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Description

[0001] The invention relates to an LED luminaire, in particular an LED spotlight according to the preamble of claims 1 and 2.

[0002] Such an LED luminaire is known from WO 2007/069181.

[0003] A spotlight is known from DE 100 63 134 A1, which comprises a curved reflector, a lamp arranged within the hollow space of the curved reflector, a converging lens arranged in the direction of emission in front of the reflector and a diverging lens arranged between the reflector and the converging lens in order to achieve a high light yield and a uniform light distribution. In order to focus the light emitted from the spotlight, the reflector with the lamp or the diverging lens can be moved in the direction of the main optical axis of the spotlight.

[0004] An optical system for a stepped lens spotlight is known from EP 1 241 399 B1, which for an improved light efficiency in a spot position as well as in a flood position of the light distribution whilst retaining the uniformity of the illumination in the light field, comprises an elliptic reflector, a lamp and at least one stepped lens, the surface thereof or the light-reflecting surface of the reflector is structured. Depending on the opening angle of the light beam emerging from the spotlight to be adjusted, the distance of the lamp and the stepped lens to the reflector is adjustable in a permanently coupled manner.

[0005] Known from PCT/EP 2008/060892 is an LED spotlight with a light generating unit or “light engine” comprising multiple light-emitting diodes or LEDs, which is arranged on a circuit board which is connected to a cooling body in a good heat-conducting manner. A light shaping device is coupled to the light generating unit, which contains an optical unit with a lens or a lens system for light mixing and/or beam shaping of the light beams emitted by the light generating unit and which is adjustable for focussing the light beams or for changing the semi-scattering angle in the direction of the optical axis of the LED spotlight. The light shaping device can be connected to a spotlight accessory for changing the emission angle and/or for generating special light effects, which device consists of lens plates which are displaceable with respect to one other, a barn door, a grid or diffusor or of scrims, gobos, holographic scattering films or the like.

[0006] The object of the present invention is to provide an LED luminaire comprising a light source composed of a plurality of light-emitting diodes (LEDs), which allows for a wide adjustment range of the semi-scattering angle, guarantees a homogenous, softly fading out light field and provides a hard light source in the flood setting as well as a soft light source in the spot setting.

[0007] This object is solved according to the invention by an LED luminaire comprising a light source composed of a plurality of light-emitting diodes (LEDs) according the characterizing feature of claims 1 and 2.

[0008] The solutions according to the invention provide an LED luminaire comprising a light source composed of a plurality of light-emitting diodes which allows for a wide adjustment range of the semi-scattering angle, guarantees a homogenous, soft fading out light field and provides a hard light source in the flood setting, since here the light source is close to the field optical unit and generates only a small light spot on the field optical unit, whilst it provides a soft light source in the spot setting, since in this setting the light source is so far removed from the field optical unit that the light fills out the diameter of the field optical unit

[0009] Accordingly, in a first solution the collimation optical unit has on its light entrance side conical total internal reflection lenses, which are in each case arranged directly in front of an LED and aligned therewith, and on its light exit side a stepped lens structure in the manner of a Fresnel lens and deflects the light beams emitted by the LEDs such that they fill the light entrance surface of the mixing optical unit substantially completely with light.

[0010] Due to the arrangement of a collimation optical unit which collects the light emitted by the LEDs of the active light source and directs it onto a surface and focuses it, the downstream mixing optical unit is illuminated over the complete light entrance surface and can optimally mix the light focused and directed onto a surface, which is incident from different directions, and can emit it with the same angle to a field optical unit, which receives the light emitted by the mixing optical unit and emits it into the far field with a predefined light distribution.

[0011] In a second solution, the collimation optical unit consists of discrete optical elements which focus the light emitted in the same emission direction by the LEDs arranged on a planar surface onto a remote surface, wherein the LEDs are arranged with the optical elements on a circuit board which is situated in the plane of the mixing optical unit and receives or surrounds the mixing optical unit in a central region, and in that the light beams emitted by the optical elements are directed onto a reflector, which reflects the light beams onto the mixing optical unit, which emits the mixed light counter to the emission direction of the LEDs.

[0012] In this particularly space-saving embodiment, the LEDs and the collimation optical units are arranged on a circuit board which is located in the plane of the mixing optical unit, wherein the LEDs emit in the opposite direction to the mixing optical unit. The circuit board itself has at its centre an opening for the mixing optical unit so the LEDs are arranged in an annular shape around the mixing optical unit. A planar mirror having approximately half the diameter of the LED circuit board is located in the emission direction of the LEDs and directs the light back to the mixing optical unit. In this way, only half the overall length is required between the LEDs and the mixing optical unit.

[0013] In a further embodiment, a concavely curved to conical and preferably faceted mirror is located at the position of the aforesaid mirror, which also emits the light of the LEDs back to the mixing optical unit. The particular advantage of this arrangement consists in that all the collimation optical units of the individual LEDs emit the light straight backwards and thus can again be designed identically.

[0014] In one embodiment of the two aforesaid embodiments, both angularly deflecting collimation optical units and also rectilinearly emitting collimation optical units are used, the beams of which are reflected back to the mixing optical unit by planar or curved mirror surfaces. This is advantageous when on the one hand a large number of collimation optical units are to be avoided and on the other hand, a specific angle of incidence at the mixing optical unit should not be exceeded.

[0015] In a further embodiment, the reflecting element consists of a convexly curved to conical, preferably faceted reflector and the LEDs with the collimation optical units arranged in one or more rings around the principal optical axis of the spotlight. This arrangement also makes it possible to use one type of identical collimation optical unit per ring and optimal heat removal from the LEDs which can then be coupled onto the outside of the LED luminaire. The disadvantage of this arrangement again consists in that the LEDs must be mounted and electrically contacted in a complex manner.

[0016] In order to avoid this, a polygonal outer shell can also be used, wherein then however collimation optical units must be used, which deflect the light in up to two different directions.

[0017] The annular or polygonal arrangement of the LEDs and the collimation optical units can be supplemented in order to achieve a higher power density by further LEDs and collimation optical units which are located on the plane of the mixing optical unit and which emit backwards. In this case, a planar reflector is required when using deflecting collimation optical units and a concave reflector is required for rectilinearly emitting collimation optical units. Other mixed forms of differently oriented LEDs, differently light-deflecting collimation optical units and differently positioned and curved mirror surfaces are feasible.

[0018] In order to take account of the wavelength-dependent refraction of the optical elements downstream of the active light source, the LEDs emitting short wavelength light are predominantly arranged in the central area and the LEDs emitting long wavelength light are predominantly arranged in the outer area of an

LED circuit board, since long wavelength light is refracted more strongly than short wavelength light.

[0019] A further advantage of the relatively widely distributed arrangement of the LEDs is that it provides space for the collimation lenses, which act more effectively and focus more strongly, the larger is the available space around the LED.

[0020] The number and the types of the LEDs emitting coloured light on the LED circuit board are preferably adjusted to a predefined colour temperature, for example, to a colour temperature of 2800 °K to 6500 °K.

[0021] Alternatively, the number and the types of the LEDs emitting the coloured light on the LED circuit board can be adjusted to a variable colour temperature, in particular to an adjustable colour temperature range of 2800 °K to 6500 °K.

[0022] Preferably at least a part of the light emitted by the LEDs is directed through a colour filter, such that the spectrum of the light emitted by the spotlight is changed in a predefinable manner.

[0023] By combining the spectral emitting characteristics of the LEDs and the spectral transmission of the colour filter, in particular a colour sheet, the light emitted by the spotlight is optimized in colour such that a desired colour location and/or a desired colour reproduction is achieved at maximum brightness.

[0024] In a preferred embodiment, the colour sheet is structured or perforated for obtaining a certain transmission characteristic.

[0025] Due to the complete or partial filtration of the light emitted by the LEDs, for example, white LEDs with inferior colour reproduction but high efficiency can be used. The spectrum emitted by the LEDs is shifted so far with the aid of the colour filter that the colour reproduction is optimized. The efficiency can then be even higher than if suitable LEDs had been used. The colour location and the colour temperature can also be shifted with the aid of a colour filter, in particular a colour filter sheet.

[0026] In order to remove the heat produced during the light generation, the LED circuit board is connected to a cooling body or to a cooling device with a movable cooling medium, in particular with a fan for cooling the LEDs.

[0027] Due to the arrangement of the LEDs in an area, which is large compared to the dimensions of the LEDs, only a low power density is obtained. The dissipation of the lost heat is therefore easily possible using this construction principle and can also be achieved with simple, passive cooling bodies up to powers of several hundred Watts. In contrast, in the case of a luminaire area with high power density, a dissipation of the heat by heat pipes combined with fans is usually required.

[0028] The collimation optical unit preferably reshapes the light beams emitted by the LEDs into a parallel or slightly convergent beam path, which fills the light entrance surface of the mixing optical unit substantially completely with light.

[0029] The primary or active light source is composed of a plurality of identically or differently coloured LEDs, which are optionally already provided with a primary optical unit, in particular if these have already been installed by the manufacturer.

[0030] The LEDs of the active light source can be arranged alternatively on a planar surface or on the inside of a curved surface. When arranging the LEDs on a planar surface, for example, on a planar circuit board, a metal core board, an epoxy resin board or a ceramic board, the LEDs emit the light in the same emission direction, wherein the collimation optical unit is composed of a plurality of discrete optical elements with different emission direction, which focus the light emitted by the LEDs in a point or in a plane.

[0031] The advantage of such an arrangement of the LEDs on a planar surface is that the LEDs can be loaded by machine and optionally together with other components onto the planar circuit board, metal core board, epoxy resin board or ceramic board and can be electrically contacted. The disadvantage is that each optical element of the collimation optical unit is configured differently since each LED emits light at a different angle in respect to the downstream mixing optical unit.

[0032] In the alternative arrangement of the LEDs of the active light source on the inside of a curved surface, for example a tall partial sphere or hemisphere, a hollow parabola or an aspherical hollow surface, the LEDs emit light towards the centre of curvature or focal point of the curved surface, such that the same collimation optical unit can be provided for a plurality of or all the LEDs of the active light source.

[0033] The advantage of this arrangement is that the same type of collimation optical unit can be used for a plurality of or all the LEDs since the LEDs already have the desired emission direction. The disadvantage is a more complex assembly and a more complex electrical connection of the LEDs since they are located on a curved surface and depending on the height of the LEDs and the collimation optical unit, a large distance of the LEDs with respect to one other is required.

[0034] The collimation optical unit is a lens system that is connected to the LEDs in the emission direction of the light emitted by the LEDs and which collimates or focuses the light in a point or in a plane. A colour mixing is already carried out here due to the superposition of the light of the single LEDs. Collimating or focusing lenses or lens systems, preferably made of optical plastics, can be used as collimation optical unit, which capture the highest possible proportion of the radiation emitted by the LEDs and emit in emission direction of the LED luminaire with a desired light distribution. Preferably TIR lenses (Total Internal Reflection) are used for optimizing the efficiency.

[0035] When arranging the LEDs of the active light source on a planar surface, the collimation optical unit consists of optical elements with different directions of emission or of an optical circuit board, into which optical surfaces with different emission directions are incorporated.

[0036] When arranging the LEDs of the active light source on a curved surface, on the other hand, discrete optical elements of the same type are used as collimation optical unit, which can be set above the LEDs. These optical elements can also be incorporated into a common optical component group.

[0037] The mixing optical unit consists of one or a plurality of optical elements, which mix the light emitted by the collimation optical unit with regard to colour. The exit side of the mixing optical unit works thereby as a secondary or passive light source.

[0038] The mixing optical unit emits the light impinging from different directions at approximately the same angle and has at least one optical element, which mixes the light emitted by the collimation optical unit in the emission direction and is thus effective as a secondary light source on the light exit side.

[0039] Possible embodiments of the mixing optical unit are

- a diffusor disc or a diffusor body with more or less strong scattering, for example in form of a milk glass sheet, a diffuse plastic sheet or a diffuse hemisphere made of plastic. The advantage of this embodiment consists in optimal colour mixing with high scattering, the disadvantage is a low transmission and thus a low efficiency at high scattering;

- an optionally also completely permeable diffusor with a structure on the entrance side and/or the exit side, for example, in form of honeycombs, prisms, microlenses and the like;

- a so-called holographic diffusor, which is obtained by moulding from a master hologram and which has a defined scattering combined with a higher efficiency than a conventional, absorbing diffusor;

- a diffusor with an intensifier on the light exit side which consists of a cone, which is reflectively coated on the inside and has thus an improved efficiency;

- a honeycomb condenser, having the advantage of the high transmission and the disadvantage that a certain angle of incidence and exit of the light cannot be exceeded and that therefore a large overall length of the optical system or the spotlight is required;

- a light-mixing rod or taper having the advantage of the high transmission and the disadvantage of the large overall depth and decreasing transmission with good colour mixing.

[0040] The field optical unit preferably configured as a field lens comprises a beam expanding structure on the light entrance side and a focusing structure, in particular a Fresnel structure on the light exit side.

[0041] The field optical unit can either be configured as a single converging lens, which images the exit surface of the mixing optical unit or secondary or passive light source in the far field and has different distances to the mixing optical unit to achieve a variable emission angle, or can be designed as a lens system with predominantly imaging properties, which images the exit surface of the mixing optical unit or the plane lying in front thereof exactly into a plane located at a great distance.

[0042] A convex lens, planoconvex lens, aspherical converging lens, stepped lens or stepped lens with incorporated scattering structure (NOFS lens) can be used as converging lens. The entrance and exit side of the converging lens can be provided with a structure, for example a honeycomb, prism, microlens or regular or irregular diffusor structure, or also with a holographic scattering structure in order to achieve improved colour mixing and/or to achieve a soft profile of the light field.

[0043] A zoom optical unit or a projection optical unit can be used as lens systems with predominantly imaging properties.

[0044] In order to achieve that the light emitted by the active light source arrives at the mixing optical unit in the desired manner, further optical elements, such as lenses or reflectors can be arranged if required between the active light source and the mixing optical unit, which deflect or reshape the light emitted by the active light source in an appropriate manner. Examples of such optical elements are planar or curved mirrors, converging lenses, fibre optics or light-mixing rods.

