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(54) LIGHTING MODULE FOR VEHICLE HEADLIGHT

(57) The present invention relates to the field of automotive front-lighting, and particularly to a lighting module for a vehicle headlight. The lighting module comprises a first light source (11), a first primary optics (12), and a multi-focal secondary optics (13). The multi-focal secondary optics (13) comprises a first focal point (F1) on a first focal plane (P1) and a second focal point (F2) on a second focal plane (P2). The first primary optics (12) is configured to receive and redirect a first part of light from the first light source (111) to a first focal area (S11) on the first focal plane (P1) and a second part of the light from the first light source (112) to a first focal area (S21) on the second focal plane (P2). The multi-focal secondary optics (13) is configured to receive and redirect light from the first focal area (S11) on the first focal plane (P1) and the first focal area (S21) on the second focal plane (P2) onto a road in front of the vehicle.

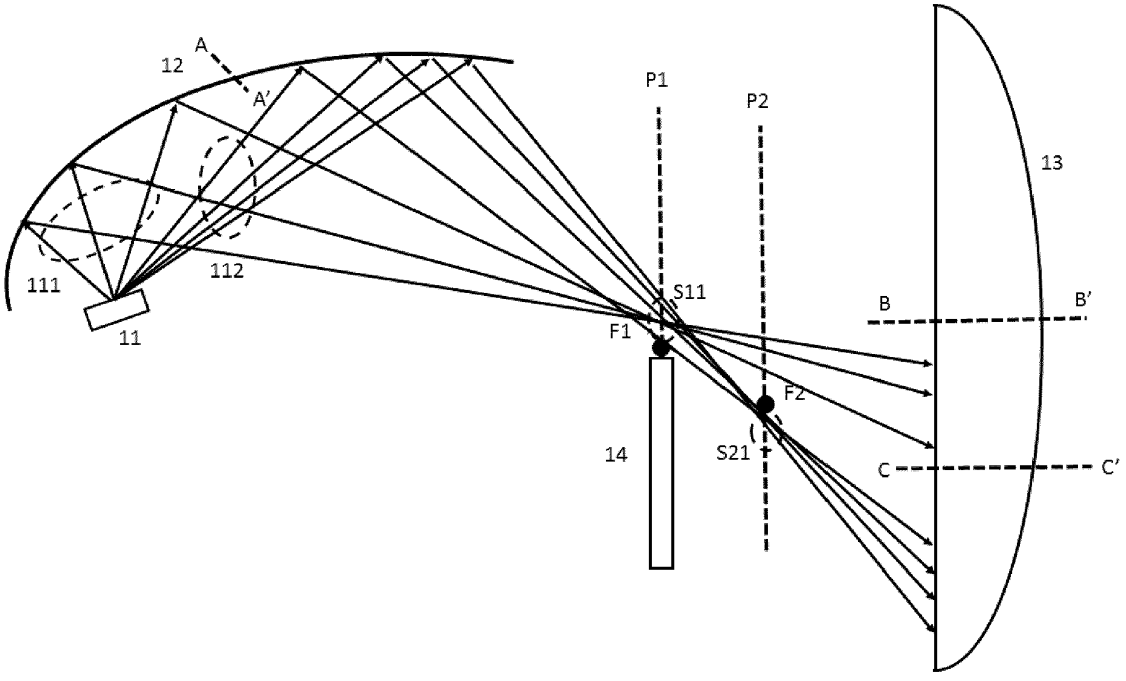


Fig. 1

EP 3 812 650 A1

Description

FIELD OF THE INVENTION

[0001] The present invention relates to the field of automotive front-lighting, and particularly to a lighting module for a vehicle headlight.

BACKGROUND OF THE INVENTION

[0002] Bi-function Poly-Ellipsoidal System (PES) solution for a headlamp has been widely used in automotive lighting today. Generally, an opaque shutter is utilized in this solution such that switching between a high beam (also known as an upper beam) and a low beam (also known as a lower beam) is enabled. In such an approach, due to a thickness of the opaque shutter itself, a dark area exists in the final projected beam pattern, especially between the high beam and the low beam.

[0003] In order to alleviate the dark area as indicated above, it has been proposed to use a transparent shutter instead of an opaque one in vehicle headlights. However, due to different designs and placings of optical elements, such as of the transparent shutter, the projection lens, the low beam light source, and the high beam light source, there is still a possibility where the dark area does not disappear completely between the projected high beam pattern and low beam pattern.

[0004] CN108644739A aims to provide more design freedom in placing low beam and high beam LEDs in vehicle headlights, and relates to a module comprising a low beam LED, a low beam reflector, a high beam LED, a high beam reflector, and a multi-focal lens, wherein the multi-focal lens comprises a first light incident plane with a focal point F1 and a second light incident plane with a focal point F2, and wherein light from the low beam LED is incident onto the focal point F1, but light from the high beam LED is incident onto the focal point F2.

SUMMARY OF THE INVENTION

[0005] The present invention provides a lighting module for a vehicle headlight, so as to eliminate or at least alleviate one or more of the above mentioned disadvantages.

[0006] According to an embodiment of the present invention, a lighting module is proposed for use in a vehicle headlight. The lighting module comprises a first light source, a first primary optics, and a multi-focal secondary optics. The multi-focal secondary optics comprises different focal planes, in particular, a first focal plane and a second focal plane, wherein the first focal plane comprises a first focal point and the second focal plane comprises a second focal point. The first primary optics is configured to receive and redirect a first part of light from the first light source to the first focal plane, especially to a first focal area on the first focal plane. Further, the first primary optics is also configured to receive and redirect a second part of the light from the first light source to the second focal plane, specifically a first focal area on the second focal plane. After being redirected onto the first focal area of the first focal plane and the first focal area of the second focal plane respectively, the two parts *(i.e.,* the first and second parts) of light from the first light source is received and redirected further by the multi-focal secondary optics onto a road in front of the vehicle.

[0007] According to practical implementations, in the above lighting module proposed by an optional embodiment of the present invention, the first light source comprises a low beam light source, which low beam light source is configured to generate a low beam having a bright/dark cut-off line, for example after redirection by the first primary optics and the multi-focal secondary optics. In this case, the first primary optics is configured in such a way that the first part of light from the low beam light source is redirected onto the first focal area centered above the first focal point on the first focal plane, and the second part of light from the low beam light source is redirected onto the first focal area centered below the second focal point on the second focal plane. Then, after a further redirection by the multi-focal secondary optics positioned at an optically downstream location, the light from the first focal area on the first focal plane (*i.e*., the first part of light coming originally from the low beam light source) is projected as a first part of the low beam below the bright/dark cut-offline, while the light from the first focal area on the second focal plane (*i.e.,* the second part of light coming originally from the low beam light source) is projected as a second part of the low beam above the bright/dark cut-offline. Together, these two parts of light constitute the final low beam pattern as projected onto the road in front of the vehicle.

