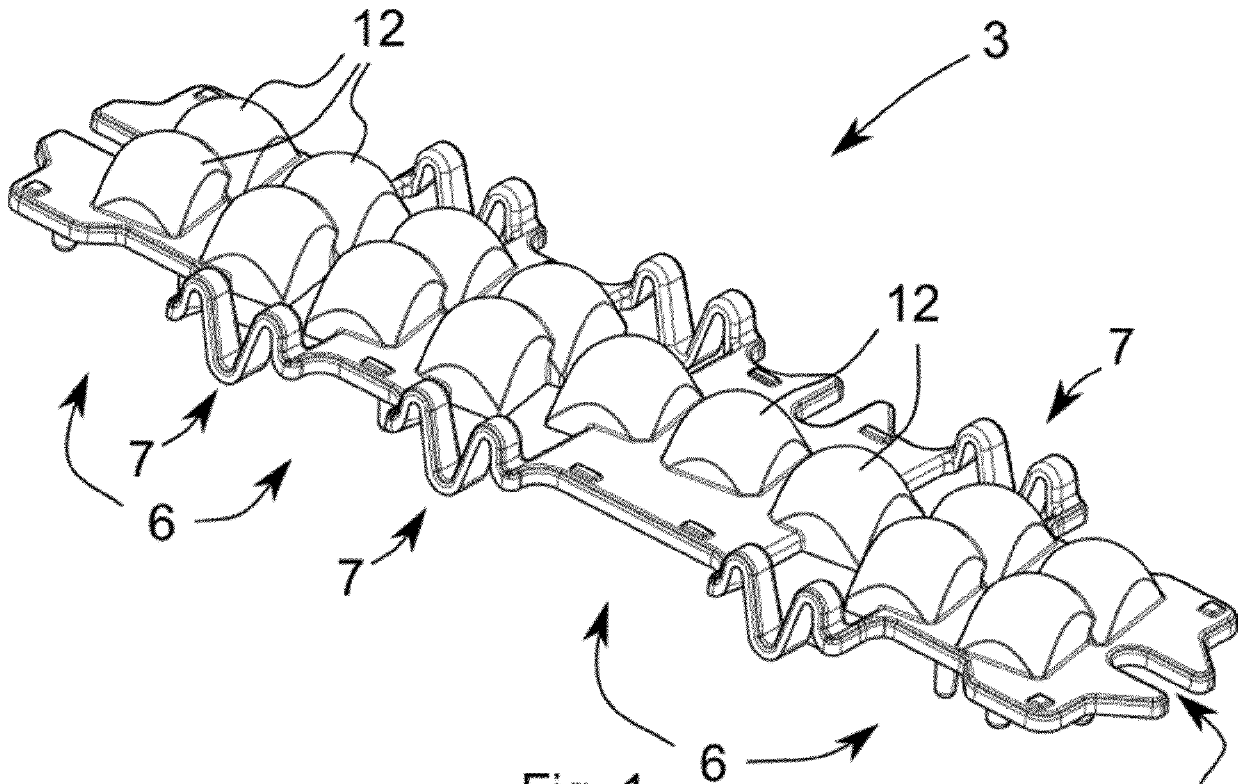

Fig. 1

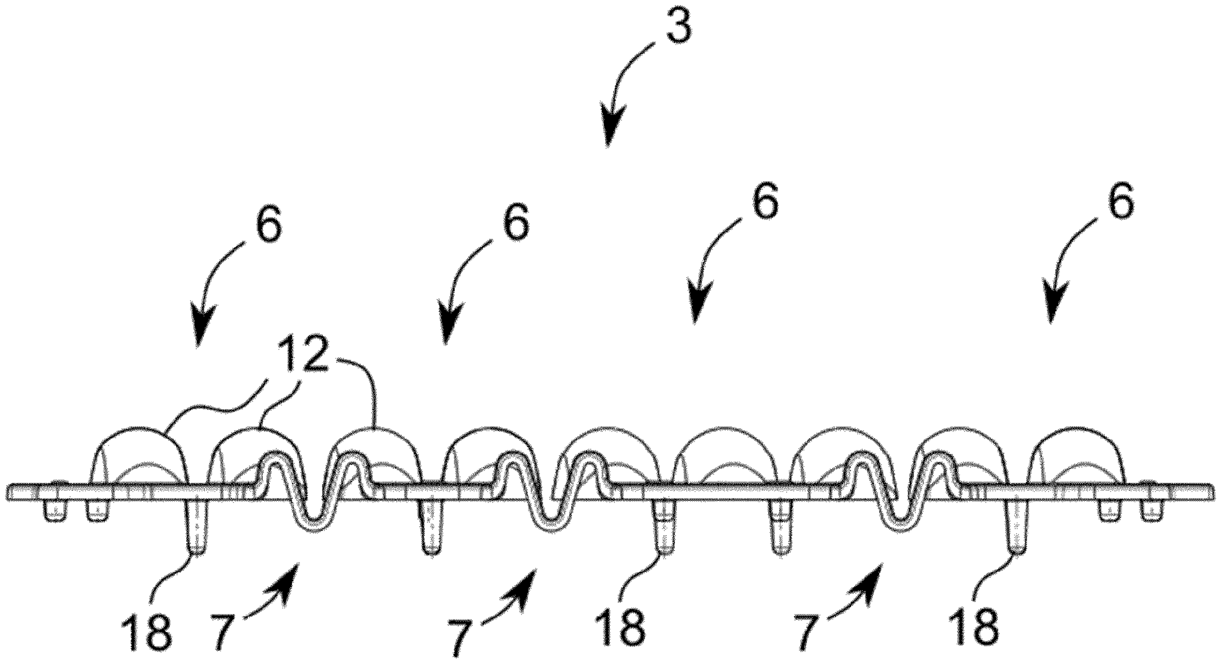

Fig. 2

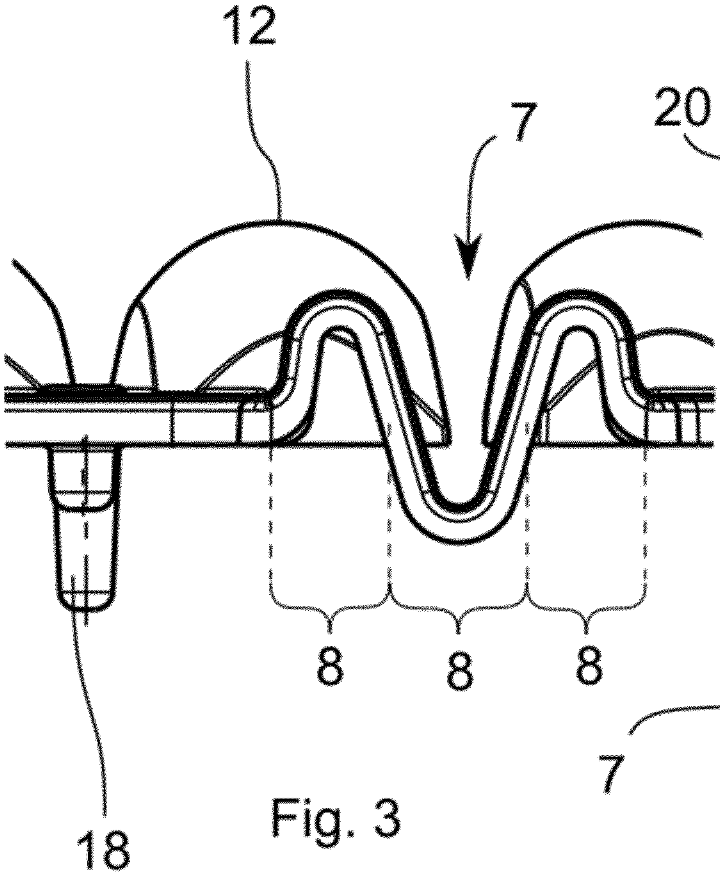

Fig. 3

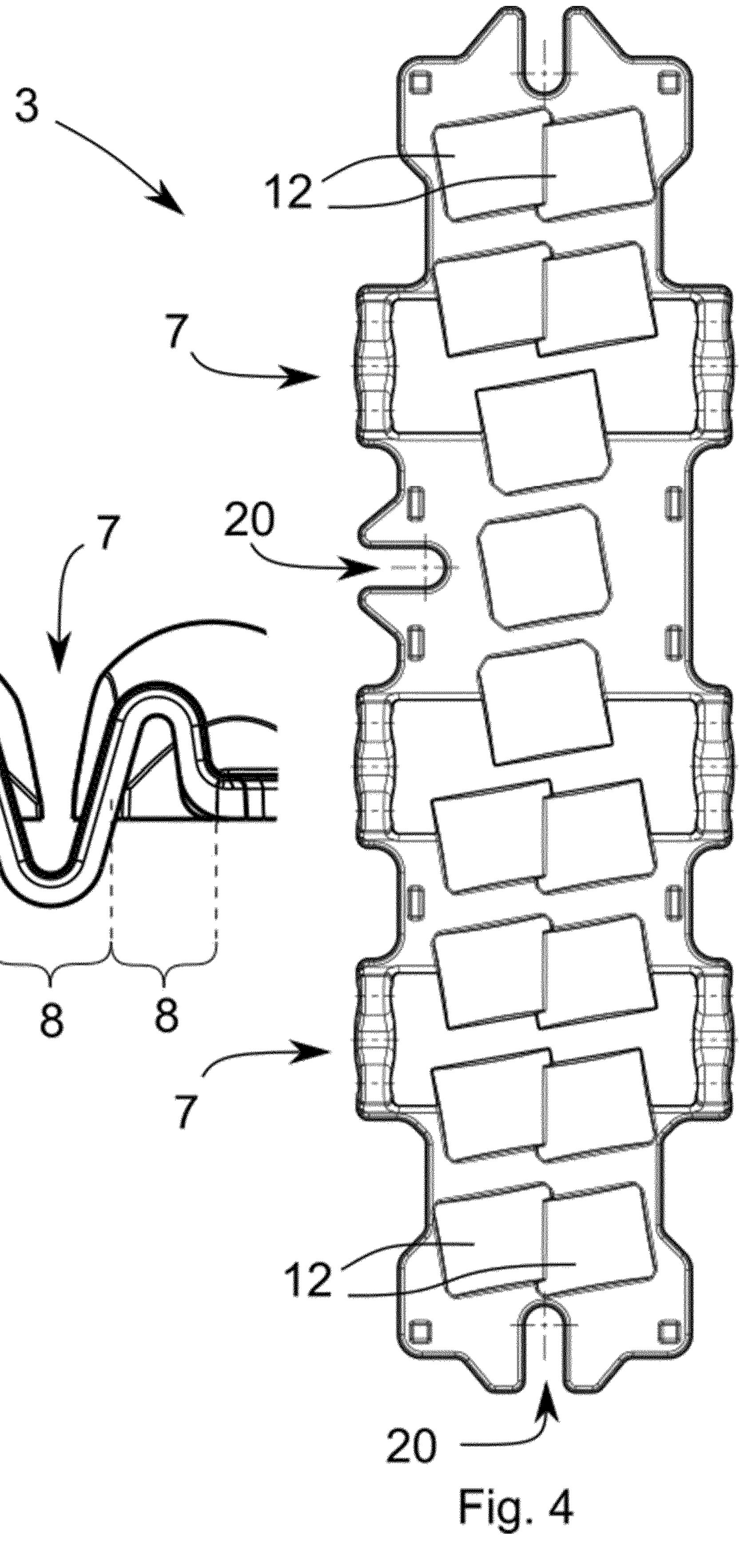

Fig. 4

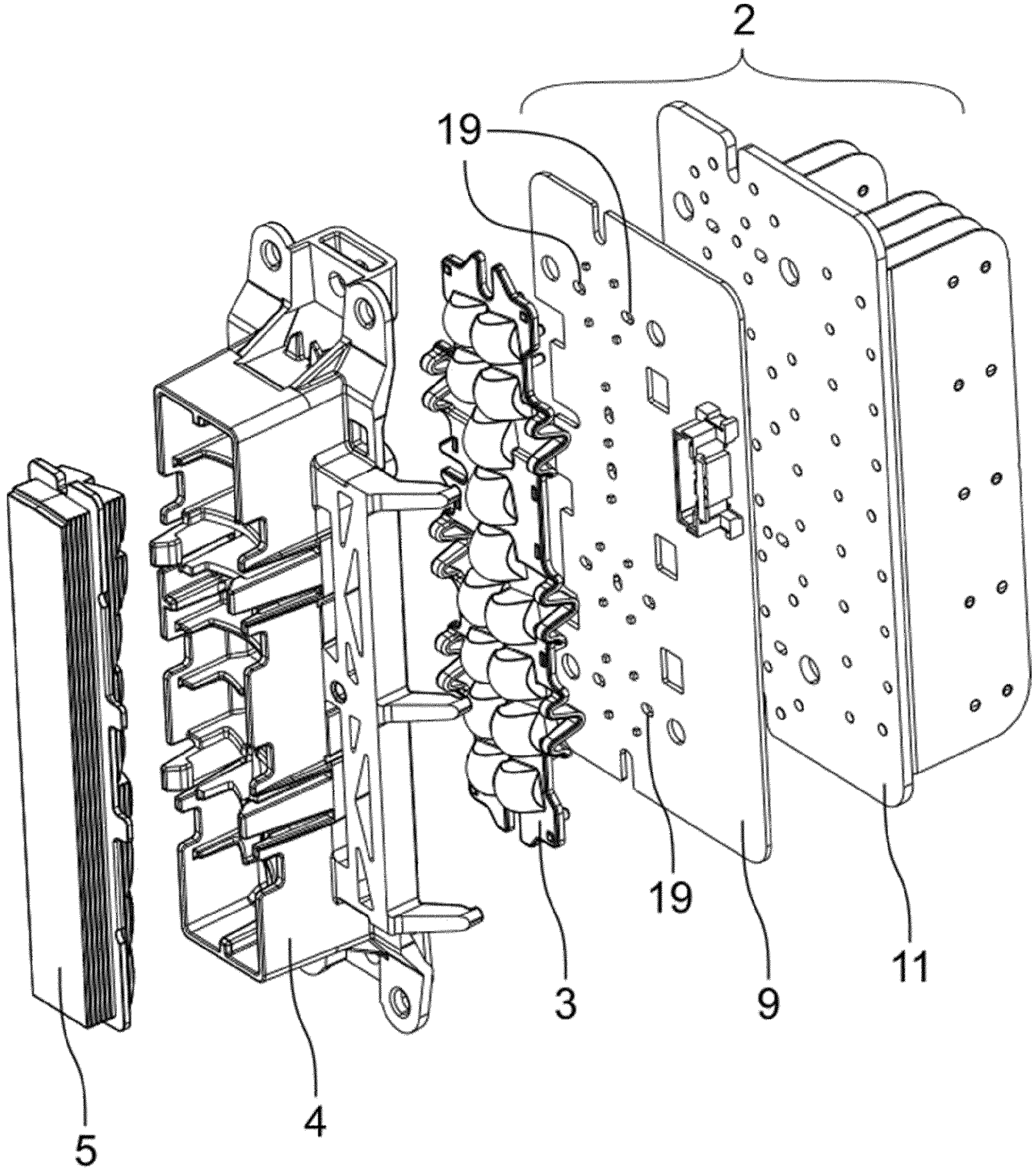

Fig. 5

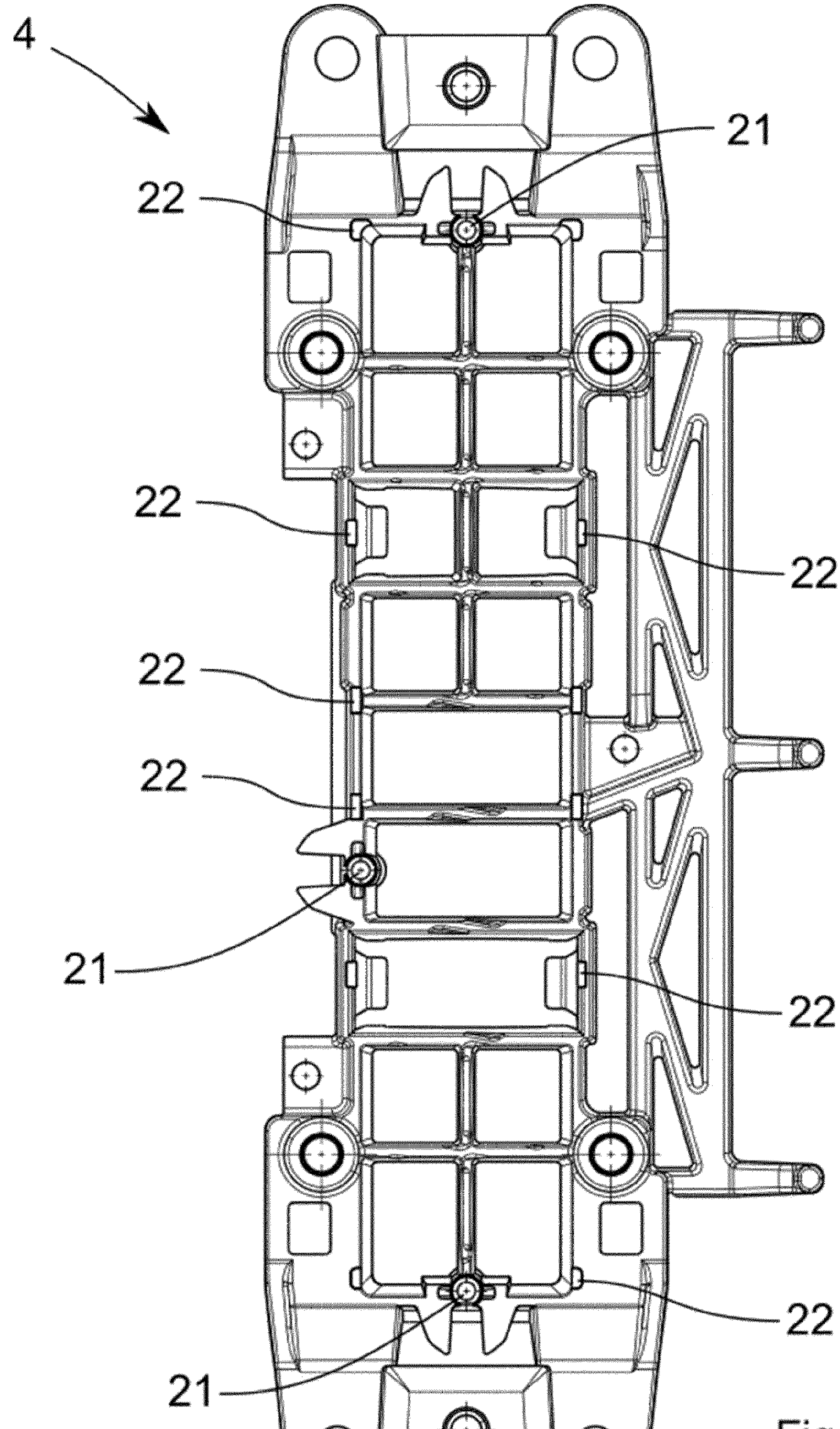

Fig. 6

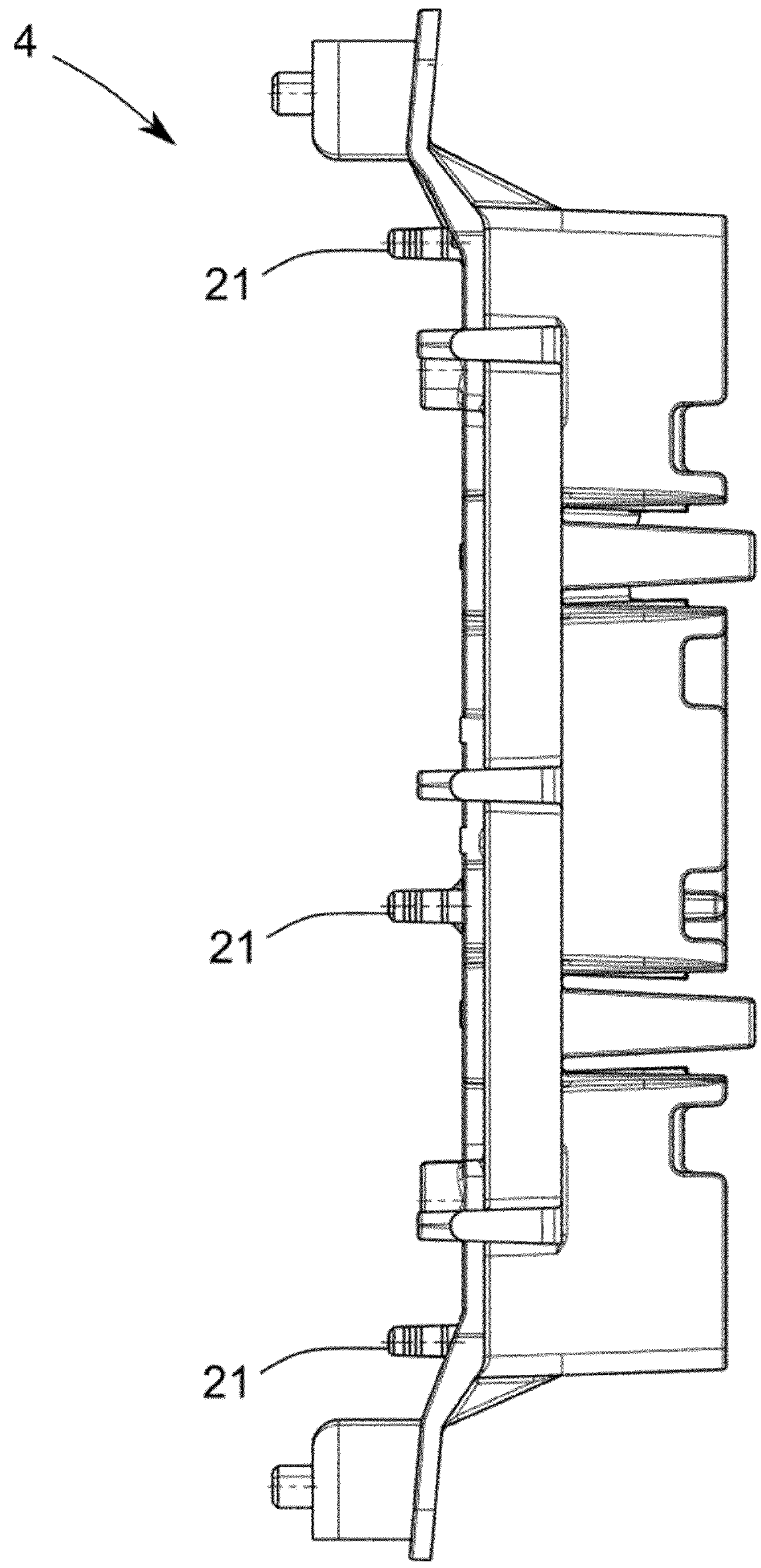

Fig. 7

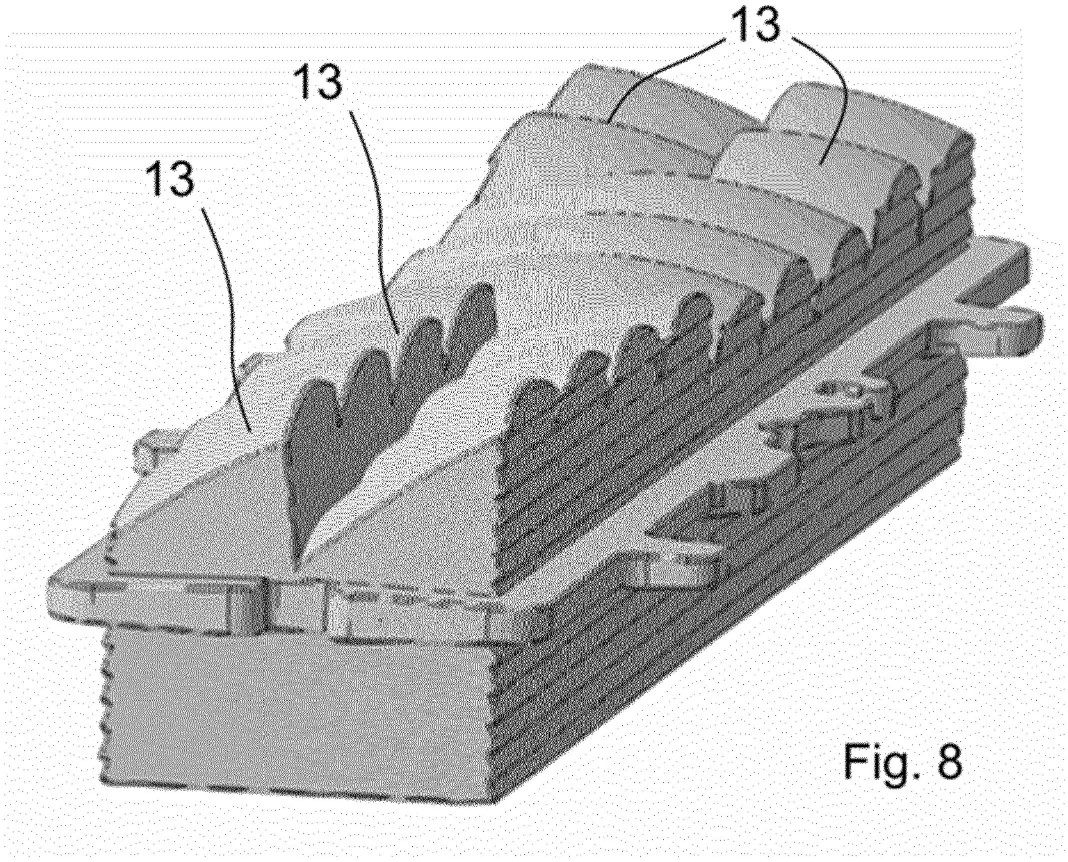

Fig. 8

5

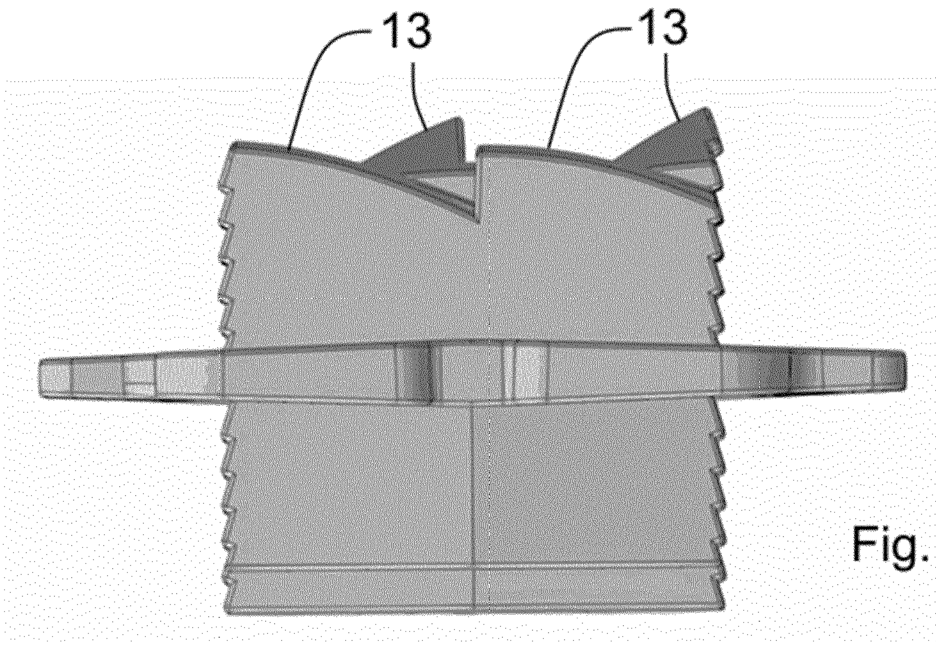