[0045] In the same way, further optical elements, as specified previously, can be arranged between the mixing optical unit and the field optical unit, which deflect or reshape the light emitted by the mixing optical unit or passive light source at the light exit side of the mixing optical unit, in order to obtain a desired light distribution in the far field.

[0046] The active light source, the collimation optical unit and the mixing optical unit can be combined to form a light generating unit, in particular for an LED spotlight. The light generating unit contains a frustroconical reflector, the lateral surface of which is reflectively coated on the inside, the open face surface of which is adjacent to the collimation optical unit and the open top surface of which is adjacent to the mixing optical unit so that the light emitted by the LEDs and detected by the collimation optical unit is not only directed to the mixing optical unit, but also scattered light which appears in the beam path is reflected back from the collimation optical unit to the mixing optical unit, and thus the efficiency is increased. Preferably the open face surface of the frustroconical reflector merges into a reflector section enclosing the collimation optical unit, which is hollow cylindrical and reflectively coated on the inside, with which the light component emitted to the outside by the LEDs is reflected back to the collimation optical unit.

[0047] In case of such a light generating unit, the mixing optical unit is preferably arranged in the opening of an annular flange, the external diameter of which is equal to the external diameter of the LED circuit board and/or a circular disc-shaped plate connected to the LED circuit board, wherein the annular flange on the one hand and the LED circuit board and/or the circular disc-shaped plate on the other hand form the end sides of a hollow-cylindrical cartridge, wherein the cylinder lateral surface of which is connected to the annular flange and the LED circuit board and/or the circular disc-shaped plate.

[0048] As a result, the cartridge receiving the light generating unit can be designed as a compact unit with a hermetically sealed watertight housing out of which only the power supply and control cable which is connected to the LEDs and the control electronics for the LEDs, is guided via an opening. In addition, the cartridge can be used in different LED spotlights by inserting said cartridge into a tube of the spotlight housing and by connecting said cartridge tightly to said tube or by arranging said cartridge movably in longitudinal direction in the tube, which substantially simplifies the production of an LED spotlight or different spotlight types.

[0049] For optimal utilization of installation space, the annular flange is connected to a control electronics circuit board via a stud acting as a spacer, which circuit board comprises on the inner side of the annular flange facing the reflector a control electronics for controlling and regulating the LEDs. The outer surface of the frustroconical reflector, of the cylinder lateral surface of the cartridge and the inner side of the annular flange enclose a sufficiently large space for receiving the control electronics and the heat radiation dissipated by the components of the control electronics.

[0050] The collimation optical unit comprises on its light entrance side a collimator facing the LED circuit board with conical total reflection lenses directed towards the individual LEDs and comprises on its light exit side a stepped lens structure in the manner of a Fresnel lens, wherein the collimation optical unit is connected to the LED circuit board via spacers, the length of which is dimensioned such that the conical total reflection lenses end at an optimal distance to the LEDs. Thereby the conical total reflection lenses collect the light emitted by the LEDs, which are arranged on the LED circuit board, over a wide range with a maximum solid angle.

[0051] The LED circuit board comprises a number of LEDs and a plurality of thermal sensors arranged in a distributed manner, which detect the temperature on the LED circuit board in different temperature zones so that the control electronics can reduce the power consumption of the LEDs when limiting values of the temperature are exceeded or can interrupt the power supply to the LEDs, whereby it is ensured that inadmissibly high temperatures do not occur at any point on the LED circuit board.

[0052] The measurement of the temperatures additionally serves as input signal for the control electronics, which can thus regulate the brightness and the colour of the emitted light to the intended value. In the same manner, an optical sensor, which is introduced into the beam path, such as for example a photodiode, a colour sensor or a minispectrometer, can provide an input signal for the control electronics for regulating the colour and brightness values.

[0053] A stepped lens, which is adjustable along the optical axis of the LED luminaire, is arranged in light emission direction of the cartridge in front of the mixing optical unit, which receives the light emitted by the mixing optical unit and emits it with a light distribution (flood, spot) that is settable by the distance of the stepped lens from the mixing optical unit into a far field.

[0054] The stepped lens has a structuring on its light entrance side which consists of spirally arranged, pentagonal optical elements.

[0055] Since in case of a planar light entrance side of the stepped lens, the local light distribution on the light exit side of the condenser of the mixing optical unit would be imaged in an angular distribution, wherein the colours emitted by the multicoloured LEDs would not be absolutely homogenously distributed after the condenser due to its principle of action, so that colour effects would occur, the specific structuring of the light entrance side of the stepped lens removes colour effects which are still present despite of the light mixing properties of the mixing optical unit so that the mixed light from the differently coloured LEDs can be output homogenously to the far field.

[0056] The cartridge and the stepped lens are arranged in the tube of a luminaire or spotlight housing for easy setting and adjustment of the light distribution, wherein

- the stepped lens is adjustable in the direction of the optical axis relative to the cartridge of the light generating unit being connected to the stationary tube,
- the tube is adjustable together with the stepped lens in the direction of the optical axis relative to the stationary cartridge of the light generating unit or
- the cartridge of the light generating unit is adjustable along the optical axis relative to the stationary stepped lens connected to the tube.

[0057] These various possibilities for setting and adjustment are provided, since the light generating unit is combined in a cartridge and can be arranged in the tube of the luminaire or spotlight housing.

[0058] An adjusting device, which can be actuated manually or by electric motor, for longitudinal adjustment of the cartridge in the luminaire or spotlight housing, is preferably arranged between the cartridge and the luminaire or spotlight housing.

[0059] The distance between the light generating unit and the optical unit of the light shaping device must be varied for focusing an LED spotlight or for varying the emission angle of the light emitted by the LED spotlight, which comprises a large scattering angle in the flood position and a small scattering angle in the spot position.

[0060] In order to achieve an emission characteristic of a stepped lens spotlight, it is thus appropriate to bring the optical unit close to the light exit opening of the light generating unit in order to achieve emission with a large scattering angle and part shadow formation in the flood position. In a position of the lens or the lens system, which is remote from the light exit opening of the light generating unit, emission with a small scattering angle and soft shadow formation is then produced in the spot position of the LED spotlight.

[0061] If the lens or the lens system is adjusted for changing the emission angle of the LED spotlight between the flood position, which is posterior in emission direction and adjacent to the light exit opening of the light generating unit to produce a large scattering angle, and the spot position, which is anterior in emission direction and remote from the light exit opening of the light generating unit to produce a small scattering angle with soft shadow formation, then the problem arises that the lens or the lens system in the posterior flood position has such a large emission angle that the spotlight housing requires a tube with a very large diameter in which the lens or the lens system is moved forward and backward to vary the emission characteristic.

[0062] Alternatively, the lens or the lens system could be adjusted together with the spotlight accessory, which is arranged in front of the lens or the lens system, which however is also problematic in particular in the case of a long adjustment path, when the LED spotlight is inclined out of the horizontal downwards or upwards and in case of heavy accessories, as for example motorized barn doors.

[0063] It is furthermore problematic to adjust the lens or the lens system together with the spotlight accessory precisely along the optical axis of the LED spotlight. A further problem is that the distance of the light exit surface of the LED spotlight to an object illuminated by the LED spotlight is changed, which leads to a change of the area of the object illuminated by the LED spotlight.

[0064] A further object thus consists in making it possible to change the emission characteristic of the LED spotlight between a flood position with a large scattering angle and a spot position with a small scattering angle with easy handling and precise variation of the emission angle without structural variation of the LED spotlight and variation of the distance of the light exit surface of the LED spotlight from the object.

[0065] By arranging a cylindrical tube in the luminaire or spotlight housing and a cartridge containing the light generating unit and a field lens on the light exit side of the LED luminaire, which are arranged relatively movably with respect to one other in the tube, an easy handling and precise change of the emission angle is ensured, since the required operating elements can furthermore be attached to the stationary luminaire or spotlight housing and the precision of the guidance of the cartridge receiving the light generating unit or the field lens along the optical axis can be maintained. Since the light exit opening of the LED spotlight must be only insignificantly larger than the field lens or the field optical system, no constructional modification of the LED spotlight is required. Since the light exit surface is arranged on the stationary part of the LED spotlight, there is also no change in the distance of the light exit surface of the LED spotlight to the illuminated object.

[0066] By connecting the light shaping device attached to the luminaire or spotlight housing to the spotlight accessories such as lens plates which are displaceable with respect to one another, barn door, grids, diffusor, scrims, gobos, holographic scattering sheets or the like, it is additionally ensured that heavy accessories such as motorized barn doors need not be moved when changing the emission angle of the LED spotlight so that the handling of the LED spotlight is further simplified and no complex guiding devices resisting high adjustment forces are required.

[0067] The cartridge with the light generating unit is preferably adjustable along the optical axis of the LED spotlight relative to the field lens, which forms a unit with the luminaire or spotlight housing firmly connected to the light shaping device, which leads to a significant advantage during the production, handling and precision of the guidance as well as the distance of the light exit surface of the LED spotlight from the object compared with an adjustment of the lens or lens system and the spotlight accessories along the optical axis of the LED spotlight.

[0068] The cartridge with the light generating unit is preferably guided manually or by electric motor in a longitudinally adjustable manner in the luminaire or spotlight housing so that an exact adjustment of the light generating unit along the optical axis of the LED spotlight and an easy adjustment of the light distribution (flood, spot) are ensured.

[0069] In order to facilitate and precisely set the half scattering angle of the LED spotlight, an adjustment device for longitudinal adjustment of the cartridge can be provided between the luminaire or spotlight housing and the tube, which is connected as a manual adjustment device to an adjusting lever guided towards the outside of the basis housing or an adjusting wheel or comprises an electric-motor-driven spindle or rack gear as an electric-motor adjustment device.

[0070] Pivot joints can furthermore be arranged on the luminaire or spotlight housing, which are connected to a retaining bracket or a tripod.

[0071] The cartridge of the light generating unit is configured to be hemispherical on its rear side opposite the light exit opening of the LED spotlight and has cooling ribs on its hemispherical rear side, via which the heat being received from the cooling device and dissipated by the light generating unit is discharged to the outside.

[0072] The idea forming the basis of the invention will be explained by the means of several exemplary embodiments illustrated in the drawings and further embodiments will be described. In the figures:

Fig. 1 shows a schematic block diagram of the optical system according to the invention for an LED luminaire, in particular for an LED spotlight;

Fig. 2 shows a schematic view of an active light source with LEDs arranged on a planar plate or circuit board and emitting light in the same direction;

Fig. 3 shows a schematic view of an active light source with LEDs arranged on the inside of a curved surface and emitting light towards the centre of curvature or focal point of the curved surface;

Fig. 4 shows a schematic section through an active light source with LEDs arranged on a circuit board and collimation optical unit, a mixing optical unit inserted into the circuit board and a planar reflector reflecting the light of the active light source to the mixing optical unit;

Fig. 5 shows a schematic section as in Fig. 4 with a concavely curved or conical reflector;

Fig. 6 shows a schematic section through an active light source with LEDs arranged in one or multiple rings about the principal optical axis of the LED luminaire and collimation optical unit and a convexly curved or conical, preferably facetted reflector;

Fig. 7 shows a schematic section through an arrangement of the LEDs combined from the arrangements according to Figs 4 to 6 and collimation optical unit 5, the mixing optical unit and a concavely curved reflector.

Fig. 8 shows a schematic section through a mixing optical unit configured as a diffusor disc or as a diffusor with entrance and/or exit side structure;

Fig. 9 shows a schematic section through a mixing optical unit configured as a diffusor with exit side intensifier;

Fig. 10 shows a schematic view of an optical system for an LED spotlight with a honeycomb condenser in a flood setting of a LED spotlight;

Fig. 11 shows a schematic view as in Fig. 10 in a spot setting of the LED spotlight;

Fig. 12 shows a schematic perspective view of an LED spotlight with a light generating unit arranged in a cartridge and a field optical unit configured as a stepped lens;

Fig. 13 shows a schematic view of the interfaces of the light generating unit;

Fig. 14 shows a schematic view of an LED circuit board loaded with LEDs and NTC resistors;

Fig. 15 shows a schematic view of the colour distribution of coloured LEDs arranged on the LED circuit board according to Fig. 14;

Fig. 16 shows a schematic outline of the optical beam path of the LED spotlight;

Fig. 17 shows a perspective view of the active light source, collimation optical unit and mixing optical unit and a frustroconical reflector,

Fig. 18 shows a perspective view of the arrangement according to Fig. 17 with the view of a control electronics, which is arranged on a annular flange arranged around the mixing optical unit;

Fig. 19 shows a top view of the light entrance side of the collimation optical unit;

Fig. 20 shows a side view of the collimation optical unit according to Fig. 19;

Fig. 21 shows a section through the collimation optical unit along the line A-A according to Fig. 19;

Fig. 22 shows a top view of the light exit side of the collimation optical unit;

Fig. 23 shows a perspective view of the collimation optical unit;

Fig. 24 shows a top view of the light entrance side of a condenser used as mixing optical unit;

Fig. 25 shows a top view of the light exit side of a condenser according to Fig. 24;

Fig. 26 shows a side view of the condenser according to Fig. 24;

Fig. 27 shows a section through the condenser along the line A-A according to Fig. 24;

Fig. 28 shows a top view of the light exit side of a stepped lens used as field optical unit;

Fig. 29 shows a section through the stepped lens along the line A-A according to Fig. 28;

Fig. 30 shows a perspective section from the centre of the light entrance side of the stepped lens according to the Figs. 28 and 29;

Fig. 31 shows a perspective section from the edge of the light entrance side of the stepped lens according to Figs. 28 and 29;

Fig. 32 shows a schematic longitudinal cross view through the LED spotlight according to the Figs. 12-31;

Figs. 33-36 show different schematic views of the light emission in flood and spot settings of the LED spotlight;

Fig. 37 shows an isometric view of an LED spotlight with a base housing and an adjusting housing with a light generating unit, which is adjustable with respect to the basis housing along the optical axis of the LED spotlight;

Fig. 38 shows a side view of the LED spotlight according to Fig. 1 in a flood position of the light generating unit with a large scattering angle and

Fig. 39 shows a side view of the LED spotlight in a spot position of the light generating unit with a small scattering angle.