[0008] As can be seen, in the above proposed lighting module according to the present invention, or in a vehicle headlight comprising such a lighting module, light emitted out from the low beam light source is split into two parts, both of which are incident onto the respective primary optics, *i.e.,* the first primary optics as indicated above. In this case, the two parts of light coming from the low beam light source (also recited as low beam light hereinafter) is redirected by the first primary optics onto different focal areas respectively. For example, the first part of low beam light is redirected onto the first focal area on the first focal plane of the secondary optics, while the second part of low beam light is redirected onto the first focal area on the second focal plane of the secondary optics. After redirection by the first primary optics onto the above respective focal areas, the two parts of low beam light are then incident onto the multi-focal secondary optics located at an optically downstream position, and projected thereby onto the road in front of the vehicle, thus providing the final low beam pattern for the vehicle or a driver in the vehicle.

[0009] As also indicated above, the final low beam pattern projected onto the road in front of the vehicle comprises the bright/dark cut-offline. Further, on the first focal

plane of the multi-focal secondary optics, the first focal area is centered above the first focal point, meaning that after redirection by the first primary optics, the first part of low beam light is incident onto an area centered above the first focal point on the first focal plane of the multi-focal secondary optics. In this case, after a further redirection by the multi-focal secondary optics, the first part of low beam light will be projected as the first, main part of the low beam pattern, which is located below the bright/dark cut-offline. Similarly, on the second focal plane of the multi-focal secondary optics, the first focal area is centered below the second focal point, meaning that after redirection by the first primary optics, the second part of low beam light is incident onto an area centered below the second focal point on the second focal plane of the multi-focal secondary optics. In this case, after a further redirection by the multi-focal secondary optics, the second part of low beam light will be projected as the second, additional part of the low beam pattern, which is located above the bright/dark cut-off line.

[0010] In this way, flexibility is provided in the independent beam forming of different parts (such as the first, main part below the bright/dark cut-off line and the second, additional part above the bright/dark cut-offline) of the low beam pattern, for example by enabling them to pass through different focal areas on different focal planes of the secondary optics, thus allowing a desired light intensity and/or spot shape of the final low beam pattern.

[0011] According to other practical implementations, in the above lighting module proposed by an optional embodiment of the present invention, a shutter is also comprised, which shutter is configured to help generating the bright/dark cut-offline of the low beam pattern. For example, the bright/dark cut-off line is generated in connection with the first part of low beam light. As practical uses, the shutter can be provided close to the first focal point on the first focal plane of the multi-focal secondary optics, such that the bright/dark cut-offline is generated together with the first, main part of the final low beam pattern located below the bright/dark cut-offline. More preferably, the shutter comprises a transparent shutter, formed for example by polymethyl methacrylate (PMMA), making it not an obstruction in propagation of light incident thereon from another light source as e.g. a high beam light source.

[0012] According to other practical implementations, in the above lighting module proposed by an optional embodiment of the present invention, there are also a second light source and a corresponding second primary optics. To be specific, according to an optional embodiment, the second light source comprises a high beam light source, such that together with the above mentioned low beam light source, a high beam pattern can be also projected onto the road in front of the vehicle. In other words, the lighting module as proposed by the present embodiment comprises now two separate light sources, *i.e.,* the low beam light source and the high beam light source, for the purpose of projecting the low beam pattern and the high beam pattern respectively onto the road in front of the vehicle.

[0013] Further optionally, according to an example instance of the above embodiment, the multi-focal secondary optics of the lighting module comprises further a third focal point on a third focal plane, and also maybe a fourth focal point on a fourth focal plane. As similar to the low beam light coming out from the low beam light source, the high beam light from the high beam light source is split into two parts as well, wherein the first part of high beam light is received and redirected (for example by means of total internal reflection) by the second primary optics onto a second focal area on the third focal plane, and the second part of high beam light is received and redirected by the second primary optics onto a second focal area on the fourth focal plane. After that, again, the two parts of high beam light are further redirected by the multi-focal secondary optics onto the road in front of the vehicle.

[0014] Specifically, according to an optional embodiment, on the third focal plane of the multi-focal secondary optics, the second focal area is centered below the third focal point; and also on the fourth focal plane of the multi-focal secondary optics, the second focal area is centered close to the fourth focal point. More preferably, in the multi-focal secondary optics of the above proposed lighting module, the first focal plane and the first focal point are coincident respectively with the third focal plane and the third focal point, meaning that the first focal plane coincides with the third focal plane, and also the first focal point coincides with the third focal point. According to this special embodiment of the present invention, after a further redirection by the multi-focal secondary optics, the first part of high beam light incident onto the second focal area of the third focal plane (namely, the first focal plane) is projected as a first, main part of the final high beam pattern, which will be located above the bright/dark cut-off line as opposite to the first main part of the low beam pattern. As for the second part of high beam light incident onto the second focal area of the fourth focal plane, it is then projected by the multi-focal secondary optics as a second, additional part of the final high beam pattern, which will be located close to the bright/dark cut-off line. If compared with a high beam pattern projected by a conventional vehicle headlight and located merely above the bright/dark cut-off line, the final high beam pattern as obtained by the lighting module according to the present invention comprises also a second additional part close to the bright/dark cut-offline. The additional part of high beam pattern helps to optimize and preferably avoid the otherwise existing dark area between the high beam pattern and the low beam pattern. In this way, any sudden change in light intensity between the high beam pattern and the low beam pattern projected in front of the vehicle can be smoothed, making the vehicle headlight obtained thereby to be more favored in practical applications.

[0015] As can be seen above, in an embodiment of the

present invention, the above proposed lighting module for a vehicle headlight comprises a multi-focal secondary optics having for example four focal planes with their respective focal points. However, the multi-focal secondary optics in the above proposed lighting module can also comprise more or less focal planes. For example, only three focal planes with their respective focal points can be provided for the multi-focal secondary optics. To be specific, as indicated above, if the multi-focal secondary optics is provided with four focal planes, the first focal plane can be coincident with the third focal plane, and in the meanwhile, the first focal point may coincide with the third focal point as well. This means that the first part of low beam light and the first part of high beam light are both redirected onto the first focal plane of the multi-focal secondary optics, but onto different focal areas thereof. To be specific, the first part of low beam light is redirected by the first primary optics onto the first focal area centered especially above the first focal point of the first focal plane, while the first part of high beam light is redirected by the second primary optics onto the second focal area centered especially below the first focal point of the first focal plane. In this way, after a further redirection by the multi-focal secondary optics, the first part of low beam light and the first part of high beam light are projected respectively below and above the bright/dark cut-offline in front of the vehicle. This helps to provide the multi-focal secondary optics with a simpler structure, making it beneficial in manufacture and processing.

