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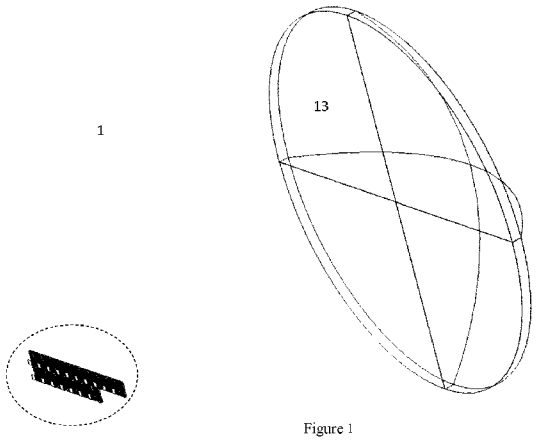

Figure 1

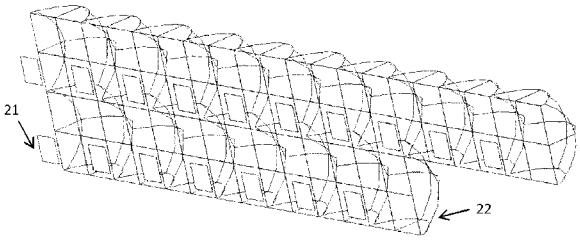

Figure 2

(57) Abstract: The present invention relates to an optical module (1) and an automotive frontlighting system of a motor vehicle comprising such an optical module (1). The optical module (1) comprises a light emitting element (21), a primary optics (22) and a secondary optics (13). Specifically, the light emitting element (21) comprises an array of light sources, such as an array of LEDs. In a similar way, the primary optics (22) comprises an array of primary lenses, wherein each primary lens is adapted to collimate light from a corresponding one of the light sources. The secondary optics (13) is further adapted to receive the collimated light from each primary lens and project it onto a road in front of the motor vehicle. A first distance between each light source and its corresponding primary lens, a second distance between the primary optics (22) and the secondary optics (13), a first focal length of each primary lens, and a second focal length of the secondary optics (13) are adapted such that light passing through a primary lens and originating from light sources other than the light source corresponding to this primary lens will exit this primary lens with an output angle large enough for preventing such light from entering the secondary optics (13).

WO 2018/172140 A1

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OPTICAL MODULE AND AUTOMOTIVE FRONTLIGHTING SYSTEM FOR MOTOR VEHICLE

FIELD OF THE INVENTION

The present invention relates to the field of automotive frontlighting, particularly to an optical module for an automotive frontlighting system of a motor vehicle, as well as an automotive frontlighting system of a motor vehicle comprising such an optical module.

BACKGROUND OF THE INVENTION

With continued efforts spent in avoiding glare to oncoming and ahead cars, adaptive driving beam function has become a hot topic in the field of automotive frontlighting. Nowadays, there are several main approaches to help realizing this function. One of these approaches is to use a LED array and a reflector or lens, but there is no primary optics in this approach. Another approach is to use a LED array, a lens or reflector, as well as a primary optics. The first approach as indicated above has advantages such as simple structure, but with a blurred cut-off between bright and dark areas. Although a clear cut-off can be formed by the second approach, the color uniformity there is always not very good.

In addition, a solution containing a projection lens and a comb collimator is also proposed in order to obtain a glare-free driving beam lamp for use in automotive frontlighting. However, the comb collimator in this solution does not change the angle of light, and all its influence is to redistribute light on an output surface of the collimator. In this case, the color dispersion will be inevitable.

Besides, for the projection lens plus comb collimator solution, outer ends of the comb are combined together, and thus light will cross mix from neighboring collimators which renders a very low contrast between bright and dark areas.

Furthermore, the current solution containing a projection lens and a comb collimator also requires a very high positioning accuracy for the LEDs as it requires a good match between LEDs and comb collimators. In this solution, even a 0.05 mm

tolerance for the LED position will affect the system's efficiency dramatically.

WO2015198527A1 discloses a related solution where a complex shaped light guide array is used as primary optics with each LED emitting into a recess formed into each single light guide of the array. By arrangement of the LED towards the light guide's input and reflection faces, cross talk between neighboring LEDs is largely avoided.