[0073] Figure 1 shows in a block diagram the main assemblies of the optical system for an LED luminaire, which are arranged in the usually hollow cylindrical housing 1. An active light source 2 (light engine) consists of a plurality of identically or differently coloured LEDs which are arranged alternatively on a planar or curved surface and are optionally provided with primary optical units installed by the manufacturer of the LEDs. The light emitted by the LEDs of the active light source 2 is guided in emission direction A through the LED luminaire and is deflected or reshaped in the following assemblies so that the light beams are output in the desired manner to the following assembly in each case or are emitted on the light exit side of the LED luminaire into the far field.

[0074] Two alternative embodiments of the active light source 2 are illustrated in Figs. 2 and 3.

[0075] Figure 2 shows the arrangement of LEDs 21, 22, 23 on a planar surface 20 which emits the light beams L1, L1′, L1″ in emission direction A. A plate or circuit board in form of a metal core circuit board, epoxy resin circuit board or ceramic circuit board can be used as a planar surface. This arrangement has the advantage of the mechanical loading of the planar plate or circuit board with the LEDs 21, 22, 23 which can be optionally loaded together with other components and electrically contacted. The disadvantage is that each element of the downstream collimation optical unit 3, which is assigned to the individual LEDs 21, 22, 23, is configured differently since each LED 21, 22, 23 emits at a different angle in relation to the downstream mixing optical unit 4.

[0076] Figure 3 shows in a schematic view this arrangement of LEDs 21, 22, 23 of the active light source 2 on the inside of a curved surface 200 formed as a hollow sphere, hollow parabola or aspherical hollow surface. The LEDs 21, 22, 23 emit light L2, L3, L4 towards the centre of curvature or focal point of the curved surface 200. The advantage here is that similar collimation optical units can be used for a plurality of or all the LEDs 21, 22, 23, since the LEDs 21, 22, 23 already emit light in the desired emission direction. The disadvantage is a more complex assembly and a more complex electrical connection of the LEDs 21, 22, 23 on the curved surface 200 and as well as a larger distance of the LEDs 21, 22, 23 with respect to one another depending on the height of the LEDs 21, 22, 23 and the collimation optical units assigned to the LEDs 21, 22, 23.

[0077] The light emitted by the active light source 2 is collimated or focused in the collimation optical unit 3 in a point or in a plane, wherein the collimation optical unit consists of individual lenses, which are placed on the individual LEDs or which are connected as primary optical units to the LEDs by the manufacturer or it consists of a lens system, which is assigned to groups of LEDs or all the LEDs. Collimating or focusing lenses or lens systems are used as collimation optical unit 3, preferably made of optical plastics which collect the highest possible proportion of the light beams emitted by the LEDs of the active light source 2 and emit in emission direction A with a desired light distribution. Preferably TIR-lenses (Total Internal Reflection) are used for optimizing the efficiency of the LED luminaire.

[0078] As has been explained previously, depending on the arrangement of the LEDs 21, 22, 23 of the active light source 2 on a planar surface 20 or curved surface 200, the collimation optical unit 3 can consist of similar, discrete optical elements placed above the LEDs 21, 22, 23 or of discrete optical elements with different emission directions or alternatively it can be designed as a complete optical plate with incorporated optical surfaces.

[0079] The light beams K1, K2 emitted by the collimation optical unit 3 are optionally guided via an optical device 6, which contains optical elements as lenses or reflectors, which deflect or reshape the light K1, K2 emitted by the collimation optical unit 3 such that it is supplied in the desired manner as light beams E to the downstream mixing optic 4.

[0080] Figures 4 to 7 show various space saving arrangements of an active light source with LEDs and collimation optical units connected to the LEDs, a mixing optical unit and a reflector.

[0081] Figure 4 shows an arrangement with LEDs 21 to 24 arranged on planar circuit board 20 with collimation optical units 31 to 34 placed thereon. The circuit board 20 is located in the plane of the mixing optical unit 4 and comprises a central opening for receiving the mixing optical unit 4 in the principal optical axis HA of the LED luminaire so that the LEDs 21 to 24 are arranged in an annular manner around the mixing optical unit 4 with the collimation optical units 31 to 34 located thereon. The reflector 91 configured as a planar mirror is arranged at a distance from the circuit board 20 which reflector reflects the light beams K1, K2 of the collimation optical units 31 to 34 emitted in the opposite direction to the mixing optical unit 4 back to the mixing optical unit 4, which emits the mixed light, which is characterized by the edge beams M1 and M2, via its light exit surface.

[0082] Due to this arrangement only half of the overall length between the LEDs 21 to 24 or collimation optical units 31 to 34 and the mixing optical unit 4 is required for the most complete possible illumination of the light entrance surface of the mixing optical unit 4.

[0083] Figure 5 shows as a modification of the arrangement according to Fig. 4 the arrangement of a reflector 92, configured as a concavely curved or conical and preferably facetted mirror, which reflects the light K1, K2 emitted by the LEDs 21 to 24 via the collimation optical units 31 to 34 back to the mixing optical unit 4 arranged in the principal optical axis HA of the LED luminaire. Due to the arrangement of the concavely curved or conical and preferably facetted mirror as reflector 92, it is possible to use rectilinearly emitting and thus identically configured collimation optical units 31 to 34.

[0084] Figure 6 shows an embodiment with a convexly curved to conical and preferably facetted reflector 93 and LEDs 21 to 24 arranged in a ring or in a plurality of rings around the principal optical axis HA of the LED luminaire with collimation optical units 31 to 34 arranged thereon. The convexly curved to conical and preferably facetted reflector 93 reflects the light K1, K2 emitted by the LEDs 21 to 24 via the collimation optical units 31 to 34 back to the mixing optical unit 4 arranged in the principal optical axis HA of the LED luminaire, which emits light with the edge beams M1, M2 to the downstream optical devices.

[0085] In this embodiment also, similar collimation optical units 31, 33 or 32, 34 can be used for each ring and due to the cylindrical annular arrangement of the LEDs 21 to 24, optimal heat dissipation via the hollow cylindrical housing of the LED luminaire is ensured.

[0086] Alternatively, a polygonal outer shell for receiving the LEDs 21 to 24 or a polygonal housing form of the LED luminaire can be used for simpler assembly and electrical contacting of the LEDs 21 to 24, if simultaneously collimation optical units 31 to 34 are used, which deflect the light emitted by the LEDs 21 to 24 in two different directions.

[0087] In the embodiment according to Fig. 7 an annular or polygonal arrangement of LEDs 21 to 24 with the assigned collimation optical units 31 to 34 is combined with LEDs 25, 26 arranged on a planar surface with assigned collimation optical units 35, 36 to achieve a higher power density, wherein the plane with the LEDs 25, 26 is located in the plane of the mixing optical unit 4 and is for example configured as a circuit board with a central opening for receiving the mixing optical unit 4. This arrangement is provided with a combined reflector 94, which comprises a planar surface for reflection of the light beams emitted by the LEDs 25, 26 or the assigned collimation optical units 35 and 36 and comprises a concavely arched surface for the light beams emitted by the annularly or polygonally arranged LEDs 21 to 24 and the collimation optical units 31 to 34.

[0088] The mixing optical unit 4 consists of one or a plurality of optical elements, which mix the incident light E in regard to colour. The mixing optical unit 4 acts on its exit side as a secondary or passive light source, which emits light beams M1, M2.

[0089] Two exemplary embodiments for the mixing optical unit 4 are shown in the Figs. 8 and 9.

[0090] The mixing optical unit shown in section in Fig. 8 consists of a diffusor disc or a diffusor body 60 with a more or less strong scattering, which scatters the incident light beams E in a number of beams M1 emitted in different directions. In particular, a milk glass plate, a diffuse plastic plate or a diffuse hemisphere made of plastic are suitable as diffusor disc or body. Instead of a diffusor disc or a diffusor body, an optionally completely translucent diffusor 61 can be used, which is provided with a structure on the light entrance side and/or the light exit side, for example in the form of honeycombs, prisms, microlenses or the like.

[0091] In the embodiment according to Fig. 9, the mixing optical unit consists of a diffusor with an intensifier on the light exit side in form, for example, of a cone 62 reflectively coated on the inside, which reflects the light beams M1 incident on said cone back into the cone interior as light beams M2 and serves to reduce the emission angle similarly to a taper.

[0092] The beams M1, M2 emitted by the mixing optical unit 4 are guided as required via optical elements 7, in which the light emitted by the mixing optical unit 4 with the edge light beams M1, M2 is deflected or reshaped so that the edge light beams N1, N2 emitted by the further optical elements 7 meet in a downstream field optical unit 5 so that a desired light distribution is obtained in the far field. The further optical elements can be planar or curved mirrors, converging lenses, diverging lenses, optical fibres or light mixing rods.

[0093] In addition to the embodiments of the mixing optical unit 4 described by reference to Figs. 8 and 9, a honeycomb condenser or a light mixing rod or taper can alternatively be used.

[0094] A single converging lens or lens system with predominantly imaging properties can be used as the field optical unit 5. In case of a field optical unit 5 configured as a single converging lens, the exit surface of the mixing optical unit 4 or the secondary or passive light source is imaged in the far field and the converging lens has different distances from the mixing optical unit 4 to achieve a variable emission angle.

[0095] A convex lens, planoconvex lens, an aspherical converging lens, a stepped lens or a stepped lens with incorporated scattering structure (NOFS lens) can be used as a converging lens. The entrance and exit side of the converging lens can be provided with a structure, for example a honeycomb, prism, microlenses or regular or irregular diffusor structure in order to achieve a better colour mixing and/or to achieve a soft profile of the light field.

[0096] A field optical unit 5 configured as a lens system with predominantly imaging properties images the exit surface of the mixing optical unit 4 or a plane situated in front thereof exactly into a plane situated far away.

[0097] A zoom optical unit or a projection optical unit can be used as a lens system having predominantly imaging properties.

[0098] A specific embodiment of the LED luminaire according to the invention is shown in a schematic longitudinal section in Figs. 10 and 11.

[0099] An active light source 2 comprises a plurality of LEDs 21, 22, 23, 24, 25 arranged on a planar circuit board 20 connected to a cooling body 26, on which collimation optical units 31, 32, 33, 34, 35 assigned to the individual LEDs 21, 22, 23, 24, 25 are placed, which collimate or focus the light emitted by the LEDs 21-25 corresponding to the input light beams K1, K2 to a mixing optical unit 4. The light mixed in regard to colour by means of the mixing optical unit 4 for example configured as a honeycomb condenser is emitted with the edge light beams M1, M2 to a field optical unit 5 located close to the mixing optical unit 4, for example in form of a stepped lens with incorporated scattering structure (NOFS lens), which in this flood setting of the LED luminaire, emits diverging edge light beams F1, F2 to the far field.

[0100] Alternatively to this, according to the schematic sectional view according to Fig. 11, the field optical unit 5 is located in a position remote from the mixing optical unit 4 so that the edge light beams M1, M2 emitted by the mixing optical unit 4 are emitted as converging edge light beams F3, F4 in the spot setting of the LED luminaire to the far field.

[0101] As a result of the space available radially between the mixing optical unit 4 and the housing 1 of the LED luminaire, the electronics of the LED luminaire can be arranged in the area 8 shown hatched inside the LED luminaire. Since the heat emitted by the LEDs 21-25 of the active light source 2 is discharged via the cooling body 26 to the outside, the space 8 available for the electronics has a comparatively low temperature.

[0102] In the Figs. 12 to 39 different LED spotlights and the elements thereof are shown as exemplary embodiments for the variants of an LED luminaire shown in the Figs. 1 to 11 and previously described.

[0103] Figure 12 shows in a schematic perspective view a light generating unit 9 and a field optical unit 5 of an LED spotlight arranged in the beam path of the light generating unit 9 and configured as a stepped lens. The light generating unit 9 is arranged in a hollow cylindrical cartridge 10, which comprises a cylinder lateral surface 101, the end sides of which are closed by a circular disc flange 102 and/or a circular disc-shaped LED circuit board 20 with a thermal interface 12 and an annular flange 103. A mixing optical unit 4 configured as a condenser as described in the following by the means of the Figs. 24 to 27 is arranged in an annular opening 104 of the annular flange 103 of the cartridge 10.

[0104] The LED circuit board 20 comprises a plurality of LEDs on its surface facing the inner space of the cartridge 10, the arrangement and distribution of which can be deduced from the illustration according to Fig. 15 and is explained in more detail hereinafter.

[0105] The LED circuit board 20 and/or the annular flange 102 of the cartridge 10 form a thermal interface on the outwardly directed outer surface thereof, which interface is connected to a cooling body or to a cooling device with a movable cooling medium, in particular to a fan for cooling the LEDs.

[0106] The LED circuit board 20 is connected in the emission direction of the LEDs via spacers 16 to a collimation optical unit 3 illustrated in the Figs. 19 to 23, which focuses the light emitted by the individual LEDs to the mixing optical unit 4 and according to the top view illustrated in Fig. 19, the side view illustrated in Fig. 20, the section along the line A-A according to Fig. 19 and illustrated in Fig. 21, and the perspective complete view according to Fig. 23, comprises on its light entrance side a collimator facing the circular disc-shaped LED circuit board 20 with conical total reflection lenses 37 aligned to the individual LEDs of the active light source 2 and comprises on its light exit side a stepped lens structure in the manner of a Fresnel lens. The conical total reflection lenses collect the light emitted by the LEDs arranged on the LED circuit board 20 over a large width with a maximum solid angle or are located with their light entrance side immediately in front of the LEDs. For this purpose, the length of the spacers 16 is dimensioned so that the conical total reflection lenses end at an optimal distance shortly before the LEDs arranged on the LED circuit board 20.