[0016] Further, according to a specific embodiment of the present invention, the shutter, especially, the transparent shutter of the lighting module is also integrated within the second primary optics. This means that the transparent shutter for generating the bright/dark cut-off line forms a single integral body with the second primary optics for receiving and redirecting light from the high beam light source, allowing a reduced number of components and a simplified structure in the lighting module. In this case, further optionally, the single integral body comprising both shutter and second primary optics can be also provided with a special portion, at which the second part of light from the first light source (for example the low beam light source) is received and redirected so as to reach the first focal area on the second focal plane. More preferably, this special portion of the single integral body comprises a patterned surface, where the second part of low beam light is incident onto the patterned surface and redirected thereby towards the first focal area on the second focal plane.

[0017] According to other practical implementations, in the above lighting module proposed by an optional embodiment of the present invention, the first primary optics comprises a first reflective or refractive element. More preferably, the first reflective or refractive element comprises two portions for receiving and redirecting the two parts of low beam light respectively onto the first focal area of the first focal plane and the first focal area of the second focal plane. In a similar way, the second primary optics comprises a second reflective or refractive element as well, which second reflective or refractive element also comprises two portions for receiving and redirecting the two parts of high beam light respectively onto the second focal area of the third focal plane and the second focal area of the fourth focal plane. For example, a reflector having two reflective sections can be used for the first reflective element, and so does the second reflective element. Still for example, if a transparent shutter is comprised and also integrated with the second primary optics, a refractive body having a light input surface for receiving light from the second light source and a light output surface bonded with the transparent shutter can be used for the second refractive element. Obviously, those skilled in the art, having benefitted from teachings of the present invention, shall easily conceive any other forms of first or second primary optics suitable for use in the lighting module proposed by the present invention.

[0018] According to other practical implementations, in the above lighting module proposed by an optional embodiment of the present invention, the multi-focal secondary optics comprises a multi-focal projection lens having several lens portions, and each of the several lens portions comprises a respective focal point of the multi-focal secondary optics. This means that if the multi-focal projection lens is provided with four focal planes having their respective focal points, there will be for example four lens portions, each of them having its respective focal plane and focal point. In a similar way, if only three focal planes are comprised, the multi-focal projection lens comprises three lens portions accordingly, with each lens portion having its respective focal point on the respective focal plane. As an example, according to an instance of the above embodiment, in the above proposed lighting module, the multi-focal projection lens comprises three lens portions, such as a first lens portion, a second lens portion, and a third lens portion. In this case, the first lens portion comprises the first focal point on the first focal plane, the second lens portion comprises the second focal point on the second focal plane, and the third lens portion comprises the third focal point on the third focal plane. Especially, according to a preferable embodiment of the present invention, when the lighting module is mounted in the vehicle headlight, the three lens portions are disposed such that they are located right above each other. For example, the multi-focal projection lens can be shaped into a plane-convex form, wherein the first lens portion is located at a center position, while the second lens portion and the third lens portion are disposed respectively at either side of the first lens portion.

[0019] According to other practical implementations, in the above lighting module proposed by an optional embodiment of the present invention, the first light source is located in a focal plane of the first primary optics, and/or the second light source is located in a focal plane of the second primary optics. Apparently, those skilled in the art, having benefited from teachings of the present in-

vention, can conceive a different positioning for various components, such as the first primary optics, the second primary optics, and the two light sources, in the lighting module for a vehicle headlight.

[0020] It will be appreciated by those skilled in the art that two or more of the above disclosed embodiments, implementations and/or aspects of the present invention may be combined in any way deemed useful. Different modifications and variations of the lighting module for a vehicle headlight can be carried out by a person skilled in the art based on the disclosure of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] These and other aspects of the present invention will be described now 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 a lighting module for a vehicle headlight according to an embodiment of the present invention;

Fig. 2 schematically illustrates a lighting module for a vehicle headlight according to another embodiment of the present invention;

Fig. 3 schematically illustrates a lighting module for a vehicle headlight according to still another embodiment of the present invention; and

Fig. 4 schematically illustrates simulated results for the low beam and high beam patterns as projected onto a road in front of a vehicle by a vehicle headlight comprising a lighting module according to an embodiment of the present invention.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0022] While the present invention is susceptible of embodiments in many different forms, there is shown in the drawings and will be described in detail herein only one or more specific embodiments, with the understanding that the present description is to be considered as exemplary of the basic principle of the present invention and not intended to limit the present invention only to the specific embodiments shown and described herein.

[0023] It should be noted that various components in different figures are not drawn to scale. Besides, relative positions between individual elements shown in the figures are only used to illustrate the basic principle of the present invention and should not be considered to limit the scope of the present invention.

[0024] With reference to Fig. 1, a lighting module is proposed for a vehicle headlight according to an embodiment of the present invention. Specifically, the lighting module mainly comprises a first light source 11, a first primary optics 12, and a multi-focal secondary optics 13. The first light source 11 is preferably disposed at a focal plane, such as a focal plane in the object space of the first primary optics 12. Then, light is emitted out from the first light source 11 and incident onto the first primary optics 12, which first primary optics 12 reflects the light incident thereon further towards the multi-focal secondary optics 13. As shown in Fig. 1, light emitted by the first light source 11 can be divided into two parts, *i.e.,* a first part 111 (shown by a dashed ellipse on the left side in the figure) and a second part 112 (shown by a dashed ellipse on the right side in the figure). For the purpose of receiving and redirecting light from the first light source 11, the first primary optics 12 comprises accordingly two portions, such as the left portion and the right portion separated by dashed line A-A' in the figure. Specifically, the first portion of the first primary optics 12 is configured to receive the first part 111 of light from the first light source 11, and the second portion of the first primary optics 12 is configured to receive the second part 112 of light from the first light source 11. According to an example instance of the present invention, the first light source 11 comprises a low beam light source so as to generate a low beam pattern for a vehicle comprising such a lighting module. Further optionally, the first primary optics 12 of the lighting module comprises for example a reflective element, such as the reflector shown in Fig. 1. In this case, for the purpose of receiving and redirecting the two parts 111, 112 of light from the first light source 11, the first primary reflector may comprise two sections separated and contiguous by dashed line A-A'. Alternatively, as easily conceived by a skilled person in the art, the first primary optics 12 may comprise a refractive element as well with for example two portions accordingly, as long as the two parts 111, 112 of light from the first light source 11 are received and redirected respectively. Thus, all these alternatives about the first primary optics 12 shall be encompassed within the scope of the present invention.