SUMMARY OF THE INVENTION

The present invention provides an optical module for an automotive frontlighting system of a motor vehicle as well as an automotive frontlighting system of a motor vehicle comprising such an optical module in order to eliminate or at least alleviate one or more of the above mentioned disadvantages.

According to a first aspect of the present invention, an optical module for an automotive frontlighting system of a motor vehicle is proposed. The optical module mainly comprises a light emitting element, a primary optics and a secondary optics. Specifically, the light emitting element comprises an array of light sources, such as an array of LEDs, for example 1 to 5 rows of LEDs. In a similar way, the primary optics comprises an array of primary lenses, wherein each primary lens is adapted to collimate light from a corresponding one of the light sources. In a downstream location, the secondary optics is further adapted to receive the collimated light from each primary lens and project it onto a road in front of the motor vehicle. A first distance between each light source and its corresponding primary lens, a second distance between the primary optics and the secondary optics, a first focal length of each primary lens, and a second focal length of the secondary optics are adapted such that light passing through a primary lens and originating from light sources other than the light source corresponding to this exact primary lens is prevented from entering the secondary optics.

With the above proposed optical module incorporated in an automotive frontlighting system of a motor vehicle, cross-talks between neighboring light sources in the beam pattern finally projected on the road will be avoided. The reason for this is that structural parameters of the present optical module, such as a first distance between

each light source and its corresponding primary lens, a second distance between the primary optics and the secondary optics, a first focal length of each primary lens, and a second focal length of the secondary optics, are all designed collectively such that only light emitted from a light source and passing through a primary lens associated with this exact light source could get into the secondary optics and thus be used for illuminating the road ahead of the motor vehicle. In other words, light emitted from neighboring light sources will be imaged by the primary lens outside of a light entrance aperture of the secondary optics. In this case, a high contrast of each segment (i.e. an individual light source and its relevant primary lens) in the above proposed optical module will be achieved, and hence a glare-free driving beam is enabled.

Besides, in the above proposed optical module, undesirable color fringes will also be prevented, since the primary optics is configured to collimate light from those light sources. That is, light beams after passing through the primary optics will generally have small divergence angles, such as a divergence angle below 30 degree, if the secondary lens has a focal length between 50mm and 100mm and a height less than 70mm. Certainly, light beams after the primary optics may have different small divergence angles based on different choices about the focal length and size of the secondary lens. Further, optionally, a light beam from each light source can even be collimated into parallel light by its corresponding primary lens. In this way, the whole optics' astigmatism will be acceptable, and thus undesirable color fringes can be avoided.

According to a specific embodiment of the above recited optical module, each light source is placed in a focal plane of its corresponding primary lens, especially placed at a focal point of its corresponding primary lens. In this case, the primary optics will be able to change a light distribution, especially a Lambert light distribution, from each light source into parallel light. Preferably, the primary optics is designed to have a first focal length between 2 mm and 6 mm. In this way, the optics system will exhibit an acceptable astigmatism effect.

Further optionally, in another specific embodiment of the optical module as provided by the present invention, the primary optics is also placed in a focal plane of the secondary optics, especially placed at a focal point of the secondary optics. In

addition, the secondary optics can be designed to be a projection lens having a very long focal length, such as a focal length between 50 mm and 150 mm. With parallel light from the primary optics and a long focal length of the secondary optics, the color dispersion of the light beam finally projected on the road is greatly reduced.

As a specific example, in an embodiment of the above proposed optical module, the primary lens is selected to be a freeform lens. Furthermore, this freeform lens is also configured to have a rectangular outline, which is clearly different from an existing lens with a simple form, such as a plano-convex primary lens. Alternatively, as another example implementation, the primary lens can also be a rectangular Fresnel lens. Apparently, those skilled in the art, having benefited from teachings of the present invention, will obtain some other suitable forms of the primary lenses, and the present invention should not be limited to those examples as listed above.

According to a specific embodiment, the numbers of the light sources and the primary lenses are the same. That is to say, each individual light source could have its own corresponding primary lens, and this will not incur any waste of the light sources and/or the primary lenses.

In a specific practical implementation, the primary optics can be manufactured by injection molding. Obviously, those skilled in the art, especially having benefited from teachings of the present invention, will obtain some other suitable processes for acquiring the primary optics, i.e. individual primary lenses, as well as the secondary optics. Again, the present invention should not be limited to those examples as listed above.