Fig. 9

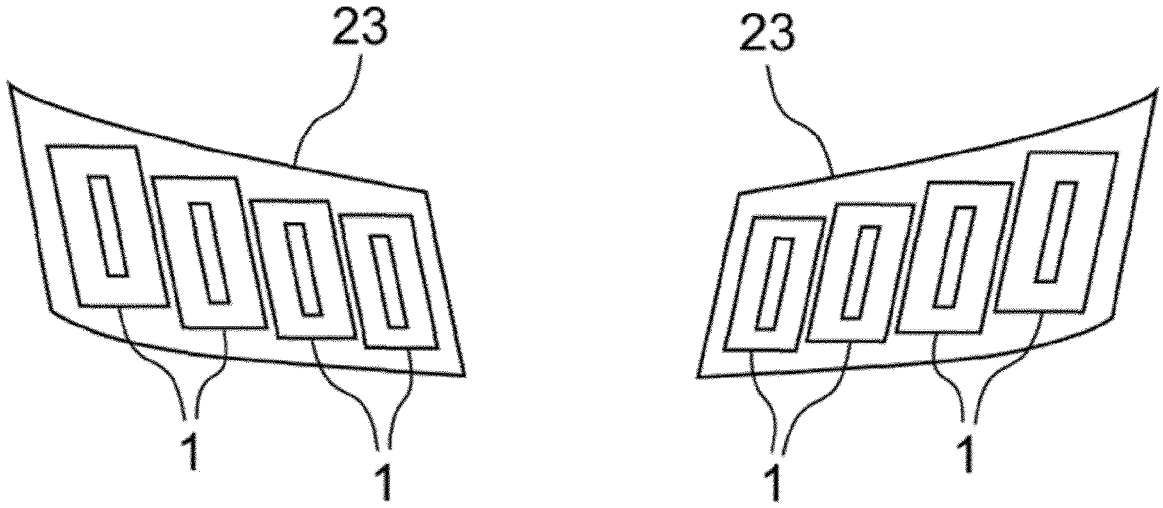

Fig. 10

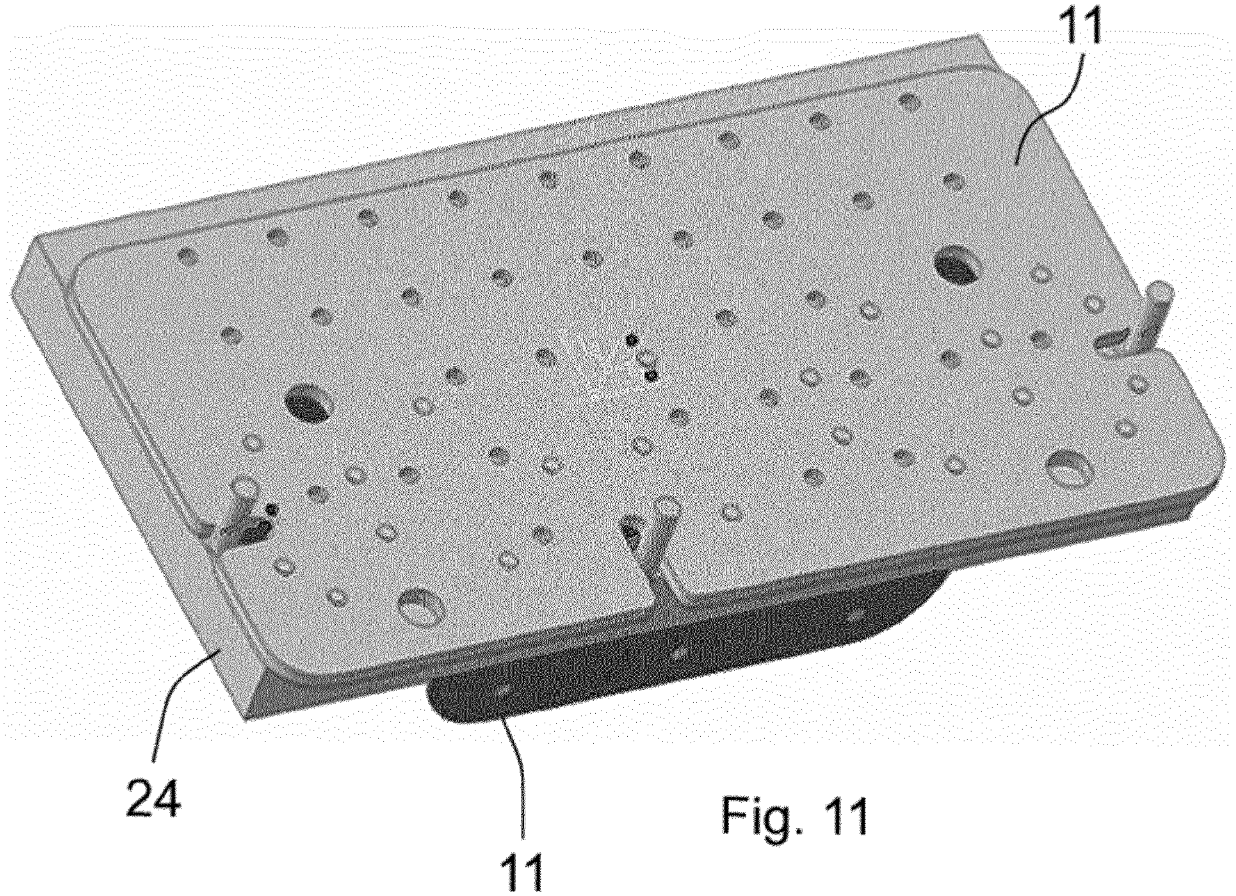

Fig. 11

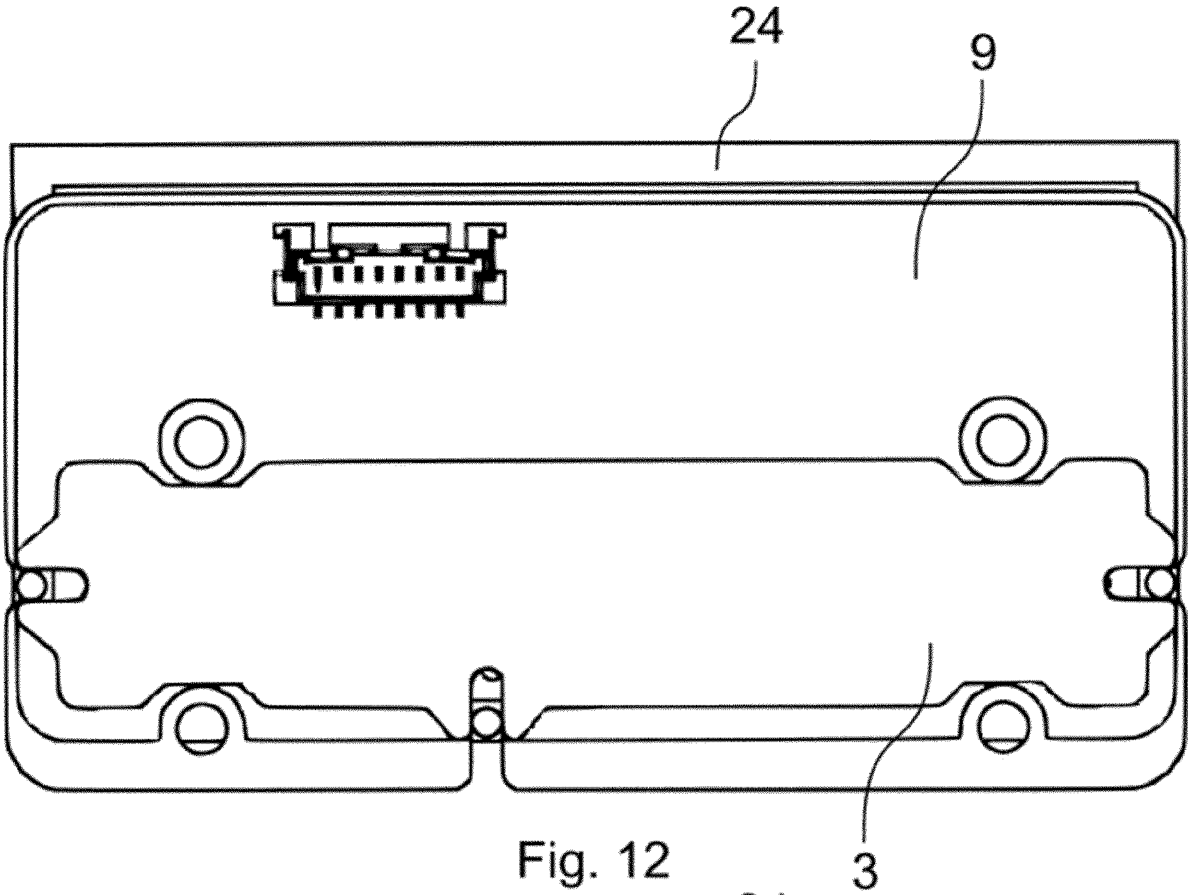

Fig. 12

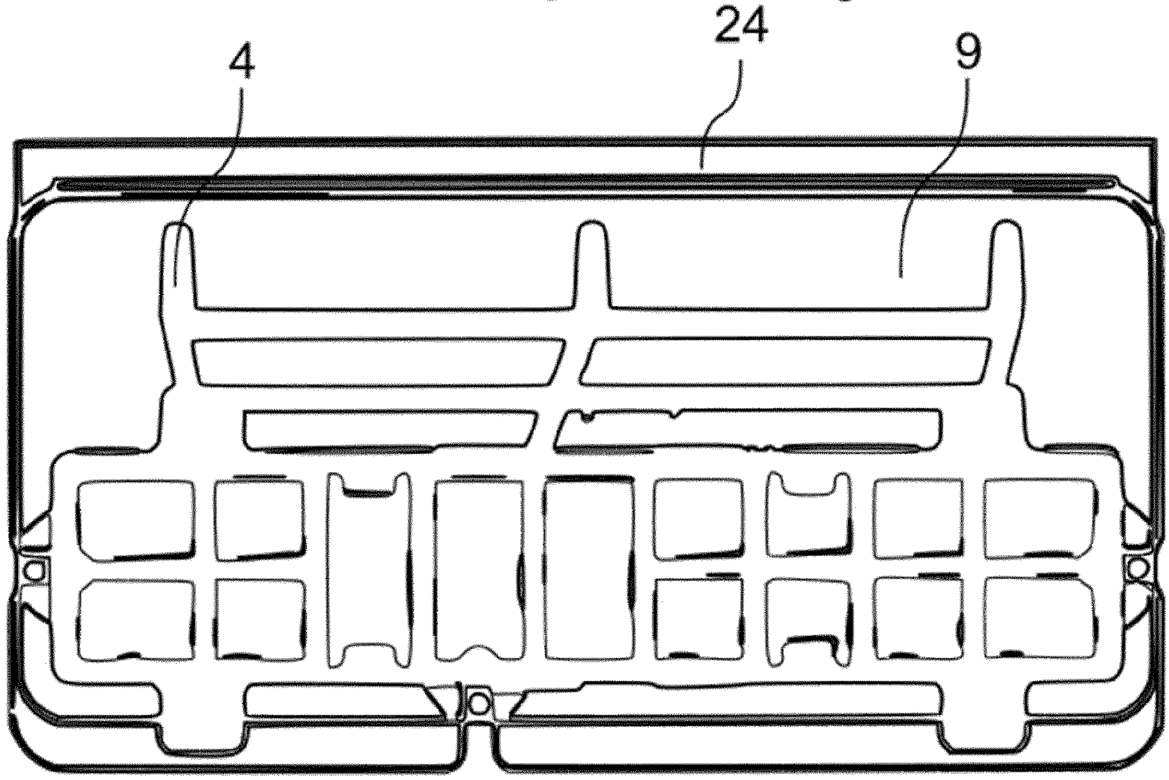

Fig. 13

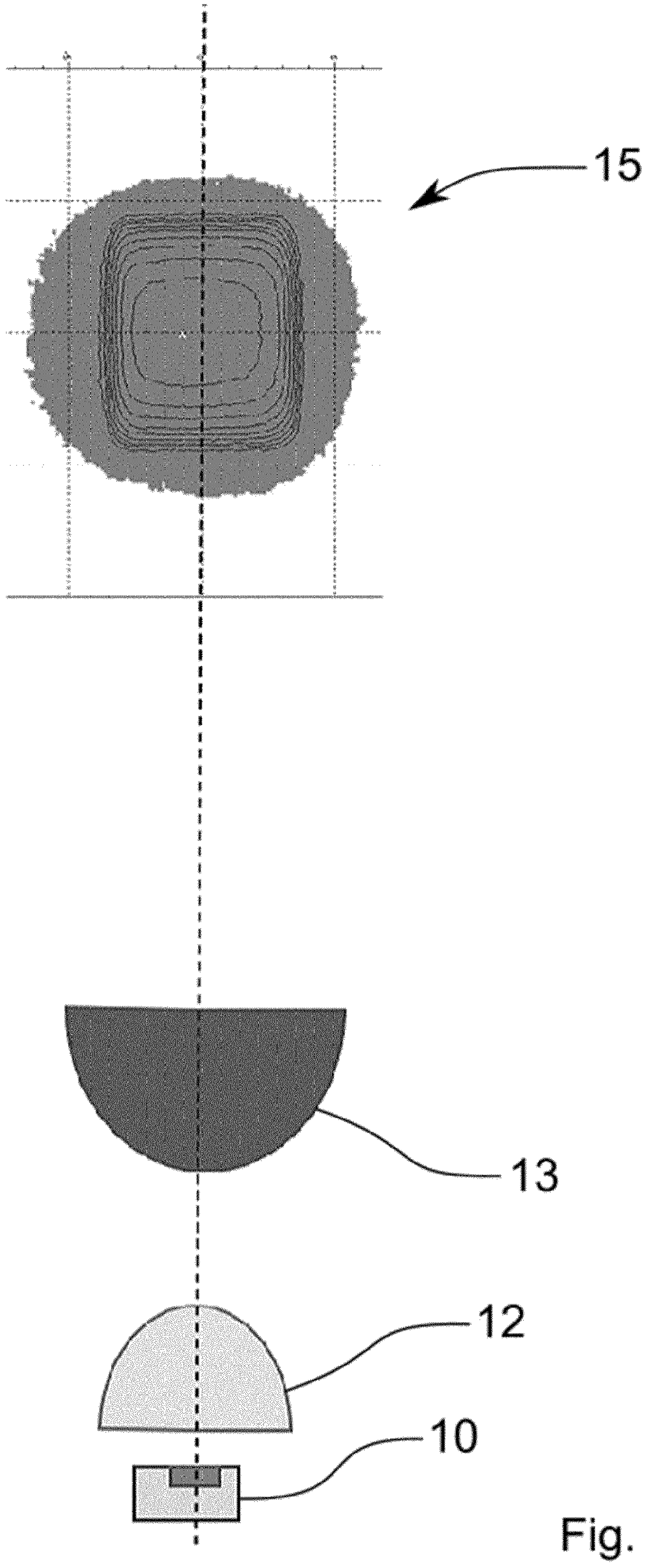

Fig. 14

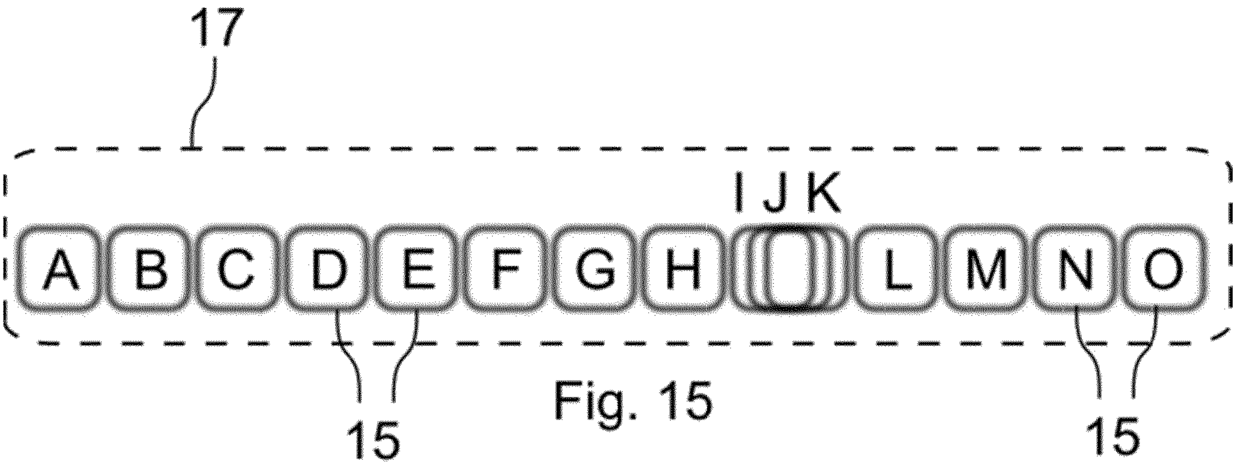

Fig. 15

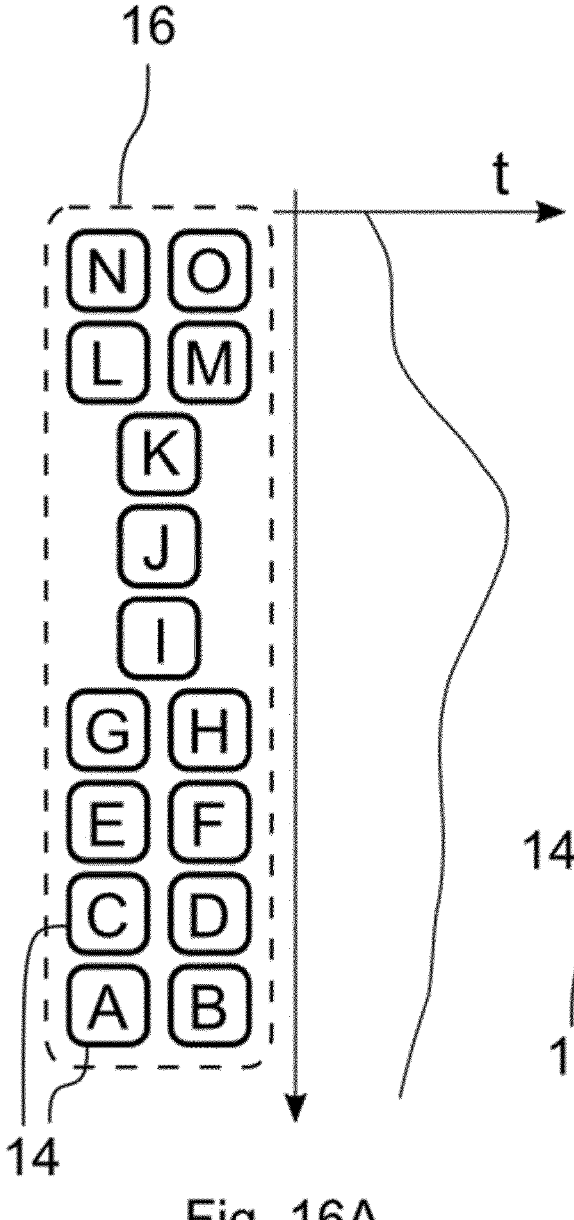

Fig. 16A

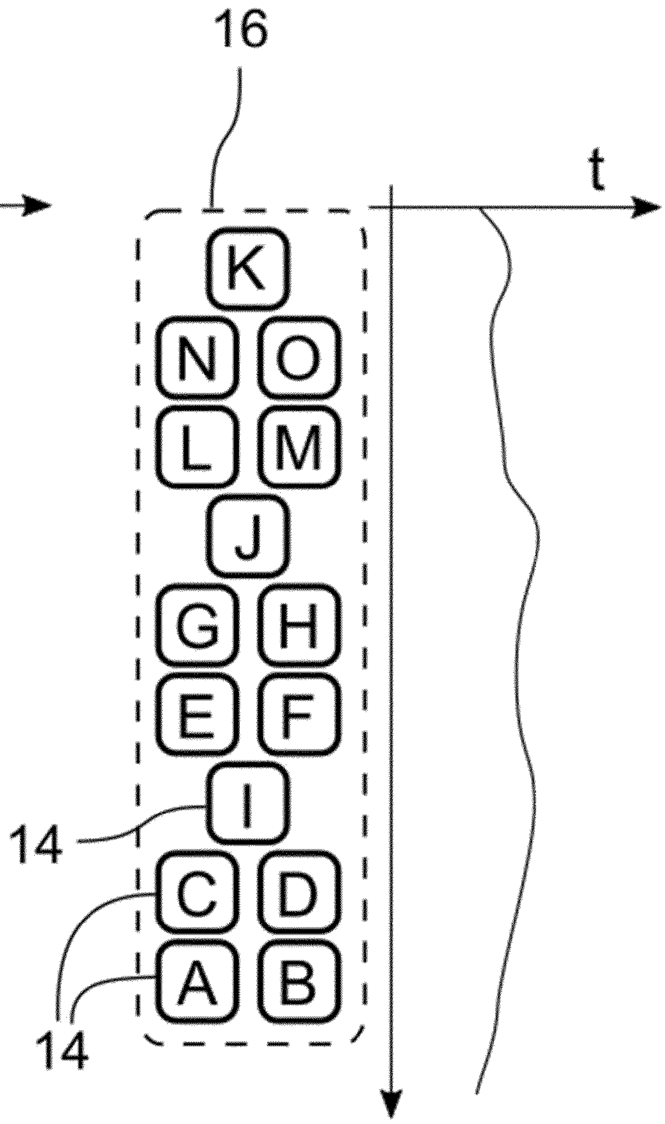

Fig. 16B