[0025] With continued reference to the above lighting module shown in Fig. 1, unlike a conventional projection lens having only a single focal plane, the multi-focal secondary optics 13 comprises several focal planes and thus several focal points, such as a first focal plane P1 and a first focal point F1 thereon, and also a second focal plane P2 and a second focal point F2 thereon. Furthermore, as shown by dashed ellipses in Fig. 1, on the first focal plane P1 of the multi-focal secondary optics 13, there is a first focal area S11 which is centered above the first focal point F1, and also on the second focal plane P2 of the multi-focal secondary optics 13, there is a first focal area S21 which is centered below the second focal point F2. In this case, special configurations are introduced to the first primary optics 12 such that the first part 111 of light from the first light source 11 can be received and redirected merely onto the first focal area S11 of the first focal plane P1, and that the second part 112 of light from the first light source 11 can be received and redirected merely onto the first focal area S21 of the second focal plane P2. In other words, in the lighting module proposed

by the present invention or a vehicle headlight comprising the same, not only light coming from the first light source 11 (for example the low beam light source) is split into two parts 111, 112, but also these two parts 111, 112 of low beam light are redirected respectively onto focal areas S11, S12 of two different focal planes P1, P2 of multi-focal secondary optics 13, such as with the help of first primary optics 12. In this way, the two parts 111, 112 of light coming originally from the low beam light source are incident onto two different sections of the multi-focal secondary optics 13 having the respective focal planes P1, P2 or focal points F1, F2, such as a first section between dashed line B-B' and dashed line C-C' and a second section under dashed line C-C' in the figure, where they are redirected further towards different areas on the road in front of the vehicle.

[0026] Still referring to Fig. 1, according to an optional embodiment of the present invention, a shutter 14 can be comprised as well in the lighting module, such as for the purpose of helping to generate a bright/dark cut-off line of the low beam pattern. As a specific instance of the above embodiment, the shutter is made of transparent material, such as polymethyl methacrylate (PMMA), and disposed right beneath the first focal point F1 of the first focal plane P1. In this way, due to the further redirection of multi-focal secondary optics 13, for example a multi-focal projection lens, the first part 111 of light from the first, low beam light source will be projected below the bright/dark cut-offline, because in the object space of projection lens, the first part 111 of low beam light is focused onto the first focal area S11 above the first focal point F1, while the shutter 14 for generating the bright/dark cut-offline is located below the first focal point F1. Thus, a first part LB1 of the low beam pattern below the bright/dark cut-off line is generated by the first part 111 of light from the first, low beam light source on the road in front of the vehicle. Apparently, it shall be easily understood by a skilled person in the art, any other means, or any other configurations of shutter, for example an opaque or translatable shutter, can be used as well for helping to generate the bright/dark cut-off line of the low beam pattern.

[0027] Furthermore, as illustrated further by Fig. 1, in the above lighting module of the present invention, the second part 112 of light coming from the first, low beam light source is redirected by the first primary reflector, especially its right section in the figure, onto the first focal area S21 centered below the second focal point F2 of the second focal plane P2. After continued propagation, this part of light from the first focal area S21 on the second focal plane P2 is incident onto a lower portion (*i.e.,* the portion below dashed line C-C' in the figure) of the multi-focal secondary optics 13 and refracted thereby further towards an area above the bright/dark cut-offline in front of the vehicle, forming a second part LB2 of the low beam pattern above the bright/dark cut-offline. The resulting low beam pattern comprising these two parts LB1, LB2 is clearly illustrated in the simulated results of Fig. 4, especially the third plot (c) thereof, where the bright/dark cut-off line L is sandwiched between the lower, first part LB1 and the upper, second part LB2 of the low beam pattern. It should be noted herein that in the third plot (c) of Fig. 4, a dotted ellipse is used to schematically represent where the upper, second part LB2 of the low beam pattern is located as compared with the bright/dark cut-off line L and the lower, first part LB 1, and according to different practical applications, various distributions of light intensity can exist within the dotted ellipse for the upper, second part LB2 of the low beam pattern.

[0028] As obvious from above, two sections of the primary reflector are used respectively to receive the two parts 111, 112 of low beam light, and to redirect them further towards two respective focal areas S11, S21 on two different focal planes P1, P2 of the multi-focal secondary optics 13. After that, the two parts 111, 112 of low beam light are projected respectively by the two portions, having the respective focal planes P1, P2 and focal points F1, F2, of secondary optics 13 towards two areas above and below the bright/dark cut-offline, thus forming together the final low beam pattern on the road in front of the vehicle. In this way, more freedom can be provided in design or beam shaping of the final low beam pattern, as it is constituted now by two separate parts LB 1, LB2 propagating along two independent light paths within the lighting module or vehicle headlight comprising the same.

[0029] Turning to Fig. 2, a lighting module according to another embodiment of the present invention is shown, where the same reference numerals are used to indicate the same components as in the lighting module of Fig. 1. In other words, the lighting module of Fig. 2 comprises also the first light source 11, the first primary optics 12, as well as the multi-focal secondary optics 13 having the first focal point F1 on the first focal plane PI and the second focal point F2 on the second focal plane P2. However, unlike Fig. 1, in the lighting module of Fig. 2, extra components, such as a second light source 15 and also a second primary optics 16, are comprised. Preferably, the second light source 15 is disposed at a focal plane, such as a focal plane in the object space, of the second primary optics 16, just like the first light source 11. In a similar way, light emitted from the second light source 15, for example a high beam light source, comprises two parts 151, 152 as well, which two parts 151, 152 are received and redirected by the second primary optics 16 respectively towards two focal areas on two focal planes of the multi-focal secondary optics 13. Optionally, the high beam light, comprising the first part 151 and the second part 152, is redirected such as through total internal reflection by the second primary optics 16, which total internal reflection can occur one or more times according to the specific configuration of second primary optics 16. For example, apart from the two focal planes P1, P2 and the respective focal points F1, F2 shown in Fig. 1, the multi-focal secondary optics 13 of Fig. 2 comprises also two other focal planes P3, P4 and their respective focal points F3, F4. In this case, the first part

151 of light from the high beam light source can be redirected by the second primary optics 16 to a second focal area S12 on the third focal plane P3 of the multi-focal secondary optics 13, while the second part 152 of light from the high beam light source can be redirected by the second primary optics 16 to a second focal area S40 on the fourth focal plane P4 of the multi-focal secondary optics 13.