[0107] In this exemplary embodiment, the mixing optical unit 4 consists of a honeycomb condenser illustrated in Fig. 24 in a top view of the light entrance side, in Fig. 25 in a top view of the light exit side, in Fig. 26 in a side view and in Fig. 27 in a section along the line A-A, which comprises a light entrance and light exit angle corresponding to the emission angle of the collimation optical unit 3 of for example 25° and an optically effective area 40 as well as a mounting edge 41.

[0108] A frustroconical reflector 11 with a lateral surface 110, which is reflectively coated on the inside, adjoins the collimation optical unit 3 with its open face surface 111 and adjoins the mixing optical unit 4 with its open top surface 112. In this case, the open face surface 111 of the frustroconical reflector 11 passes into a hollow cylindrical reflector section 113, which is reflectively coated on the inside and which encloses the collimation optical unit 3, so that the light component emitted outwards by the LEDs is reflected back to the collimation optical unit 3.

[0109] The cartridge 10 receiving the light generating unit 9 is configured as a compact unit with a hermetically closed watertight housing, out of which an electrical and control cable 70 is guided via an opening 106 which cable is connected to the LEDs and control electronics for the LEDs. As will be explained subsequently in more detail by means of Figs. 30 to 39, the cartridge 10 containing the light generating unit 9 can be inserted in a tube 1 of the spotlight housing and can be tightly connected to said tube or can be arranged movably in the longitudinal direction inside the tube.

[0110] A field optical unit adjustable along the principal optical axis HA can be inserted in the light emission direction of the light generating unit 9 in front of the mixing optical unit 4 configured as a condenser, which field optical unit consists of a stepped lens 5 illustrated in the Figs. 28 to 31, which receives the light emitted by the mixing optical unit 4 and emits the light into a far field with a light distribution as flood or spot light which can be set by the distance of the field optical unit 5 from the mixing optical unit 4.

[0111] Figure 13 shows a schematic diagram of the interfaces of the light generating unit 9 with the active light source 2, which comprises the LEDs 21 to 26 arranged on the LED circuit board 20 as well as a plurality of thermal sensors 27 which are arranged in a distributed manner and are preferably configured as NTC resistors, which detect the temperature of the LED circuit board 20 in different temperature zones. For example 85 LEDs 21 to 27 of different colours are arranged on the LED circuit board 20, these being combined in multiple colour channels, as well as five thermal sensors 27 configured as NTC resistors for detecting the temperature in different temperature zones. The LED circuit board 20 is connected via the thermal interface 12 to a cooling medium, for example a cooling body. The LED circuit board is connected via an optical interface 13 to the previously described collimation optical unit 3, the beam path of which is explained hereinafter.

[0112] The LED circuit board 20 is connected via an interface 181 and an internal conductor 18 to an interface 182 of control electronics 7 on the control and power supply side, which is connected on the output side via an electronic interface 71 inter alia to external control devices and a voltage supply. The control electronics 7 takes over the complete signal processing, temperature stabilization and colourimetry of the light generation unit 9 and is also arranged within the hermetically sealed cartridge 10.

[0113] Figure 14 shows in a perspective representation a view of the light emitting side of the LED circuit board 20 with the LEDs 21 to 26 arranged on the LED circuit board 20, the NTC resistors 27 arranged in a distributed manner for detecting the temperature on the LED circuit board 20 in different temperature zones as well as the spacer 16, via which the collimation optical unit 3 is connected to the LED circuit board 20 of the active light source 2.

[0114] Figure 15 shows in a top view of the LED circuit board 20 the arrangement of a plurality of LEDs, of which the LEDs 21 shown non-hatched emit warm white light, the LEDs 22 shown cross-hatched emit red light, the left-hatched LEDs 23 emit green light and the right-hatched LEDs 24 emit blue light. As can be seen from the schematic view of the LED colour arrangement according to Fig. 15, the blue LEDs 24 emitting short-wavelength light are arranged in the central area and the LEDs 21 to 23 emitting long-wavelength light are arranged in the outer area of the LED circuit board 20 due to the wavelength-dependent refraction of the downstream optical elements, since for example the red light beams are refracted more strongly than the blue light beams. The number and the exact type of the

LEDs 22 to 24 emitting the coloured light on the LED circuit board 20 are preferably matched to a predefined fixed colour temperature, for example to a colour temperature between 2800 °K and 6500 °K or to a variable colour temperature in this range.

[0115] The LED circuit board 20 is configured as a planar circular disc surface and consists in particular of a metal core circuit board, epoxy resin circuit board or ceramic circuit board.

[0116] Figure 16 shows in a schematic view the beam path of the LED spotlight behind the optical interface 13 according to Fig. 13.

[0117] Figure 17 shows in a perspective view the frustroconical reflector 11 with the lateral surface 110, which is reflectively coated on the inside, and the open face surface 111, which is adjacent to the collimation optical unit 3, and the open top surface 112 receiving the mixing optical unit 4, which corresponds to the opening 104 of the annular flange 103 of the cartridge 10.

[0118] Figure 18 shows in a perspective view the frustroconical reflector 11 from the opposite viewing direction with the annular flange 103 of the cartridge 10, in the opening 104 of which, which corresponds to the open top surface 112 of the frustroconical reflector 11, the mixing optical unit 4 is inserted and is connected to the annular flange 103 with its mounting edge 41, which flange has a circumferential mounting edge 105 with holes, at which and at the holes of the LED circuit board 20 or the circular disc-shaped end side 102 of the cartridge 10, the cylinder lateral surface 101 of the cartridge 10 is fixed.

[0119] The annular flange 103 serves for receiving the control electronics 7 for the control and power supply of the LEDs arranged on the LED circuit board 20. The control electronics 7 is arranged on annular circuit board 71, which is connected according to Fig. 32 by studs 72 to the annular flange 103. The outer surface of the frustroconical reflector 11, the cylinder lateral surface 101 of the cartridge 10 and the inside of the annular flange 103 enclose a sufficiently large space for receiving the control electronics 7 and the heat emitted by the components of the control electronics 7.

[0120] The field optical unit 5 configured as a stepped lens is shown in Fig. 28 in a top view of the light exit side, in Fig. 29 in a section along the line A-A of Fig. 28 and in the Figs. 30 and 31 in a perspective section from the centre of the light entrance side and the edge of light exit side of the stepped lens. The stepped lens 5 comprises on the light entrance side facing the mixing optical unit 4 a structuring 51 and on the light exit side a Fresnel structure 52. As can be seen from the diagram according to Figs. 30 and 31, the structuring 51 of the stepped lens 5 consists of a honeycomb structure with spirally arranged, pentagonal optical elements, which are strongly structured according to Fig. 30 in the centre of the light exit side of the stepped lens 5, whilst they only form weak structures according to Fig. 31 at the edge of the light exit side of the stepped lens 5.

[0121] This specific structuring of the light entrance side of the stepped lens 5 removes colour effects, which are still present despite the light mixing properties of the mixing optical unit 4, so that the light mixed by the differently coloured LEDs is emitted homogenously to the far field. In case of a planar light entrance side of the stepped lens 5, the local light distribution on the light exit side of the condenser of the mixing optic 4 would be imaged in an angular distribution, whereas the colours emitted by the multi-coloured LEDs would not be absolutely homogenously distributed after the condenser due to its principle of action, so that colour effects would occur.

[0122] Figure 32 shows in a schematic view a longitudinal section through an LED spotlight with the components of the LED spotlight explained previously by reference to Figs. 12 to 31, namely

- the tube 1 of the spotlight housing,

- the light generating unit 9 with the cartridge 10 fixedly anchored in the tube 1 or arranged longitudinally displaceably in the direction of the double arrow A within the tube 1, wherein the following are arranged

- the active light source 2 with the LED circuit board 20 and the LEDs 21 to 26,
- the collimation optical unit 3,

- the frustroconical reflector 11, which is reflectively coated on the inside,

- the mixing optical unit 4 configured as a condenser and

- the control electronics 7

and

- the field optical unit 5 configured as a stepped lens, which is arranged movably along the double arrow B within the spotlight housing 1 in order to set the desired light distribution (flood, spot).

[0123] Figure 32 shows also the various adjusting or setting possibilities for the light distribution of the LED spotlight. The double arrow A indicates a longitudinal displacement of the cartridge 10 and thus the light generating unit 9 within the tube 1 of the spotlight, the double arrow B indicates a longitudinal adjustment of the field optical unit or stepped lens 5 within the tube 1, the double arrow C indicates a length determination of the tube 1 and the double arrow D indicates a diameter determination of the tube 1. In order to illustrate these adjusting and setting possibilities, examples for the light distribution with corresponding adjustment of individual components of the LED spotlight for spot and flood settings of the LED spotlight are illustrated in Figs 33 to 36.

[0124] Figure 33 shows the light distribution with the edge beams M1 and M2 between the mixing optical unit 4 and the field optical unit 5 as well as the emission of the field optical unit 5 into the far field with the edge beams F3 and F4 in a spot setting for which the field optical unit 5 has been brought into an anterior position within the tube 1. The schematic diagram of Fig. 33 shows that when adjusting the field optical unit 5 within the tube 1 with the length L_1, an undisturbed beam path is provided in the spot setting.

[0125] In the flood setting of the spotlight illustrated in Fig. 34, in which the field optical unit 5 is moved within the tube 1 with the length L_1 close to the mixing optical unit 4, the beam path is disturbed since in case of an unchanged length L_1 of the tube 1 the outer light beams F1 and F2 emitted by the field optical unit 5 impinge upon the tube 1 so that the light distribution is cut off and does not have a full runout.

[0126] By shortening the tube 1 according to Fig. 35 to the length L_2 or alternatively by enlarging the diameter D of the tube 1, an undisturbed beam path with the edge beams F1 and F2 is again ensured in the flood setting of the LED spotlight, in which the field optical unit 5 is arranged close to the mixing optical unit 4.

[0127] Alternatively according to Fig. 36, by displacing the cartridge 10 within the tube 1, the length L_1 of which is unchanged compared to the exemplary embodiments of Figs. 32 to 34, the light generating unit 9 can achieve a flood setting with an undisturbed beam path of the edge beams F1 and F2 without changing the length or diameter of tube 1.

[0128] Figure 37 shows in an isometric view an LED spotlight with a spotlight housing 8 with two parallel side surfaces 81, a partially cylindrical upper side 83 and a partially cylindrical lower side 82. A cylindrical tube 1 is arranged within the spotlight housing 8, which projects in the light emission direction of the LED spotlight as light exit body from the front side 84 of the spotlight housing 8.

[0129] Pivot joints 15 are mounted on the side surfaces 81 of the spotlight housing 8, which are connected to the arms of a retaining bracket 14 for suspension of the LED spotlight. The pivot joints 15 can alternatively be connected to a tripod in the case of a standing arrangement of the LED spotlight. Receptacles 19 for spotlight accessories such as lens plates which are displaceable with respect to one other, a barn door, a grid, a diffusor, scrims, gobos, holographic scattering sheets or the like are arranged on the outer surface of the tube 1, distributed along the circumference, whilst a field lens 5 is inserted into the tube 1.

[0130] A cylindrical cartridge 10 containing the light generating unit 9 and a light shaping device in form of a field lens 5 are arranged in the tube 1, which are movable relative to one another, i.e., in case of a stationary field lens 5, the cartridge 10 is movable in the longitudinal direction of tube 1 or in case of a stationary cartridge 10, the field lens 5 is arranged movably in the longitudinal direction in tube 1. A hemispherical body 12 with a plurality of cooling ribs arranged in a distributed manner adjoins the rear side of the cartridge 10 of the light generating unit 9, which forms a thermal interface and faces away from the light emitting direction of the LED spotlight.

[0131] In one embodiment, the spotlight housing 8, the field lens 5 and the receptacles 19 for the spotlight accessories form a stationary unit, whilst the cartridge 10 with the light generating unit 9 can be adjusted to vary the emission angle of the LED spotlight within the tube 1 along the optical axis HA between a flood position for emitting the light with a large scattering angle and hard shadow formation, in which the light generating unit 9 is located close to the light exit opening of the LED spotlight with the field lens 5, and a spot position for emitting light with a small scattering angle and soft shadow formation in a position remote from the light exit opening, i.e. the field lens 5.

[0132] Figure 38 shows in a side view the LED spotlight according to Fig. 1 in the flood position of the light generating unit 9, in which the cartridge 10 of the light generating unit 3 is almost completely inserted in the tube 1.

[0133] Figure. 39 shows the light generating unit 9 in a spot position, in which the cartridge 10 of the light generating unit 9 is almost completely withdrawn from the tube 1 such that the light generating unit 9 is located in a position remote from the light exit opening of the LED spotlight and thus of the field lens 5.