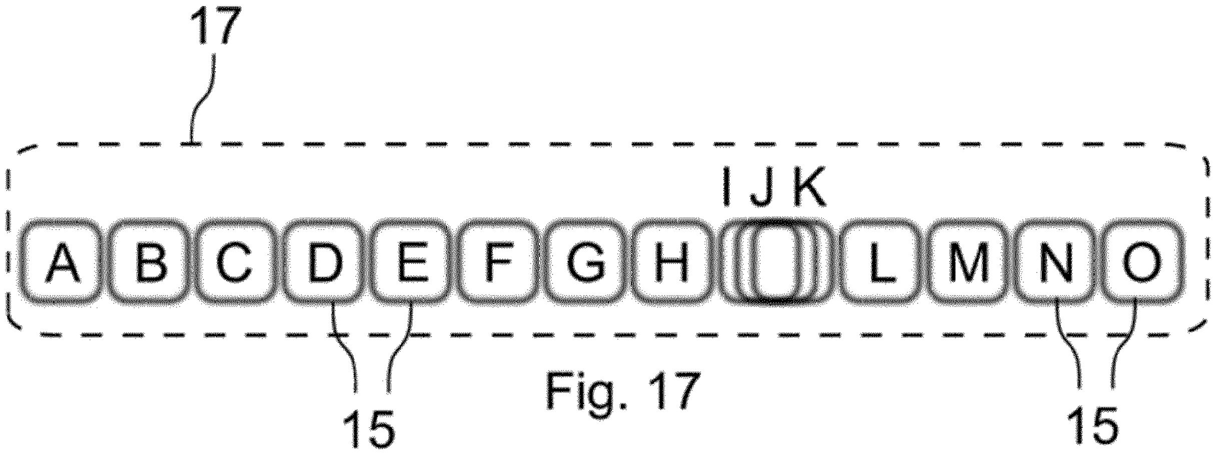

Fig. 17

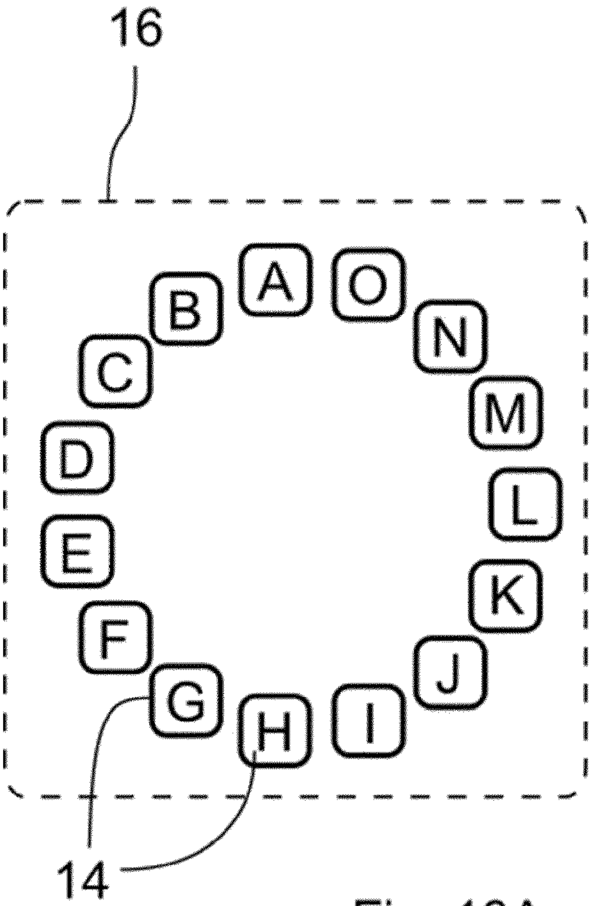

Fig. 18A

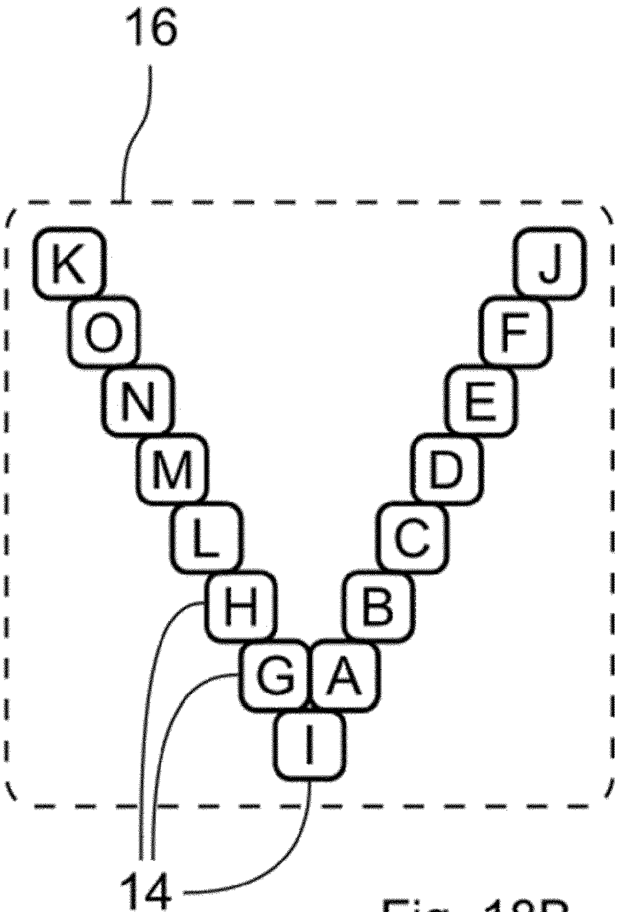

Fig. 18B

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 23 20 7052

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	JP 2019 220398 A (ICHIKOH INDUSTRIES LTD) 26 December 2019 (2019-12-26) * see attached machine translation; paragraphs [0015] - [0073]; figures 1-7 * -----	1-15	INV. F21S41/143 