[0030] As shown in Fig. 2, according to a preferable embodiment of the present invention, the multi-focal secondary optics 13 comprises merely three focal planes, where the first focal plane P1 coincides with the third focal plane P3, *i.e.,* the first focal point F1 coincides with the third focal point F3 as well. Further optionally, as illustrated by Fig. 2, the second focal area S12, where the first part 151 of high beam light is focused, is configured below the first and third focal point F1, F3. In this way, by contrast with the first part 111 of low beam light which is focused onto the first focal area S11 above the first and third focal point F1, F3, the first part 151 of high beam light will be projected by the multi-focal secondary optics 13, especially by a portion thereof having the respective focal plane P3 and focal point F3 (such as the portion between dashed line B-B' and dashed line D-D' in the figure), towards an area above the bright/dark cut-offline, thus forming a first, main part HB1 of a high beam pattern in front of the vehicle. As for the other, second part 152 of high beam light, it is received and redirected by the second primary optics 16 onto the second focal area S40 of the fourth focal plane P4, wherein the second focal area S40 is configured close to the fourth focal point F4 on the fourth focal plane P4, see for example the area S40 indicated by a dashed rectangle in Fig. 2. In this case, the second part 152 of high beam light is redirected further by the multi-focal secondary optics 13, especially by a portion thereof having the respective focal plane P4 and focal point F4 (such as the portion above dashed line D-D' in the figure), towards an area close to the bright/dark cut-offline. Thus, the second part 152 of light from the second light source 15 contributes to generate a second, additional part of the high beam pattern close to the bright/dark cut-offline.

[0031] Again, with reference to the simulated results in Fig. 4, especially the first plot (a) thereof, the final high beam pattern projected by the lighting module according to the above embodiment or a vehicle headlight comprising the same contains clearly two parts, *i.e.,* the first part HB1 above the bright/dark cut-off line L and the second part HB2 close to the bright/dark cut-off line L. This means that according to the present invention, a second, additional part HB2 of the high beam pattern is included especially close to the bright/dark cut-offline L in the final high pattern, in addition to the first, main part HB1 located above the bright/dark cut-offline L. This additional part HB2 of high beam pattern is beneficial at least to the weakening of any dark area existing between the low beam and high beam patterns. Besides, as similar to the above low beam pattern, two separate parts HB1, HB2 propagating along two independent optical paths are included too in the final high beam pattern, rendering more freedom as well in design or beam shaping of the resulting high beam such that requirements are fulfilled according to practical implementations. This again constitutes an advantage over any conventional approach with only a single part of high beam pattern located almost completely above the bright/dark cut-off line, by making comparisons for example between the first plot (a) and the second plot (b) of Fig. 4 where the resulting high beam comprises two parts HB1, HB2 and a single part HB0 respectively.

[0032] It should be indicated herein, although the second primary optics 16 shown in Fig. 2 comprises a refractive body, an alternative reflective element can be used as well for the purpose of receiving and redirecting light from the second light source 15 towards the respective focal areas S12, S40. For example, as similar to the first primary optics 12, the second primary optics 16 may comprise a reflector as well, having for example two sections being contiguous to each other and configured to redirect the two respective parts 151, 152 of light from the second light source 15. The present invention shall encompass all these alternatives suitable for the receipt and redirection of light from the second light source 15.

[0033] With reference to Fig. 3, a lighting module according to still another embodiment of the present invention is shown, where the same reference numerals are used to indicate the same components as in the lighting modules of Fig. 1 and Fig. 2. Besides, for the sake of clarity, in the lighting module of Fig. 3, the second part 152 of light from the second light source 15, and accordingly the fourth focal plane P4, the forth focal point F4, and the second focal area F40 thereon, have been omitted, but this should never be considered as a limitation to the present invention. Also, apart from the first light source 11, the first primary optics 12, the second light source 15, as well as the multi-focal secondary optics 13 having the first focal point F1 on the first focal plane P1, the second focal point F2 on the second focal plane P2, and the third focal point F3 on the third focal plane P3, the lighting module of Fig. 3 comprises a single integral body 17 consisting for example of the second primary optics and the transparent shutter as indicated above. In other words, in the lighting module of Fig. 3, the transparent shutter can be integrated with the second primary optics, for example at a surface of the second primary optics where light is otherwise output therefrom, such as at the upper-right surface in the figure. In this case, fewer components are used in the lighting module, leading to a simpler structure and reduced manufacturing cost.

[0034] According to an optional embodiment of the present invention, in the above proposed lighting module, the single integral body 17 comprises a portion, for example an upper-left portion in the figure, at which portion the second part 112 of light from the first light source 11 is incident and refracted properly towards the second focal area S21 on the second focal plane P2. Especially,

as an optional example, the above mentioned portion of the single integral body 17 is provided further with a patterned surface 170, where the second part 112 of light from the first light source 11 is incident thereon. The patterned surface 170 helps to facilitate the correct receipt and further redirection of second part 112 of low beam light towards the second focal area S21 on the second focal plane P2, and in the meanwhile, to reduce potential loss of second part 112 of low beam light due to such receipt and redirection. It should be noted herein that although the patterned surface 170 of the single integral body 17 is shown in Fig. 3 as a step surface, this is merely provided to explain rather than limit the present invention. Having benefitted from teachings of the present invention, a skilled person in the art shall easily conceive any other suitable shapes of the patterned surface 170, such as a sawtooth form.

[0035] It is important to note that light rays shown in the figures, only represent part, but not all, of the light rays within the whole lighting module. In fact, the light rays shown in all the figures are only used as representative examples for the purpose of illustrating the basic principle of the present invention, and clearly should not be read as exhaustive examples of all the light rays within the entire lighting module.

[0036] It should also 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.

[0037] 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. 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 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.

LIST OF REFERENCE NUMERALS:

[0038]

11 f	irst light source
111	first part of light from first light source
112	second part of light from first light source
12	first primary optics
13	multi-focal secondary optics
14	shutter
P1	first focal plane of multi-focal secondary optics
F1	first focal point on first focal plane
S11	first focal area on first focal plane
P2	second focal plane of multi-focal secondary optics
F2	second focal point on second focal plane
S21	first focal area on second focal plane
15	second light source
151	first part of light from second light source
152	second part of light from second light source
16	second primary optics
P3	third focal plane of multi-focal secondary optics
F3	third focal point on third focal plane
S12	second focal area on first or third focal plane
P4	fourth focal plane of multi-focal secondary optics
F4	fourth focal point on fourth focal plane
S40	second focal area on fourth focal plane
17	single integral body
170	patterned surface
L	bright/dark cut-off line
LB1	first or main part of low beam or low beam pattern
LB2	second or additional part of low beam or low beam pattern
HB1	first or main part of high beam or high beam pattern
HB2	second or additional part of high beam or high beam pattern
HB0	single part of high beam or high beam pattern in the prior art

Claims

1. A lighting module for a vehicle headlight, comprising

- a first light source (11),
- a first primary optics (12), and
- a multi-focal secondary optics (13),

wherein

- the multi-focal secondary optics (13) comprises a first focal point (F1) on a first focal plane (P1) and a second focal point (F2) on a second focal plane (P2),
- the first primary optics (12) is configured to receive and redirect a first part (111) of light from the first light source (11) to a first focal area (S11) on the first focal plane (P1) and a second part (112) of the light from the first light source (11)

to a first focal area (S21) on the second focal plane (P2), and
- the multi-focal secondary optics (13) is configured to receive and redirect light from the first focal area (S11) on the first focal plane (P1) and the first focal area (S21) on the second focal plane (P2) onto a road in front of the vehicle.