REFERENCE LIST

[0134]

1	Tube
2	Active light source (light engine)
3	Collimation optical unit
4	Mixing optical unit (condenser)
5	Field optical unit (stepped lens)
6	Optical elements
7	Control electronics
8	Spotlight housing
9	Light generating unit
10	Cartridge
11	Frustroconical reflector
12	Thermal interface (cooling body)
13	Optical interface
14	Retaining bracket
15	Pivot joint
16	Spacer
18	Control and power supply cable
19	Receptacle for spotlight equipment
20	Planar surface (circuit board)
21-26	LEDs
27	Thermal sensor (NTC resistor)
30	Stepped lens structure (Fresnel structure)
31-36	Collimation optical unit
37	Conical total reflection lenses
40	Optical area

41 Mounting edge
51 Light entrance side of the stepped lens (spiral honeycomb structure)
52 Light exit side of the stepped lens (Fresnel structure)
53, 53′ Pentagonal optical elements
60 Diffusor disc or diffusor body
61 Completely translucent diffusor
62 Reflectively coated cone
70 Power supply or control cable
71 Electronic interface
72 Control electronic board
73 Studs
81 Side surfaces of the spotlight housing
82 Partially cylindrical lower side of the spotlight housing
83 Partially cylindrical upper side of the spotlight housing
84 Front side of the spotlight housing
91 Planar mirror
92 Concavely curved mirror
93 Convexly curved mirror
94 Combined reflector
101 Cylinder lateral surface
102 Circular disc-shaped end side
103 Annular flange
104 Opening
105 Mounting edge
106 Sealed opening
110 Lateral surface
111 Face surface
112 To surface
113 Reflector section reflectively coated on the inside
181 Light source interface
182 Control electronics interface
200 Curved surface
A Emission direction

E Light beams on the entrance side of the mixing optical unit

F1-F4 Edge light beams on the exit side of the field optical unit

HA Principal optical axis

L1-L4 LED light beams

M1, M2 Edge light beams on the exit side of the mixing optical unit

N1, N2 Edge light beams on the exit side of the optical elements

Patentkrav

1. LED-lygte, især LED-projektør, med en aktiv lyskilde (2) med flere ens- eller forskelligfarvede LED'er (21 til 26), som er anbragt på en plan eller krum flade eller LED-platin (20, 200), og et optisk system med

- en kollimationsoptik (3), hvis enkelte linser er anbragt i lille afstand over LED'ernes udstrålingsflader og samler, koncentrerer og dirigerer på en flade det fra LED'erne (21 til 26) udstrålede lys (L1 til L4),
- en blandeoptik som optager det af kollimationsoptikken (3) på en flade dirigerede og koncentrerede lys (K1, K2, E) og blander det med hensyn til farve og/eller lysstyrke, og
- en feltoptik (5), som optager det fra blandeoptikken (4) udstrålede lys (M1, M2 henholdsvis N1, N2) og udstråler det med en på forhånd givet lysfordeling (F1 - F4) i fjernfeltet,

kendetegnet ved,
at kollimationsoptikken (3) på sin lysindgangsside har kegleformede totalrefleksionslinser (37), som hver er anbragt direkte foran en LED (21 - 26) og tilpasset disse, og på sin lysudgangsside har en trappelinsestruktur (30) af typen en Fresnellinse og omdirigerer de fra LED'erne (21 - 26) udgående lysstråler (L1 - L4) på en sådan måde, at de i det væsentlige fuldstændigt udfylder blandeoptikkens (4) lysindgangsflade med lys.

2. LED-lygte, især LED-projektør, med en aktiv lyskilde (2) med flere ens- eller forskelligfarvede LED'er (21 til 26), som er anbragt på en plan eller krum flade eller LED-platin (20, 200), og et optisk system med

- en kollimationsoptik (3), som er anbragt i en lille afstand over LED'ernes udstrålingsflader og samler, koncentrerer og dirigerer på en flade den fra LED'erne (21 til 26) udstrålede lys (L1 til L4),

- en blandeoptik som optager det af kollimationsoptikken (3) på en flade dirigerede og koncentrerede lys (K1, K2, E) og blander det med hensyn til farve og/eller lysstyrke, og

- en feltoptik (5), som optager det fra blandeoptikken (4) udstrålede lys (M1, M2 henholdsvis N1, N2) og udstråler det med en på forhånd givet lysfordeling (F1 - F4) i fjernfeltet,

kendetegnet ved,

at kollimationsoptikken (3) består af diskrete optiske elementer (31 - 35), som koncentrerer det lys (L1 - L4), som udstråles i samme udstrålingsretning fra de LED'er (21 - 26), som er anbragt på en plan flade (20), på en fjern flade, hvorved LED'erne (21 - 24) er anbragt med de optiske elementer (31 - 35) på en platin (20), som befinder sig i blandeoptikkens (4) plan og i et centralt område optager eller omgiver blandeoptikken (4), og at de lysstråler (K1, K2), som afgives af de optiske elementer (31 - 35), rettes imod en reflektor (91, 92), som kaster lysstrålerne (K1, K2) tilbage på blandeoptikken (4), som afgiver det blandede lys (M1, M2) modsat LED'ernes (21 - 24) udstrålingsretning.

3. LED-lygte ifølge krav 2, **kendetegnet ved,** at reflektoren består af et i afstand fra platinerne (20) anbragt, konkavt krummet eller kegleformet eller fortrinsvis facetteret spejl (92).

4. LED-lygte ifølge krav 2 eller 3, **kendetegnet ved** vinkelafledende og retlinet udstrålende kollimationselementer (31 - 34), hvis lysstråler er rettet imod en reflektor (93, 94) med en plan eller krum spejlflade, som tilbagespejler lysstrålerne til blandeoptikken (4).

5. LED-lygte ifølge i det mindste et af kravene 2 til 4, **kendetegnet ved** en konveks krummet eller kegleformet, fortrinsvis facetteret reflektor (93, 94) og LED'er (21 - 26) og kollimationsoptikker (31 - 36), som er anbragt i en ring, flere ringe eller en polygonal yderkappe omkring LED-lygtens optiske hovedakse (HA).

6. LED-lygte ifølge i det mindste et af kravene 2 til 5, **kendetegnet ved** LED'er (21 - 26) og kollimationselementer (31 - 36), som er anbragt i en ring, flere ringe eller en polygonal yderkappe omkring LED-lygtens optiske hovedakse (HA) samt befinder sig i mikrooptikkens plan og optager eller omgiver blandeoptikken (4) i et centralt område, og en plan reflektor ved anvendelse af afbøjende kollimationselementer (31 - 36) og en konktav reflektor (94) ved lige udstrålende kollimationselementer (31 - 36).

7. LED-lygte ifølge krav 1 eller 2, **kendetegnet ved,** at kollimationsoptikken (3) er tildannet som optik-plade, hvori der er indarbejdet optiske flader med forskellig udstrålingsretning.

8. LED-lygte ifølge i det mindste et af de foregående krav, **kendetegnet ved,** at blandeoptikken (4) udstråler det fra forskellige retninger optrædende lys med omtrent samme vinkel og omfatter mindst et optisk element, som blander det lys (K1, K2; E), som udstråles i udstrålingsretningen (A) fra kollimationsoptikken (3) og således virker på lysudgangssiden som sekundære lyskilder.

9. LED-lygte ifølge krav 8, **kendetegnet ved,** at blandeoptikken (4) består af en som skive eller legeme tildannet diffusor (60, 61) med på forhånd opgivelig spredningsgrad eller af en translucent glasskive især af en diffus plastskive eller diffus halvkugle af plast.

10. LED-lygte ifølge krav 8, **kendetegnet ved,** at blandeoptikken (4) på lysindgangssiden og/eller lysudgangssiden har en struktur, som består af bikager, prismer eller mikrolinser eller af en lysblandestang eller taper.

11. LED-lygte ifølge i det mindste et af de foregående krav, **kendetegnet ved,** at der imellem de aktive lyskilder (2) og blandeoptikken (4) er anbragt optiske elementer (6), der er tildannet som linser, linsesystemer og/eller reflektorer, og som omdirigerer eller omformer lyset på en sådan måde, at det afgives på på forhånd opgivelig måde til blandeoptikken (4).

12. LED-lygte ifølge i det mindste et af de foregående krav, **kendetegnet ved,** at feltoptikken (5) består af

- en samlelinse, især af en konvekslinse, en plan-konvekslinse eller en asfærisk samlelinse, hvis indgangs- og udgangssider fortrinsvis har en struktur, især en bikage-, prisme- eller mikrolinsestruktur, eller
- en trappelinse, især af en trappelinse med indarbejdet spredestruktur (NOFS-linse) eller
- et fortrinsvis som zoom- eller projektionsoptik tildannet linsesystem med overvejende afbildende egenskaber, som afbilder mikrooptikkens (4) udgangsflade eller et foran denne liggende plan nøjagtig i et langt fjernt beliggende plan.

13. LED-lygte ifølge krav 12, **kendetegnet ved,** at feltlinsen henholdsvis feltoptikken på lysindgangssiden har en stråle-udvidelsesstruktur og på lysudgangssiden en fokuserende struktur, især en Fresnel-struktur.

14. LED-lygte ifølge i det mindste et af de foregående krav, **kendetegnet ved,** at der imellem blandeoptikken (4) og feltoptikken (5) er anbragt optiske elementer (6), der er tildannet som linser, linsesystemer og/eller reflektorer, og som omdirigerer eller omformer lyset på en sådan måde, at der i fjernfeltet opstår i en forhånd given lysfordeling.

15. LED-lygte ifølge i det mindste et af de foregående krav, **kendetegnet ved** en keglestubformet reflektor (11), hvis kappeflade (110) er indvendigt spejlende, hvis åbne grundflade (111) støder op til kollimationsoptikken (3), og hvis åbne dækflade optager blandeoptikken (4) eller grænser op til denne.

16. LED-lygte ifølge i det mindste et af de foregående krav, **kendetegnet ved,** at LED-platinen (20) omfatter et antal LED'er (21 - 26) og flere fordelt anbragte termofølere (27), som registrerer temperaturen på LED-platinen (20) i forskellige temperaturzoner.

17. LED-lygte ifølge i det mindste et af de foregående krav, **kendetegnet ved** en i det fra LED'erne (21 - 26) afgivne lys' strålegang anbragt optisk sensor, især en fotodiode, en farvesensor eller et minispektrometer, hvis udgangssignal afgives på på forhånd givet måde som indgangssignal til styreelektronikken (7) til reguleringen af det fra LED'erne (21 - 26) udstrålede lys' lysstyrke og/eller farve.

18. LED-lygte ifølge krav 16 eller 17, **kendetegnet ved,** at der i LED-lygtens lysudstrålingsretning foran blandeoptikken (4) er anbragt en trappelinse (5), som er indstillelig langs LED-lygtens optiske akse (HA), og som optager det fra blandeoptikken (4) udstrålede lys og udstråler med ved hjælp af trappelinsens (5) afstand fra blandeoptikken (4) indstillelig lysfordeling (Flood, Spot) i et fjernfelt.

19. LED-lygte ifølge krav 18, **kendetegnet ved,** at trappelinsen (5) er indstillelig i tubusen (1) i retning af LED-lygtens optiske akse (HA).

20. LED-lygte ifølge i det mindste et af de foregående krav 16 til 19, **kendetegnet ved,** at blandeoptikken (4) er anbragt i en ringflanges (103) åbning (104), hvis udvendige diameter er den samme som LED-platinens (20) udvendige diameter og/eller er en med LED-platinen (20) forbundet cirkelskiveformet plade (101), at ringflangen (103) på den ene side og LED-platinen (20) eller den cirkelskiveformede plade (101) på den anden side danner frontsiden af en hulcylinderformet kartouche (10), hvis cylinderkappe (101) er forbundet med ringflangen (103) og LED-platinen (20) og/eller den cirkelskiveformede plade (101), at kartuschen (10) og trappelinsen (5) er anbragt i lygte- eller projektørhusets tubus (1), og at

- trappelinsen (5) og tubussen (1) er indstillelig i retning af LED-lygtens optiske akse (HA), eller
- trappelinsen (5) og tubussen (1) er indstillelig i retning af LED-lygtens optiske akse (HA) i forhold til kartussen (10), eller
- trappelinsen (5) er forbundet med tubussen (1), og kartuschen (10) er indstillelig langs LED-lygtens optiske akse (HA) i forhold til tubussen (1).

21. LED-lygte ifølge i det mindste et af de foregående krav, **kendetegnet ved,** at mindst en del af det lys, som afgives af LED'erne, afbøjes ved hjælp af et farvefilter, således at det fra projektøren udstrålede lys' spektrum ændres på en på forhånd givet måde, hvorved kombinationen af LED'ernes spektrale udstrålingskarakteristik og farvefilterets spektrale transmission, især en farvefilm, optimerer det af projektøren udstrålede lys med hensyn til farve på en sådan måde, at der hermed opnås et ønsket farvested og/eller en ønsket farvegengivelse ved maksimal lysstyrke.

22. LED-lygte ifølge i det mindste et af de foregående krav, **kendetegnet ved,** at den aktive lyskilde (2) har flere LED'er (21 - 26), som er anbragt på indersiden af en krum flade (200), som består af en hul del- eller halvkugle, en hulparabel eller en atmosfærisk hulflade, og som udstråler lys til krumningsmidtpunktet eller brændpunktet for den krumme flade (200), og at der er tilvejebragt samme kollimationsoptik (3) til flere af eller samtlige den aktive lyskildes (2) LED'er (21 - 26).