According to a second aspect of the present invention, an automotive frontlighting system of a motor vehicle is proposed. Specifically, the automotive frontlighting system of a motor vehicle here comprises at least one optical module as provided in any of the above embodiments of the present invention.

It will be appreciated by those skilled in the art that two or more of the above mentioned embodiments, implementations, and/or aspects of the invention may be combined in any way deemed useful.

Modifications and variations of the automotive frontlighting system of the motor vehicle, which correspond to the described modifications and variations of the

optical module, can be carried out by a person skilled in the art on basis of the present description.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other aspects of the present invention will now be described in more detail, with reference to the appended drawings showing embodiments and forming a part of the present invention.

Specifically, in the drawings:

Fig. 1 schematically illustrates an optical module for an automotive frontlighting system of a motor vehicle according to an embodiment of the present invention;

Fig. 2 schematically illustrates an enlarged view of the portion (i.e. the light emitting element and the primary optics contained in the optical module) indicated by the dotted circle of Fig. 1, where the light emitting element comprises an array of LEDs and the primary optics comprises an array of freeform lenses;

Fig. 3 schematically illustrates a simulated beam pattern to be projected onto the road based on the optical module of Fig. 1, where one LED is switched off to form a reference dark area;

Fig. 4 schematically illustrates a light emitting element and a primary optics contained in an optical module according to another embodiment of the present invention, where the light emitting element comprises an array of LEDs and the primary optics comprises an array of Fresnel lenses; and

Fig. 5 schematically illustrates a simulated beam pattern to be projected onto the road based on an optical module comprising the light emitting element and the primary optics of Fig. 4, where one LED is, similarly to Fig. 3, switched off to form a reference dark area.

DETAILED DESCRIPTION OF THE EMBODIMENTS

While this invention is susceptible of embodiments in many different forms, there is shown in the drawings and will be described in detail herein one or more specific embodiments, with the understanding that the present description is to be

considered as exemplary of principles of the present invention and not intended to limit the present invention to the specific embodiments as shown and described herein.

It should be noted that various components in different figures are not drawn to scale. Besides, relative positions between individual elements as shown in the figures are only used to illustrate basic principles of the present invention and should not be considered to limit the scope of the present invention.

With reference to Figs. 1-3, an optical module for use in an automotive frontlighting system of a motor vehicle according to an embodiment of the present invention will be described in detail. To be specific, Fig. 1 schematically illustrates the optical module as a whole; Fig. 2 schematically illustrates an enlarged view of the portion within the dotted circle of Fig. 1, i.e. the light emitting element and the primary optics; and Fig. 3 schematically gives a corresponding simulated beam pattern to be projected on the road using the optical module as shown in Fig. 1.

In particular, in the exemplary embodiment as shown by Figs. 1-3, the optical module 1 comprises a light emitting element 21, a primary optics 22, and a secondary optics 13. Specifically, the light emitting element 21 in this embodiment comprises two rows of LEDs, wherein there are 10 LEDs in the upper row and 7 LEDs in the lower row. Accordingly, the primary optics, in this particular embodiment, also comprises an array of 17 rectangular freeform lenses. Respectively, 10 freeform lenses correspond to the 10 upper LEDs, and 7 freeform lenses correspond to the 7 lower LEDs. Each primary freeform lens is adapted to collimate light from a corresponding LED. In the downstream part, the secondary optics 13 is further adapted to receive the collimated light from each freeform lens and project it onto a road in front of the motor vehicle. These three portions of the optical module 1, i.e. the light emitting element 21, the primary optics 22, and the secondary optics 13, contribute to realize a glare-free driving beam lamp in an automotive frontlighting application.

Advantageously, apart from two rows of LEDs, the light sources could also be designed in other forms of semiconductor light sources, such as single chip LEDs or SMD LEDs. With regard to materials for making the primary lens, organic or inorganic glass or silicone rubber (LSR, liquid silicone rubber) can be used. For example, organic glasses may include polymethyl methacrylate (PMMA), cyclo-olefin copolymer (COC),

cyclo-olefin polymer (COP), polycarbonate (PC), polysulfone (PSU) or polymethacryl methylimide (PMMI). Additionally, as for fabrication processes suitable for manufacturing the primary optics, an injection molding could be adopted. Apparently, the present invention shall not be limited only to injection molding, and any other suitable means could be used for preparing the primary optics.