2. The lighting module for the vehicle headlight according to claim 1, wherein

- the first light source (11) comprises a low beam light source to generate a low beam with a bright/dark cut-offline (L),
- the first primary optics (12) is configured such that the first focal area (S11) on the first focal plane (P1) is centered above the first focal point (F1), and the first focal area (S21) on the second focal plane (P2) is centered below the second focal point (F2), and
- the multi-focal secondary optics (13) is configured to redirect the light from the first focal area (S11) on the first focal plane (P1) as a first part of the low beam (LB1) below the bright/dark cut-offline (L), and to redirect the light from the first focal area (S21) on the second focal plane (P2) as a second part of the low beam (LB2) above the bright/dark cut-off line (L).

3. The lighting module for the vehicle headlight according to claim 2, further comprising

- a second light source (15), and
- a second primary optics (16),
wherein
- the multi-focal secondary optics (13) further comprises a third focal point (F3) on a third focal plane (P3),
- the second primary optics (16) is configured to receive and redirect a first part (151) of light from the second light source (15) to a second focal area (S12) on the third focal plane (P3), and
- the multi-focal secondary optics (13) is configured to receive and redirect light from the second focal area (S12) on the third focal plane (P3) onto the road in front of the vehicle.

4. The lighting module for the vehicle headlight according to claim 3, wherein

- the multi-focal secondary optics (13) further comprises a fourth focal point (F4) on a fourth focal plane (P4),
- the second primary optics (16) is configured to receive and redirect a second part (152) of the light from the second light source (15) to a second focal area (S40) on the fourth focal plane (P4), and
- the multi-focal secondary optics (13) is configured to receive and redirect light from the second focal area (S40) on the fourth focal plane (P4) onto the road in front of the vehicle.

5. The lighting module for the vehicle headlight according to claim 4, wherein

- the second light source (15) comprises a high beam light source to generate, together with the low beam light source, a high beam,
- the second primary optics (16) is configured such that the second focal area (S12) on the third focal plane (P3) is centered below the third focal point (F3), and the second focal area (S40) on the fourth focal plane (P4) is centered close to the fourth focal point (F4), and
- the multi-focal secondary optics (13) is configured to redirect the light from the second focal area (S12) on the third focal plane (P3) as a main part of the high beam (HB1) above the bright/dark cut-offline (L), and the light from the second focal area (S40) on the fourth focal plane (P4) as an additional part of the high beam (HB2) close to the bright/dark cut-offline (L) for avoiding a dark area within the high beam close to the bright/dark cut-off line (L).

6. The lighting module for the vehicle headlight according to claim 3, further comprising

- a shutter (14) for the first part (111) of the light from the low beam light source (11) so as to generate the bright/dark cut-offline (L) of the low beam.

7. The lighting module for the vehicle headlight according to claim 6, wherein

- the shutter (14) is transparent and integral with the second primary optics (16).

8. The lighting module for the vehicle headlight according to claim 7, wherein

- the shutter (14) comprises a portion for receiving and redirecting the second part (112) of the light from the first light source (11) to the first focal area (S21) on the second focal plane (P2), which portion of the shutter (14) comprises a patterned surface (170) where the second part (112) of the light from the first light source (11) is incident thereon.

9. The lighting module for the vehicle headlight according to claim 3, wherein

- the second primary optics (16) is configured to

redirect the first part (151) of the light from the second light source (15) through total internal reflection to the second focal area (S12) on the third focal plane (P3).

10. The lighting module for the vehicle headlight according to any one of claims 1-9, wherein

- the first primary optics (12) comprises a first reflective or refractive element, which first reflective or refractive element comprises
- a first portion for receiving and redirecting the first part (111) of the light from the first light source (11) to the first focal area (S11) on the first focal plane (P1), and
- a second portion for receiving and redirecting the second part (112) of the light from the first light source (11) to the first focal area (S21) on the second focal plane (P2).

11. The lighting module for the vehicle headlight according to any one of claims 4-5, wherein

- the second primary optics (16) comprises a second reflective or refractive element, which second reflective or refractive element comprises
- a first portion for receiving and redirecting the first part (151) of the light from the second light source (15) to the second focal area (S12) on the third focal plane (P3), and
- a second portion for receiving and redirecting the second part (152) of the light from the second light source (15) to the second focal area (S40) on the fourth focal plane (P4).

12. The lighting module for the vehicle headlight according to any one of claims 3-9, wherein

- the first focal point (F1) of the multi-focal secondary optics (13) coincides with the third focal point (F3) of the multi-focal secondary optics (13).

13. The lighting module for the vehicle headlight according to any one of claims 1-9, wherein

- the multi-focal secondary optics (13) comprises a multi-focal projection lens having several lens portions, wherein
- each of the several lens portions comprises a respective focal point (F1, F2, F3, F4) of the multi-focal secondary optics (13).

14. The lighting module for the vehicle headlight according to claim 13, wherein, as seen when the lighting module is mounted in the vehicle headlight,

- the several lens portions are located above each other.

15. The lighting module for the vehicle headlight according to any one of claims 1-9, wherein one or more of the following are satisfied:

- the first light source (11) is located in a focal plane of the first primary optics (12), and
- the second light source (15) is located in a focal plane of the second primary optics (16).