FIG 1

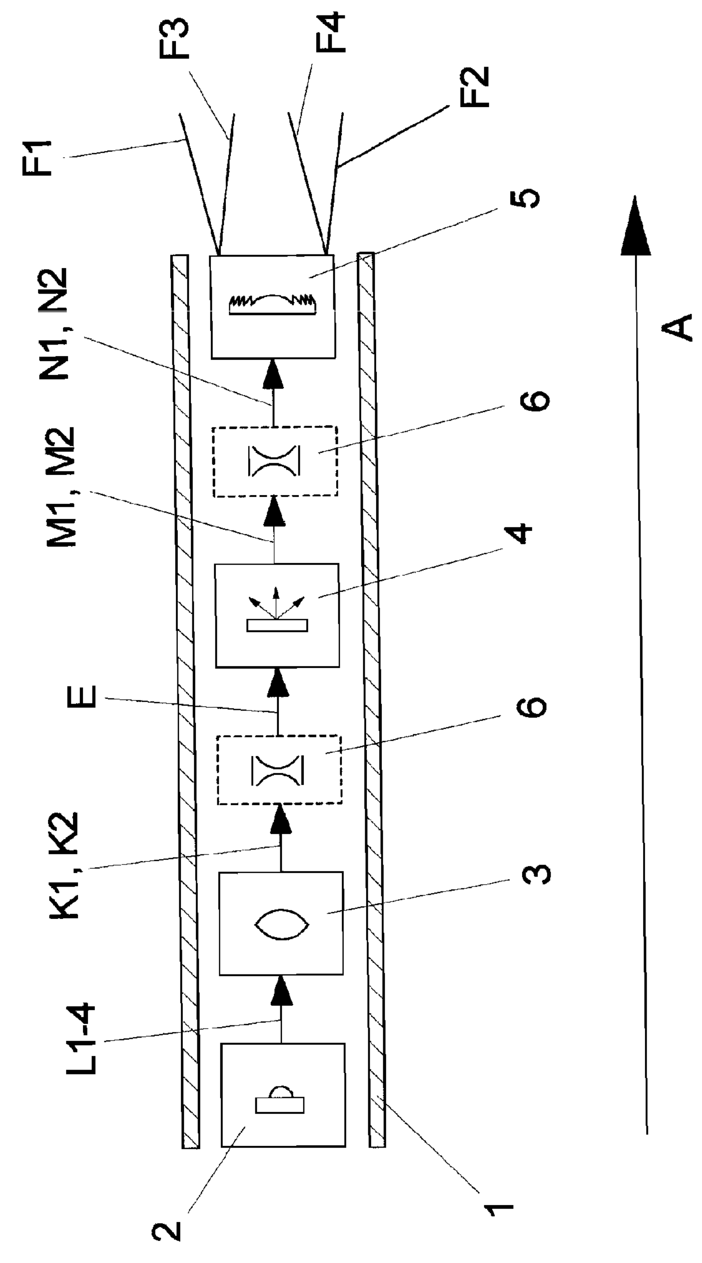


FIG 3

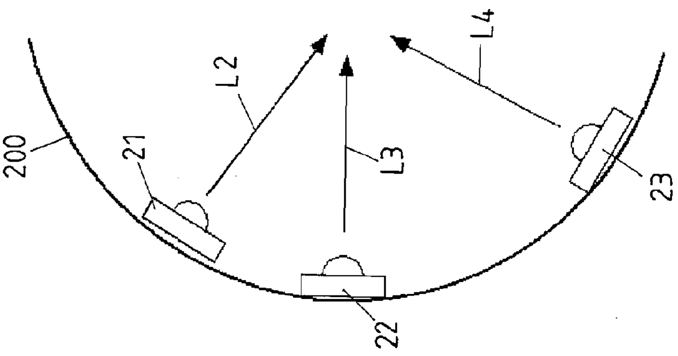


FIG 2

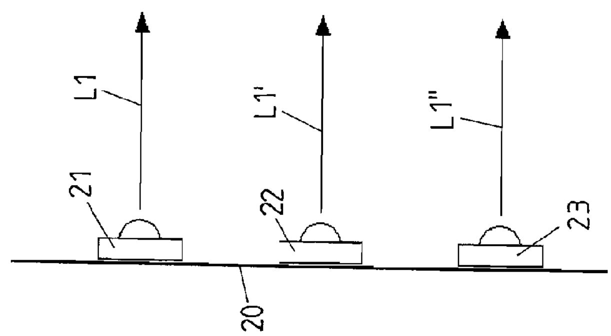


FIG 5

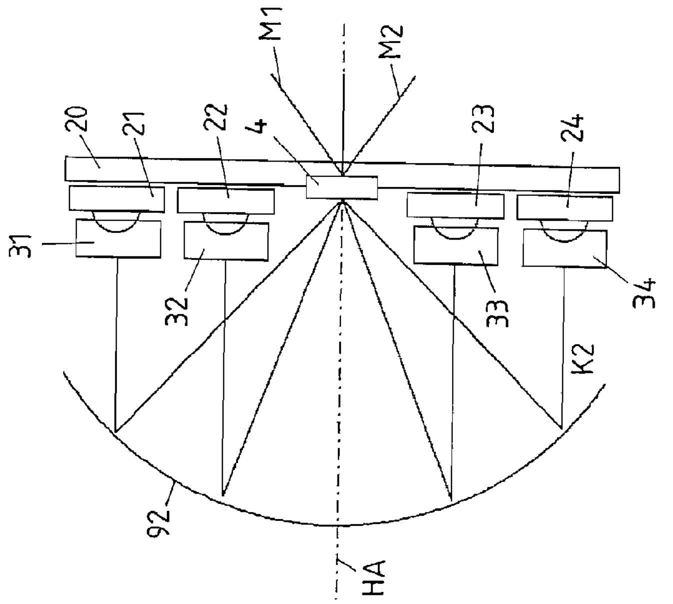

M1
M2
20
21
22
4
23
24
31
32
33
34
K2
92
HA

FIG 4

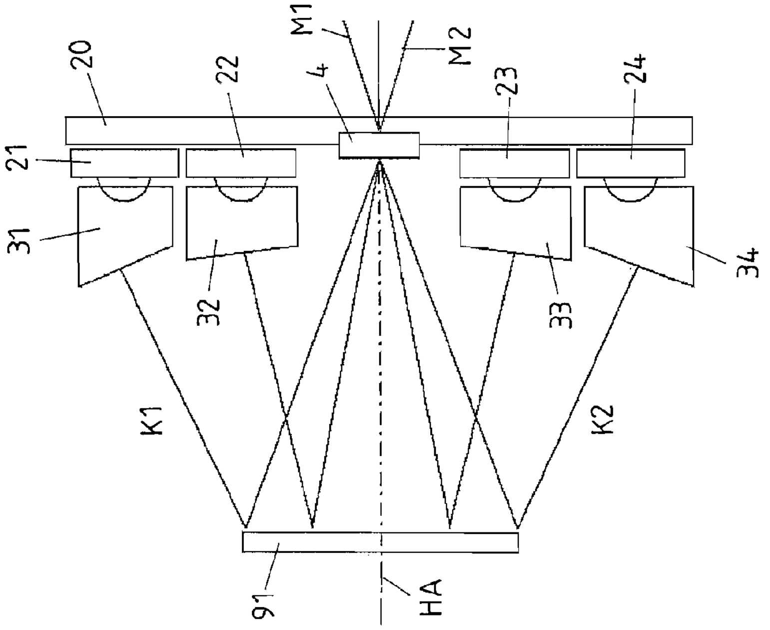

M1
M2
20
22
4
23
24
21
31
32
33
34
K1
K2
91
HA

FIG 7

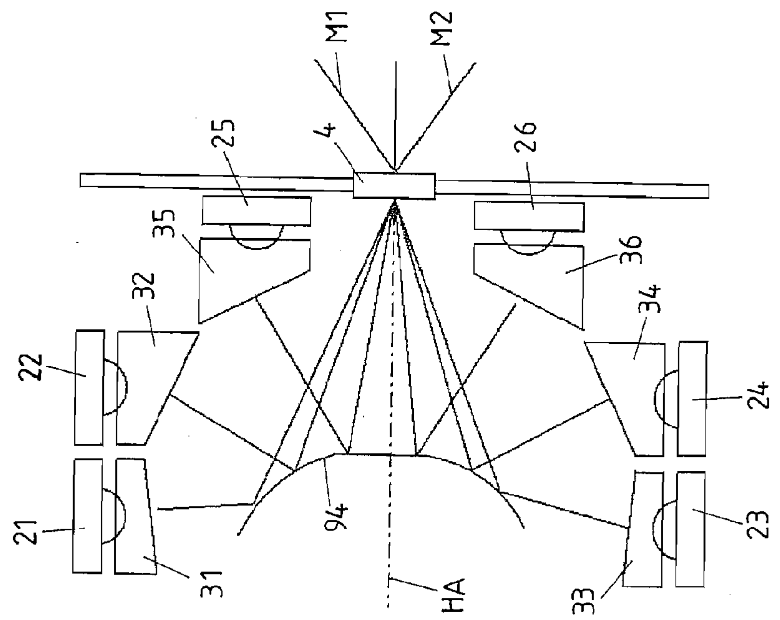

M1
M2
4
25
26
35
36
32
34
22
24
21
23
31
33
94
HA

FIG 6

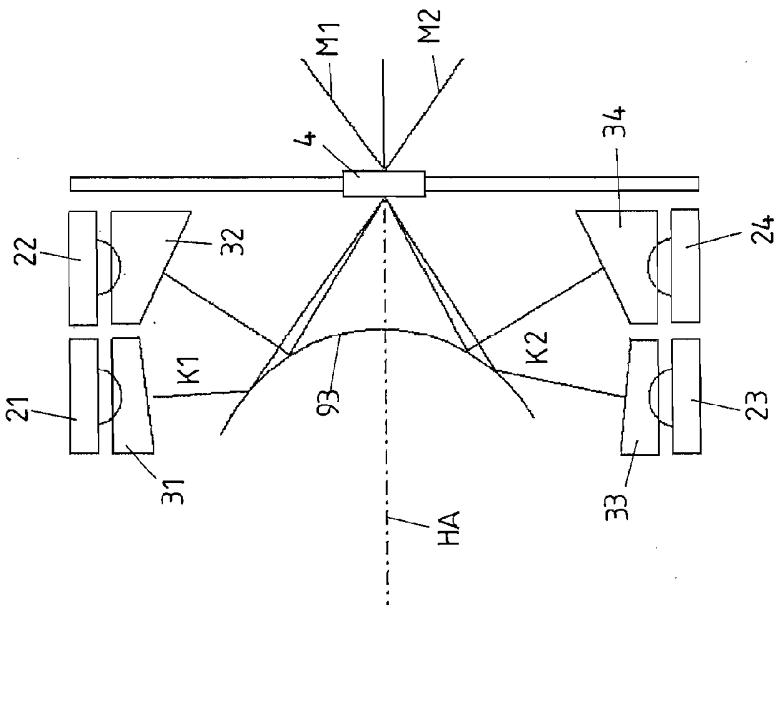

M1
M2
4
34
22
32
24
21
23
K1
K2
93
31
33
HA

FIG 9