In a preferred embodiment, as shown in Figs. 1-3, each LED can be disposed on a focal point of its corresponding freeform lens. In this case, preferably, the focal length of each freeform lens, i.e. the distance between each LED and its corresponding freeform lens, may be selected between 2 mm and 6 mm. With such a relatively short distance, a high optical efficiency will be achieved, and in the meantime, no other problem such as interferences between an LED and its primary lens will be incurred.

Besides, in another optional embodiment, the primary optics can also be disposed on a focal point of the secondary optics. In this case, preferably, the secondary optics can be designed in the form of a projection lens having a relatively long focal length such as a focal length between 50 mm and 150 mm, preferably between 70 mm and 100 mm. With such a long focal length of the secondary projection lens the maximum obtainable intensity will be elevated.

As can be seen from the above structure, although the primary freeform lenses are all combined together to form an array, light passing through a single freeform lens and originating from LEDs other than the LED corresponding to this exact freeform lens will finally go out of the whole system. In this particular embodiment, this is achieved by each LED being configured to reside on a focal point of its corresponding freeform lens, and not any focal point of the neighboring freeform lenses. In this case, the portion of light, which comes from a specific LED and passes through freeform lenses other than the freeform lens corresponding to this exact LED, will exit the freeform lens with a very big output angle. As in this embodiment the secondary optics has a very long focal length, such as a focal length between 50 mm and 150 mm, especially a focal length between 70 mm and 100 mm, this part of light will not get into the secondary optics and hence will have no contribution to the system's beam output. As a result, a very high contrast for each working segment will

be achieved. This high contrast and sharp cut-off is clearly manifested in the simulated beam pattern to be projected onto the road of Fig. 3, where for the purpose of understanding the present invention, one LED is switched off to give a reference dark area.

Furthermore, with each LED disposed on a focal point of its corresponding freeform lens, the Lambert light distribution emitted from each LED will be collimated into parallel light. In case the secondary projection has a very long focal length and thus a very large F number, the color dispersion will be significantly lowered.

Besides, in the above proposed optical module, a 0.2 mm tolerance would be acceptable for the positioning accuracy of LEDs, which is much better as compared with the current projection lens plus comb collimator solution where even a 0.05 mm tolerance will have a strong impact on the system's efficiency.

Similarly to the case as shown in Figs. 1-3, a light emitting element and a primary optics contained in an optical module according to another embodiment of the present invention will be discussed in the following with specific reference to Figs. 4-5. Specifically, Fig. 4 schematically illustrates a light emitting element 41 comprising an array of LEDs and a primary optics 42 comprising an array of Fresnel lenses; and Fig. 5 schematically illustrates a corresponding simulated beam pattern to be projected onto the road based on an optical module comprising the light emitting element and the primary optics of Fig. 4.

The light emitting element 41 in Fig. 4 is basically the same as that in Fig. 2, i.e., comprising two rows of LEDs, wherein 10 LEDs are located in the upper row and 7 LEDs are located in the lower row. Besides, each LED can be disposed on a focal point of its corresponding primary lens. The difference between Fig. 4 and Fig. 2 mainly lies in the primary optics 42. Specifically, in Fig. 4, the primary optics 42 comprise an array of 17 rectangular Fresnel lenses. Respectively, 10 Fresnel lenses are corresponding to the 10 upper LEDs, and 7 Fresnel lenses are corresponding to the 7 lower LEDs. Each Fresnel lens can be specially adapted to collimate light from its corresponding LED. In view of the fact that each LED is disposed on a focal point of its corresponding Fresnel lens, light from each LED will be collimated into parallel light.

Based on the same concept, only the light emitted from a LED and passing

through its associated primary Fresnel lens will get a chance to enter the secondary optics. In other words, portions of light exiting the primary Fresnel lenses with a relative large output angle will finally go out of the entire system, and have no contribution to the output light beam projected onto the road. As a result, cross mixtures between adjacent LEDs will be avoided, and a very high contrast of each working segment will be achieved. This high contrast and sharp cut-off is clearly illustrated in the simulated beam pattern to be projected onto the road of Fig. 5, where for the purpose of easy understanding, one LED is switched off to give a reference dark area.