F21S41/153 F21S41/19 F21S41/265 F21S41/20 F21S41/29 F21S41/50 F21S45/47
A	DE 10 2018 132065 A1 (AUTOMOTIVE LIGHTING REUTLINGEN GMBH [DE]) 18 June 2020 (2020-06-18) * paragraphs [0005] - [0007], [0025], [0030], [0032], [0040], [0042], [0067], [0068]; figures 1,6-8 * -----	1-15	
A	US 2019/338930 A1 (SPINGER BENNO [DE] ET AL) 7 November 2019 (2019-11-07) * paragraphs [0039], [0052]; figures 1-11 * -----	1-4,12, 15	
A	DE 10 2016 217121 A1 (OSRAM GMBH [DE]) 8 March 2018 (2018-03-08) * paragraphs [0006] - [0039]; figures 1-4 * -----	1-15	TECHNICAL FIELDS SEARCHED (IPC)
A	JP 2016 110818 A (ICHIKOH INDUSTRIES LTD) 20 June 2016 (2016-06-20) * see attached machine translation; paragraphs [0011] - [0077]; figures 1-8 * -----	1,8-12	F21S G02B
A	EP 3 181 990 A1 (OSRAM GMBH [DE]) 21 June 2017 (2017-06-21) * paragraphs [0008] - [0040]; figures 1-6 * -----	1-15	