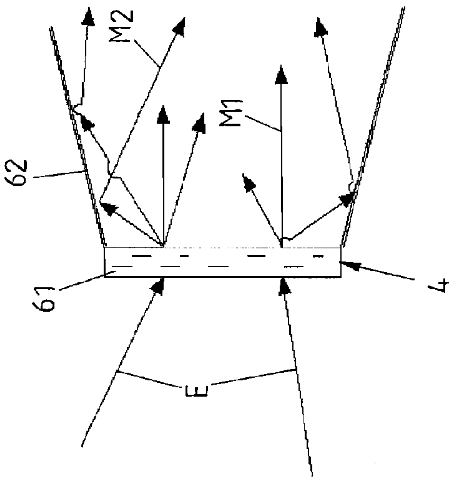


FIG 8

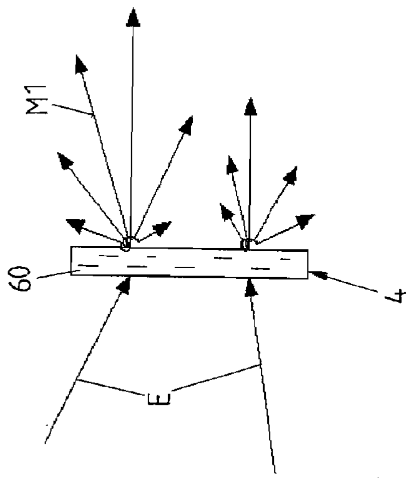


FIG 10

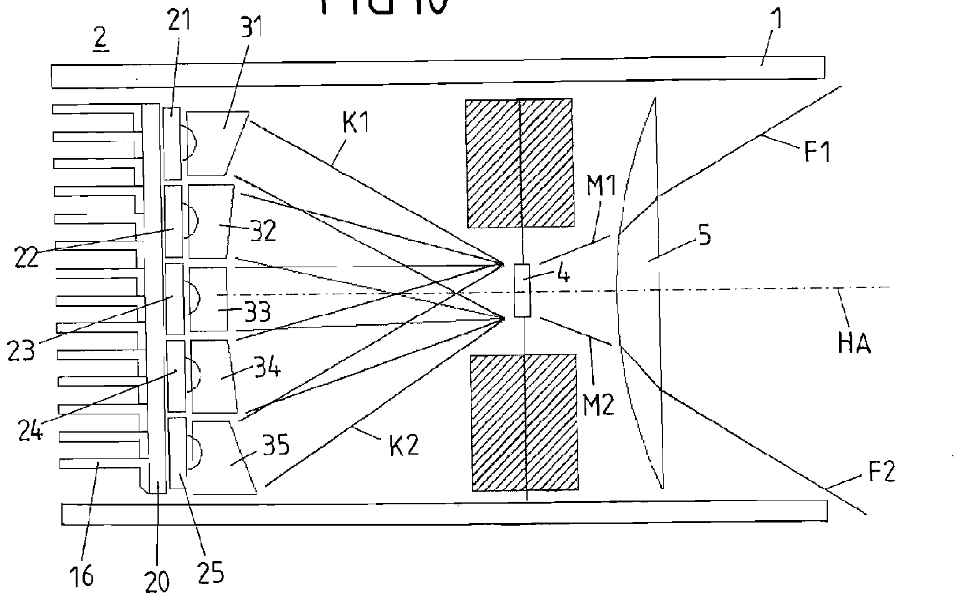

2
21
31
1
K1
F1
M1
5
22
32
4
33
23
HA
34
M2
24
35
K2
F2
16
20
25

FIG 11

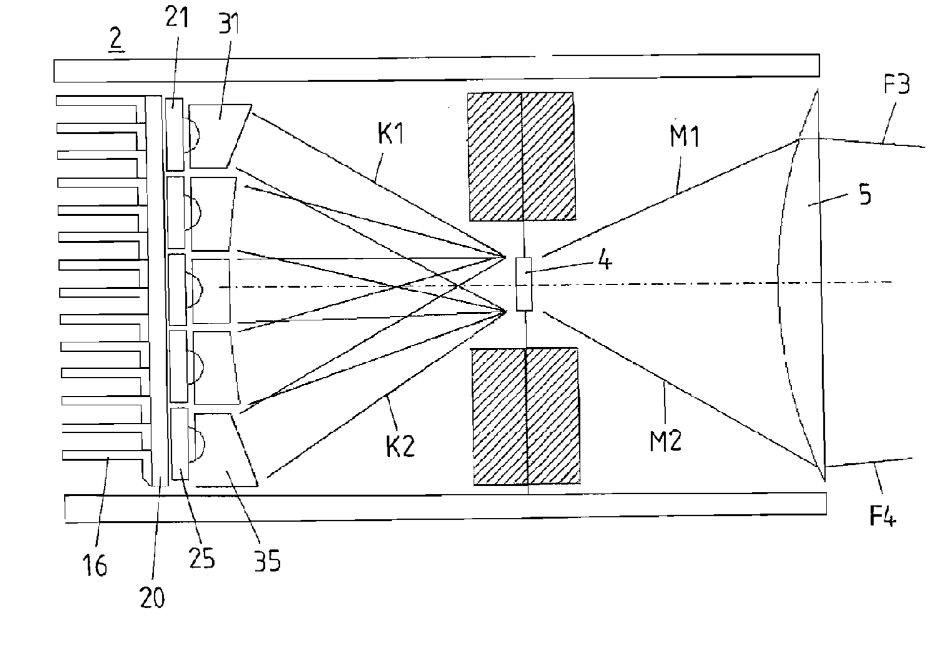

2
21
31
F3
K1
M1
5
4
K2
M2
F4
16
25
35
20

FIG 12

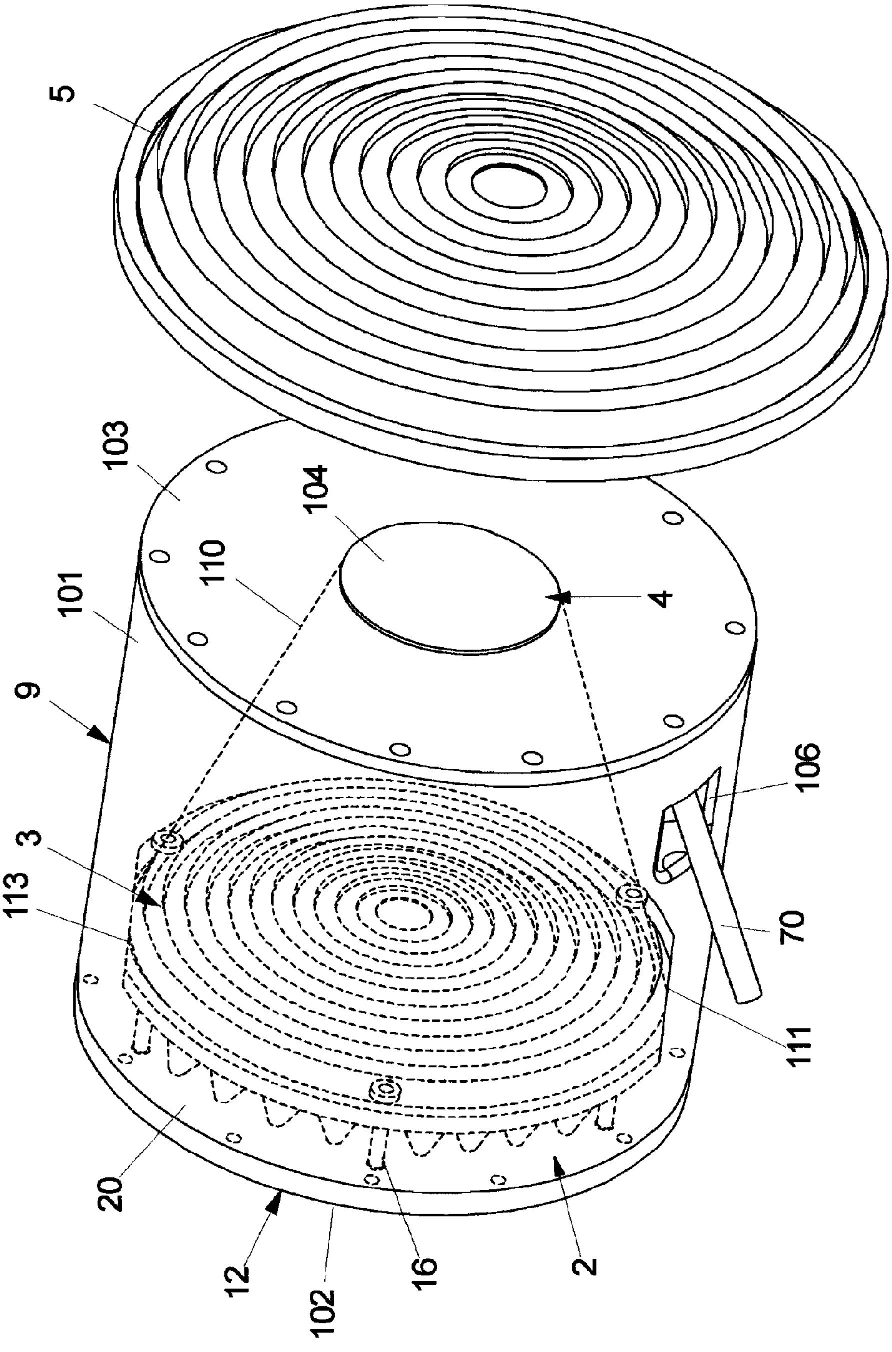


FIG 13

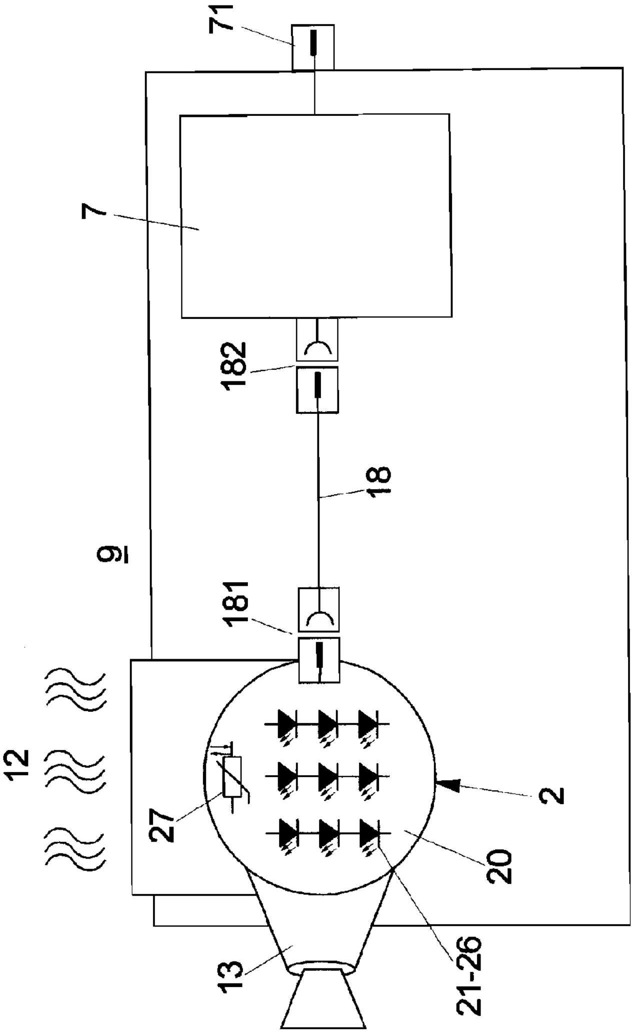


FIG 14

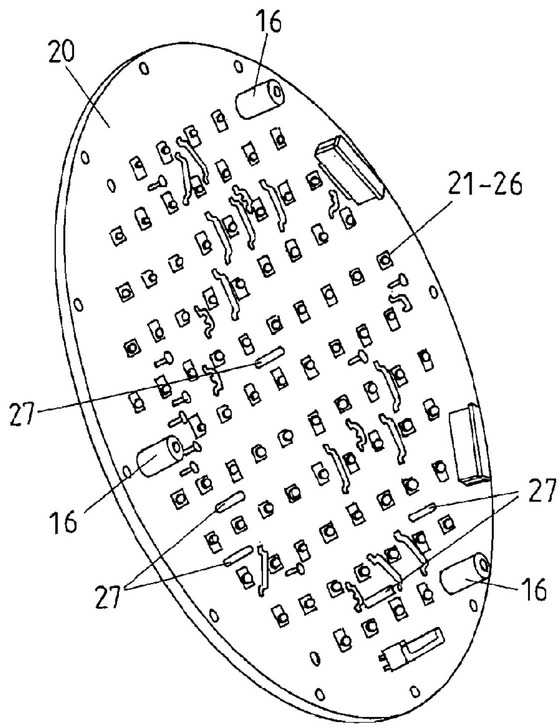


FIG 15

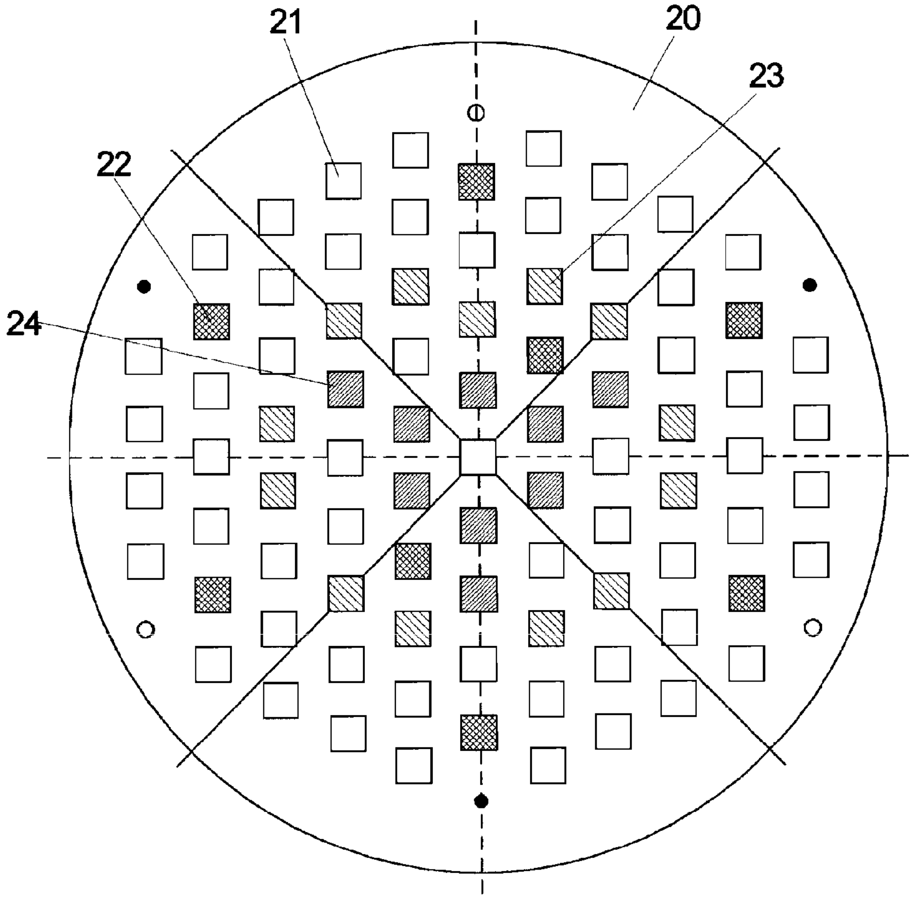
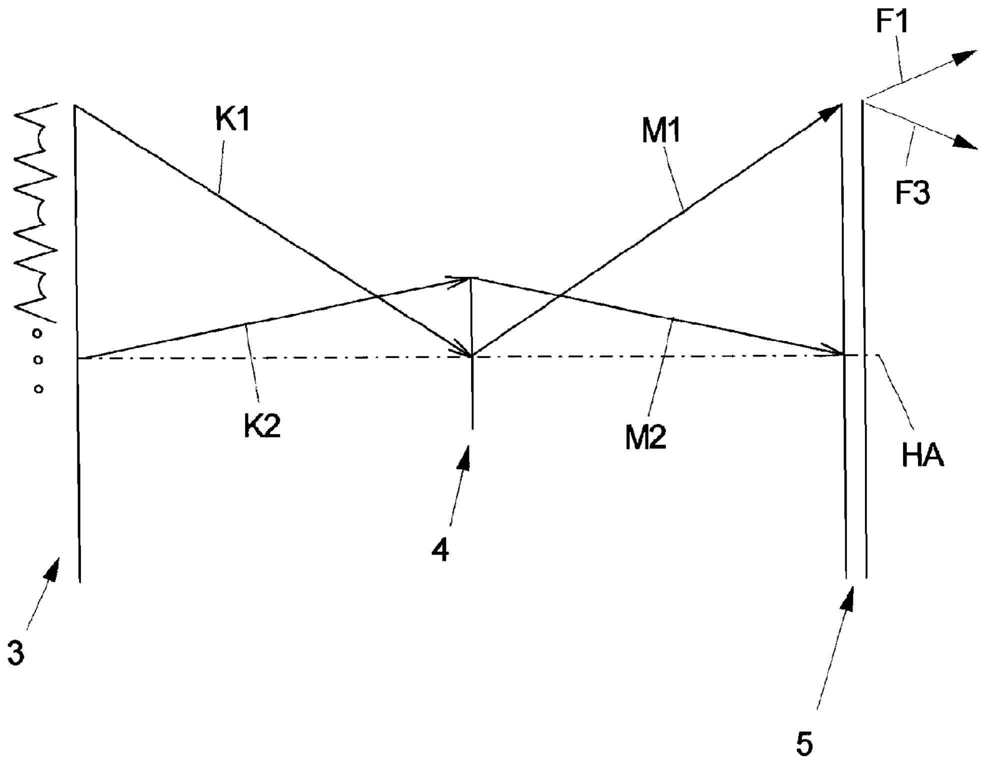