It is worth noting that in the simulated results shown by Figs. 3 and 5, a black region represents little or even zero light intensity, while on the contrary, a white region represents the maximum light intensity. Accordingly, a grey region shall represent a light intensity having a value somewhere between the maximum one and zero.

It should be noted that the above-mentioned embodiments illustrate rather than limit the present invention, and that those skilled in the art will be able to design many alternative embodiments without departing from the scope and spirit of the present invention. Although the present invention has been described in connection with some embodiments, it is not intended to be limited to the specific forms as set forth herein. Rather, the scope of the present invention is limited only by the accompanying claims. Additionally, although a feature may appear to be described in connection with particular embodiments, one skilled in the art would recognize that various features of the described embodiments may be combined in accordance with the invention.

Furthermore, although individual features may be included in different claims, these may possibly be advantageously combined, and the inclusion in different claims does not imply that a combination of features is not feasible and/or advantageous. Also, the inclusion of a feature in one category of claims does not imply a limitation to this category but rather indicates that the feature is equally applicable to other claim categories as appropriate.

In the claims, any reference signs placed between parentheses shall not be construed as limiting the claims. Use of the verb "comprise" and its conjugations does

not exclude the presence of elements or steps other than those stated in a claim. The article "a" or "an" preceding an element does not exclude the presence of a plurality of such elements. Also, references to first, second etc. are merely to be considered as labels and do not imply or describe any ordering, sequence, relation or properties of the features prefixed by these terms.

The present invention may be implemented by hardware comprising several distinct elements or software programmable by any suitable computing devices. In the device claims enumerating several means, several of these means may be embodied by one and the same item of hardware. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage.

CLAIMS:

1. An optical module (1) for an automotive frontlighting system of a motor vehicle, comprising:
a light emitting element (21) comprising an array of light sources,
a primary optics (22) comprising an array of primary lenses, wherein each primary lens is adapted to collimate light from a corresponding one of the light sources, and
a secondary optics (13), which is adapted to receive the collimated light from each primary lens and project it onto a road in front of the motor vehicle,
wherein a first distance between each light source and its corresponding primary lens, a second distance between the primary optics (22) and the secondary optics (13), a first focal length of each primary lens, and a second focal length of the secondary optics (13) are adapted such that light passing through a primary lens and originating from light sources other than the light source corresponding to this primary lens will exit this primary lens with an output angle large enough for preventing such light from entering the secondary optics (13).

2. The optical module (1) according to claim 1, wherein
each primary lens is further adapted to collimate light from its corresponding light source into light with a divergence angle below 30 degree.

3. The optical module (1) according to claim 2, wherein
each primary lens is further adapted to collimate light from its corresponding light source into parallel light.

4. The optical module (1) according to claim 1 or 2, wherein
each light source is placed in a focal plane of its corresponding primary lens.

5. The optical module (1) according to claim 1 or 2, wherein
the primary optics (22) is placed in a focal plane of the secondary optics (13).

6. The optical module (1) according to claim 1 or 2, wherein each primary lens is a freeform lens and has a rectangular outline.

7. The optical module (1) according to claim 6, wherein the rectangular freeform lens is a rectangular Fresnel lens.

8. The optical module (1) according to claim 1 or 2, wherein the secondary optics (13) comprises a projection lens.

9. The optical module (1) according to claim 1 or 2, wherein the light sources and the primary lenses are the same in number.

10. The optical module (1) according to claim 1 or 2, wherein the primary optics (22) is manufactured by injection molding.

11. The optical module (1) according to claim 1 or 2, wherein the array of light sources comprises 1 to 5 rows of LEDs.

12. The optical module (1) according to claim 1 or 2, wherein the first distance between each light source and its corresponding primary lens and the first focal length of each primary lens is 2 - 6 mm.

13. The optical module (1) according to claim 1 or 2, wherein the second distance between the primary optics (22) and the secondary optics (13) and the second focal length of the secondary optics (13) is 50 - 150 mm.

14. An automotive frontlighting system of a motor vehicle comprising at least one optical module (1) according to any one of the claims 1 - 13.