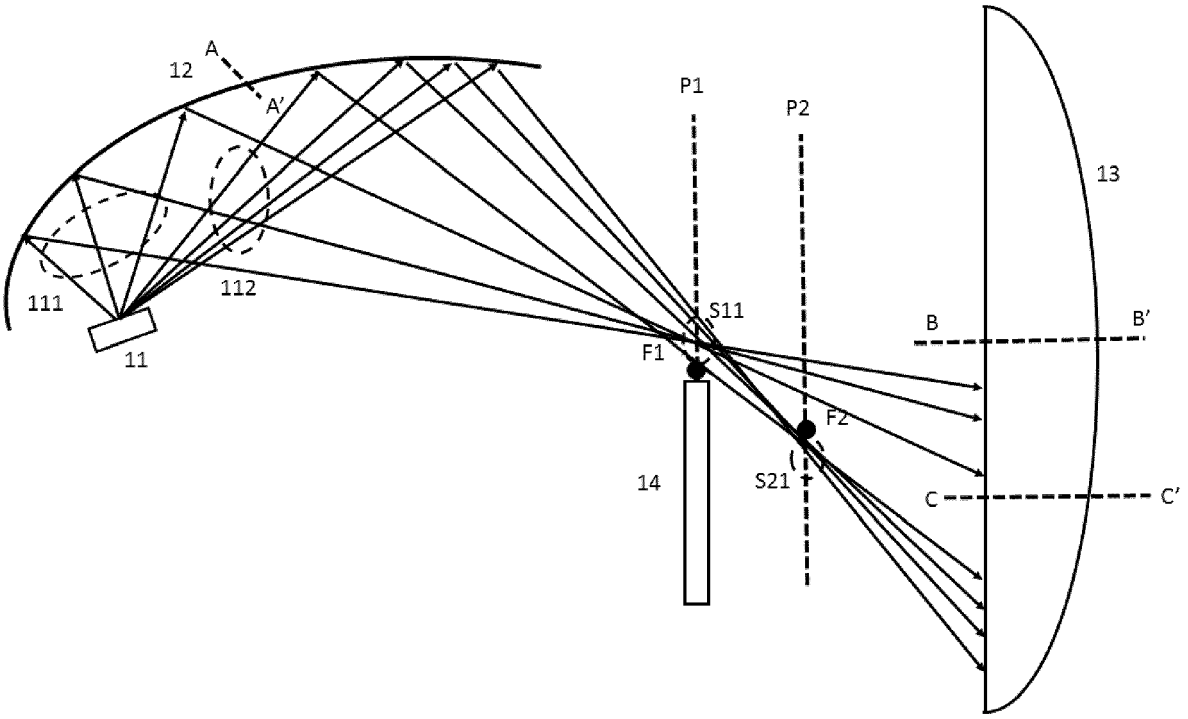
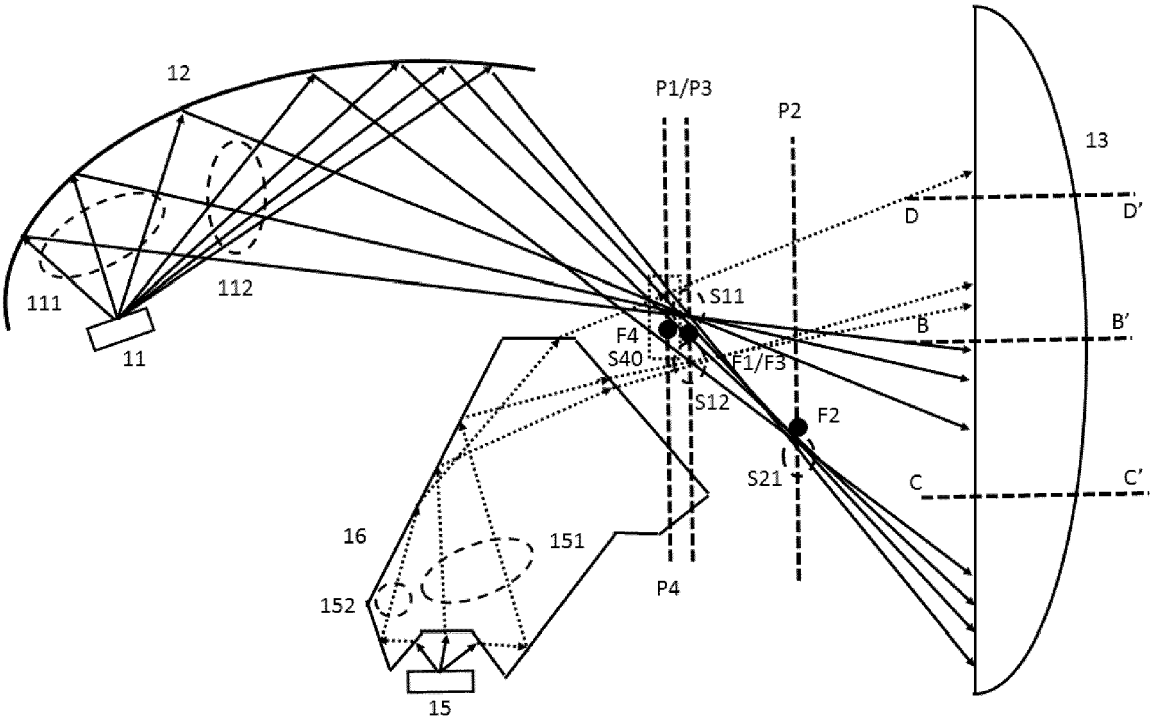

A
12
A'
P1
P2
13
111
112
S11
B
B'
11
F1
F2
14
S21
C
C'

Fig. 1


12
P1/P3
P2
13
D
D'
111
112
S11
B
B'
11
F4
S40
F1/F3
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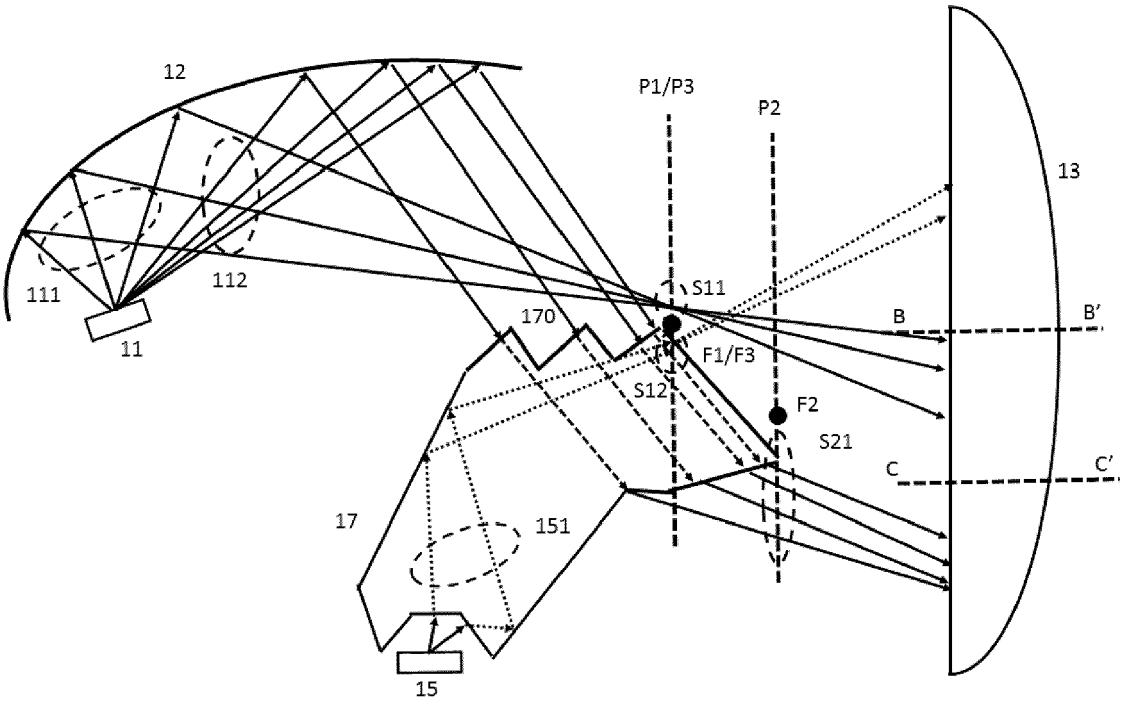
C
C'
16
151
P4
152
15