A	DE 10 2016 202571 A1 (OSRAM GMBH [DE]) 24 August 2017 (2017-08-24) * paragraphs [0020] - [0030]; figures 1-4 * -----	1	

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	20 February 2024	Goltes, Matjaz

CATEGORY OF CITED DOCUMENTS

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& : member of the same patent family, corresponding document

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 23 20 7052

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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20-02-2024

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP 2019220398 A	26-12-2019	JP 7043990 B2	30-03-2022
		JP 2019220398 A	26-12-2019
DE 102018132065 A1	18-06-2020	NONE	
US 2019338930 A1	07-11-2019	CN 108474538 A	31-08-2018
		EP 3371512 A1	12-09-2018
		JP 6450891 B1	09-01-2019
		JP 2019503048 A	31-01-2019
		KR 20180081626 A	16-07-2018
		US 2019338930 A1	07-11-2019
		WO 2018065278 A1	12-04-2018
DE 102016217121 A1	08-03-2018	DE 102016217121 A1	08-03-2018
		WO 2018046321 A1	15-03-2018
JP 2016110818 A	20-06-2016	NONE	
EP 3181990 A1	21-06-2017	CN 206786544 U	22-12-2017
		DE 102015225306 A1	22-06-2017
		EP 3181990 A1	21-06-2017
DE 102016202571 A1	24-08-2017	NONE	

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 11028987 B2 **[0002]**
- WO 2022242783 A1 **[0002] [0065]**