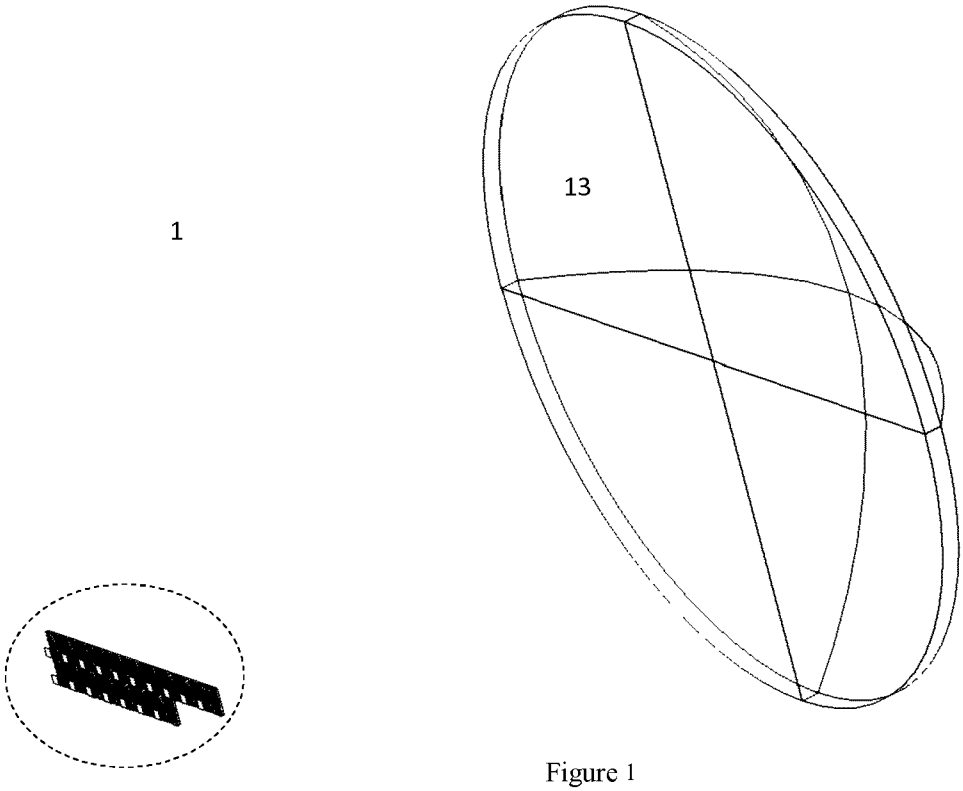

Figure 1

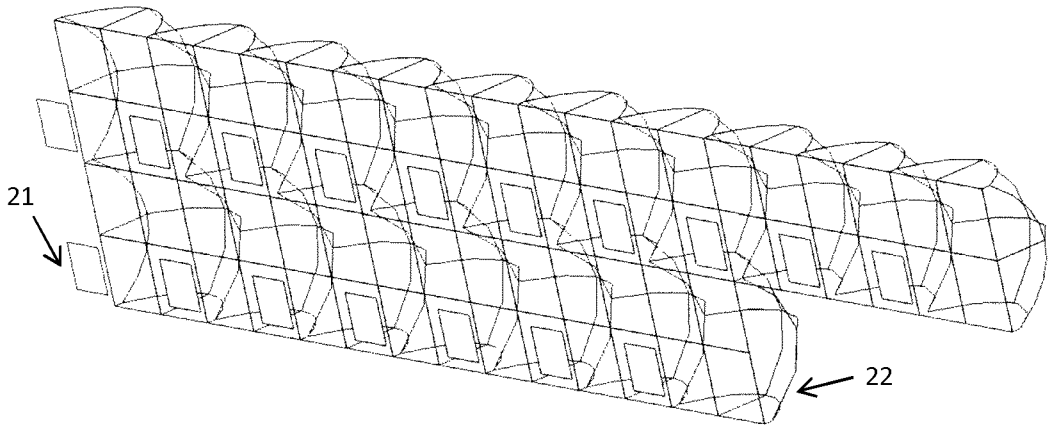

Figure 2

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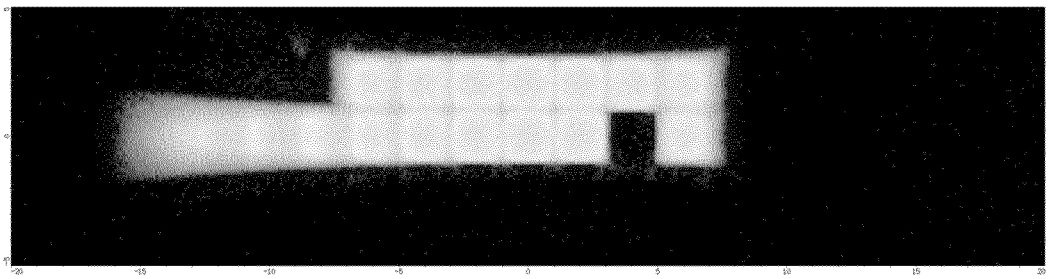