Fig. 2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P2
13
111
112
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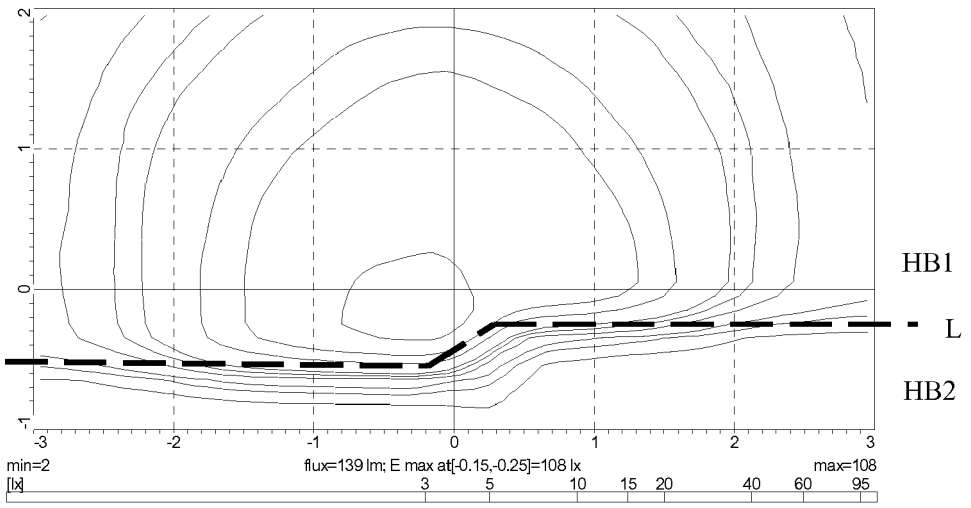
B'
11
F1/F3
S12
F2
S21
C
C'
17
151
15

Fig. 3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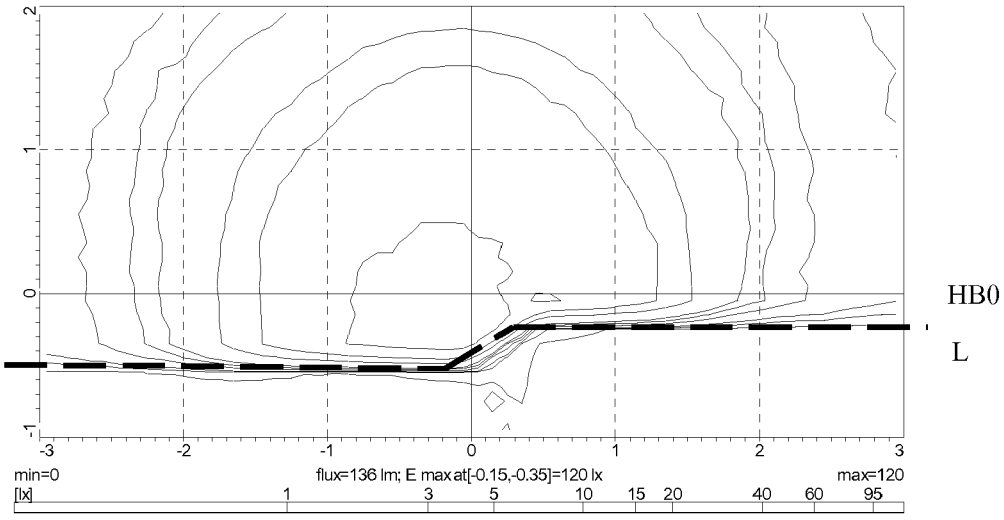
1
0
-1
-3
-2
-1
0
1
2
3
HB1
L
HB2
min=2
flux=139 lm; E max at[-0.15,-0.25]=108 lx
max=108
[lx]
3
5
10
15
20
40
60
95

(a)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max=120
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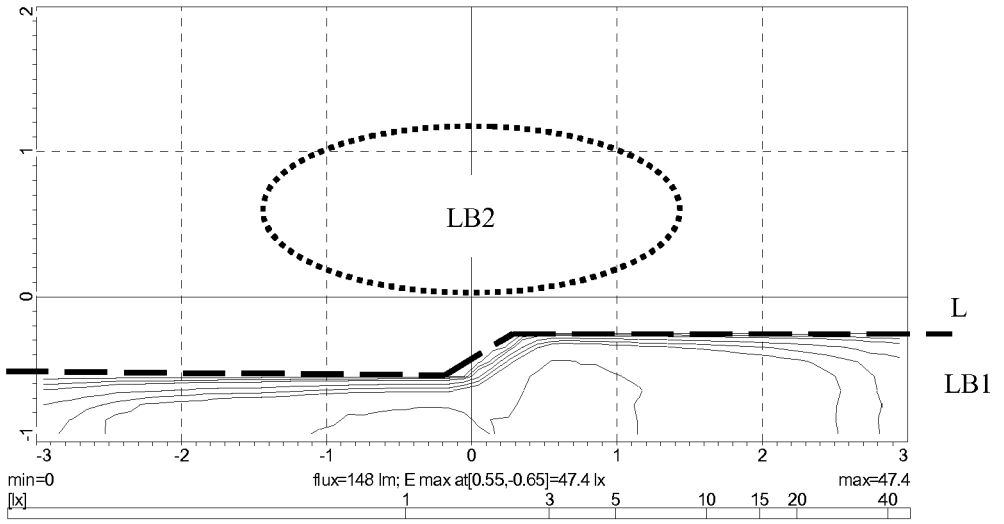
(b)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LB1
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flux=148 lm; E max at[0.55,-0.65]=47.4 lx
max=47.4
[lx]
1
3
5
10
15
20
40

(c)

Fig. 4

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EUROPEAN SEARCH REPORT

Application Number
EP 19 20 5348

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Place of search	Date of completion of the search	Examiner
Munich	24 April 2020	Panatsas, Adam

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