Figure 3

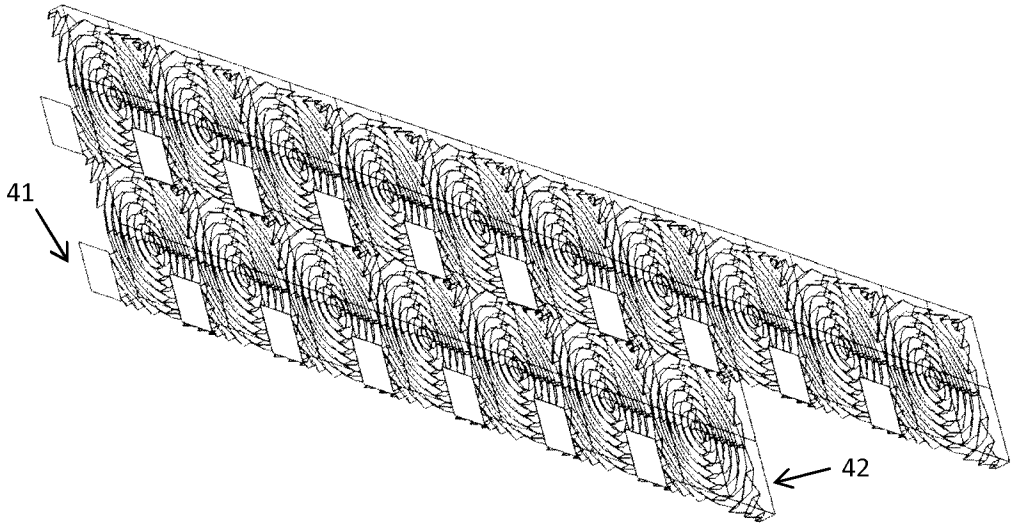

Figure 4

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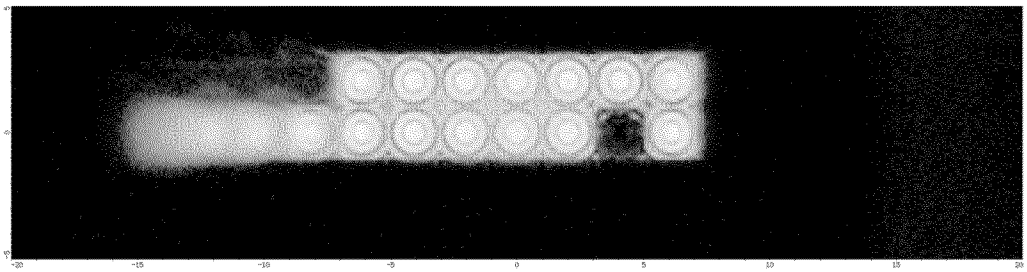

Figure 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2018/056232

A. CLASSIFICATION OF SUBJECT MATTER
INV. F21S41/143 F21S41/255 F21S41/26 F21S41/20
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F21S

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 2 306 074 A2 (AUTOMOTIVE LIGHTING REUTLINGEN [DE]) 6 April 2011 (2011-04-06) paragraphs [0032] - [0039], [0072] - [0076]; figures 3,7	1-14
X	DE 10 2014 112937 A1 (HELLA KGAA HUECK & CO [DE]) 10 March 2016 (2016-03-10) paragraphs [0043], [0044]; figure 4	1-14
A	JP 2007 109532 A (STANLEY ELECTRIC CO LTD) 26 April 2007 (2007-04-26) abstract; figures 6-8	1-14
A	EP 2 708 800 A2 (KOITO MFG CO LTD [JP]) 19 March 2014 (2014-03-19) abstract; figures 1,4a,5	1-14

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

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Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Panatsas, Adam

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Form PCT/ISA/210 (second sheet) (April 2005)

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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