FIG 16



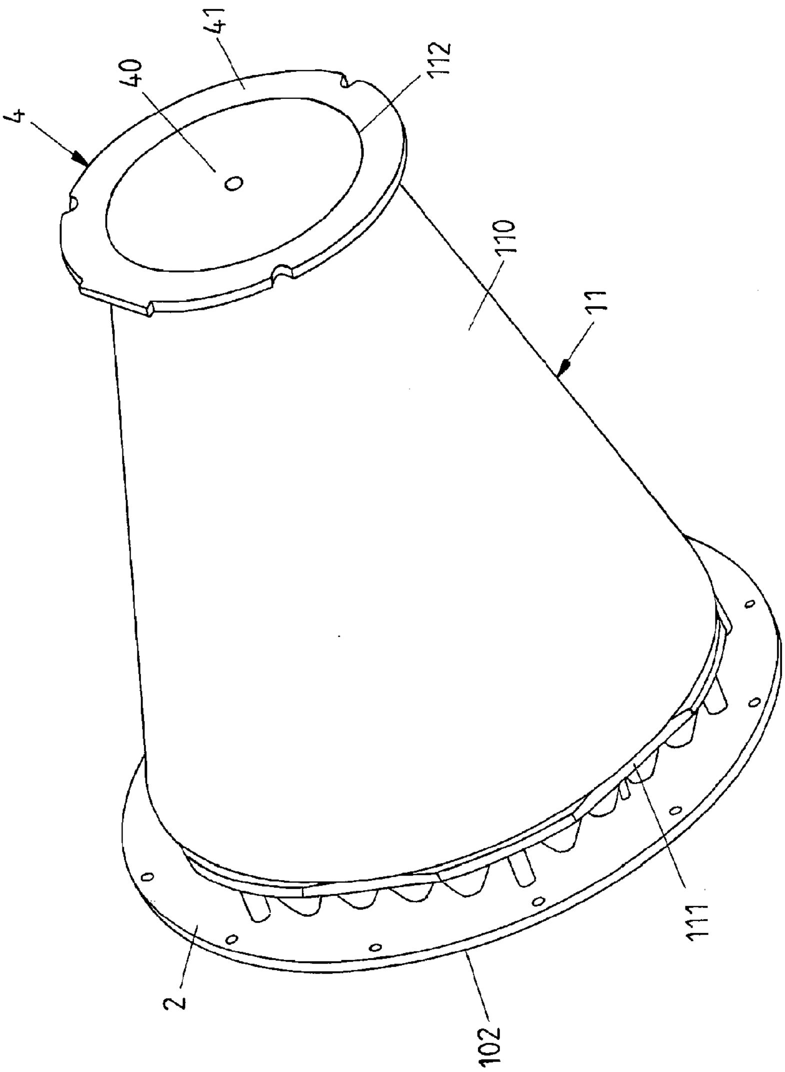


FIG 17

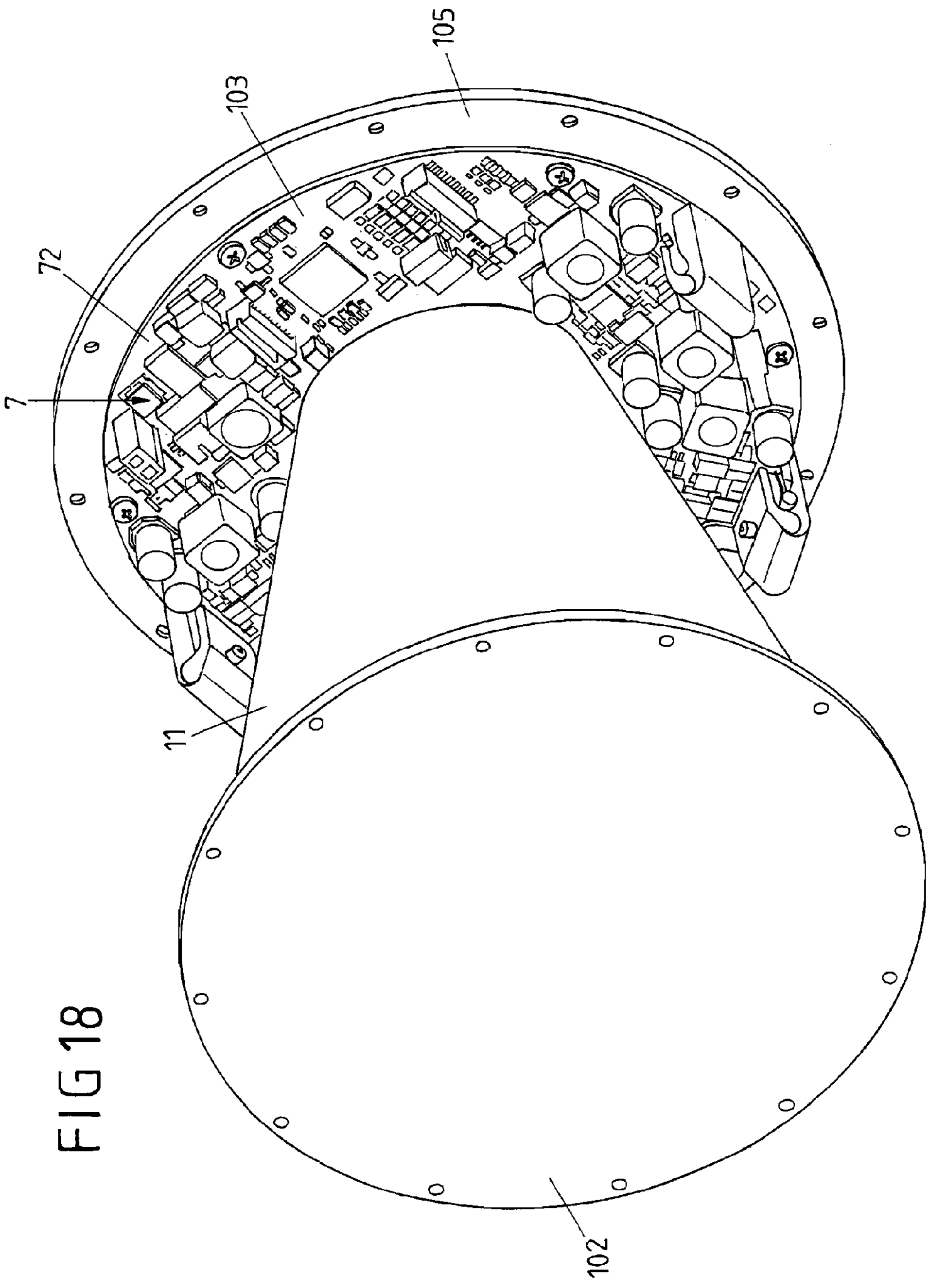


FIG 18

FIG 21

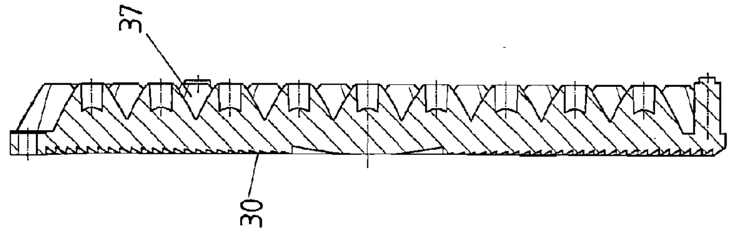


FIG 20

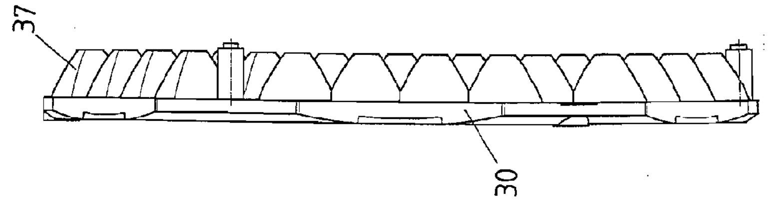


FIG 19

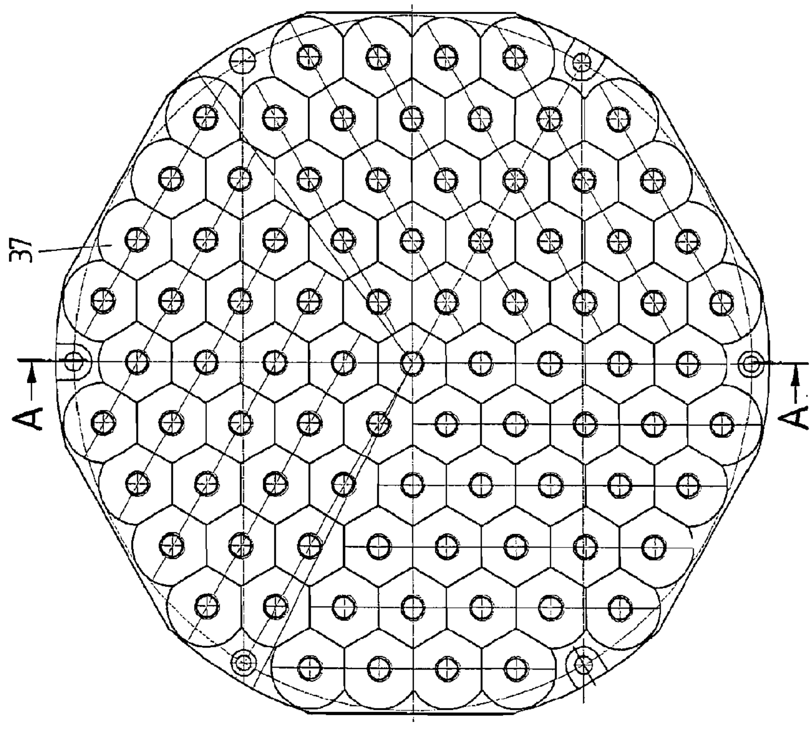


FIG 22

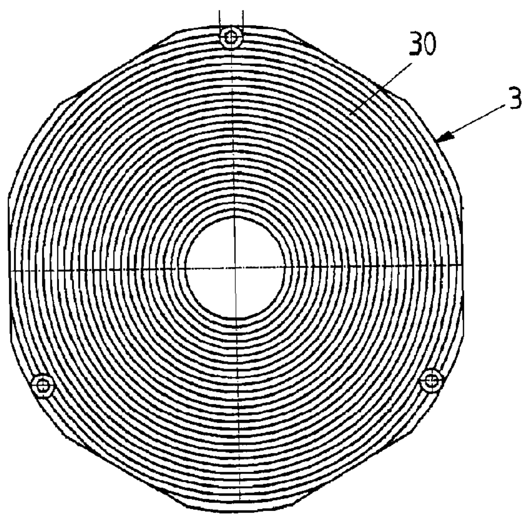
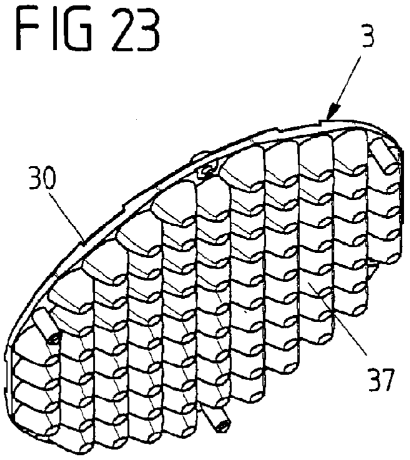


FIG 23



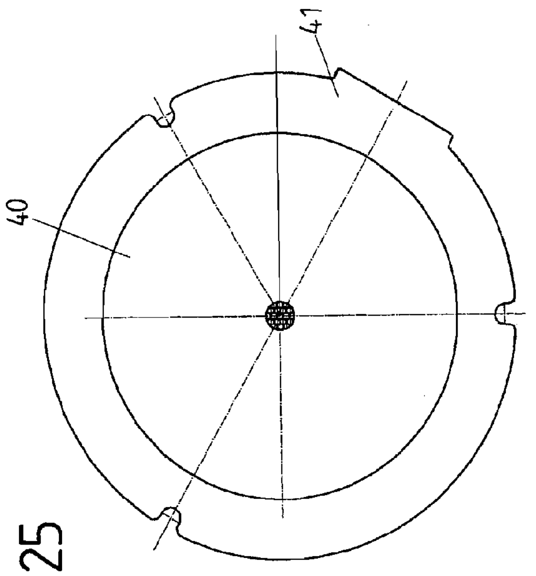


FIG 25

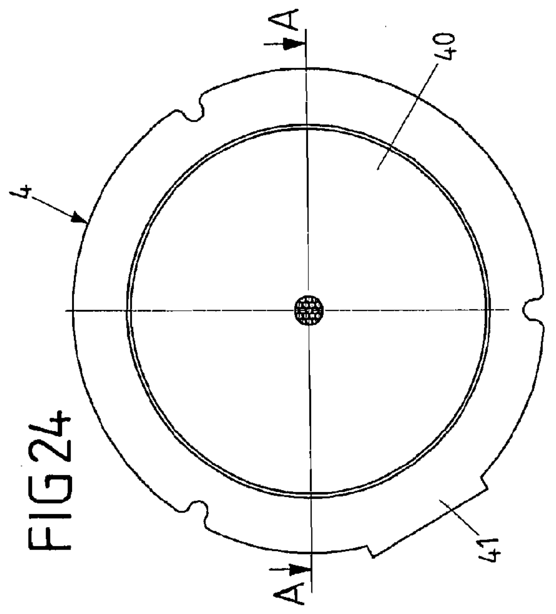


FIG 24

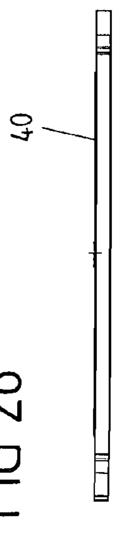


FIG 26

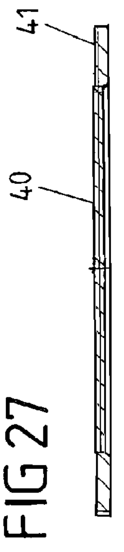


FIG 27

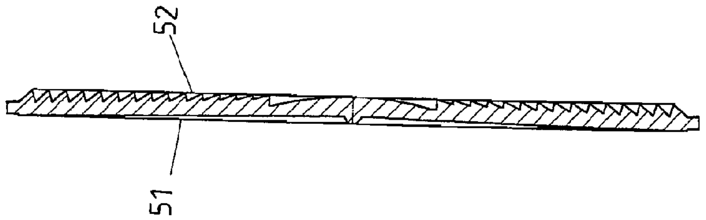


FIG 29

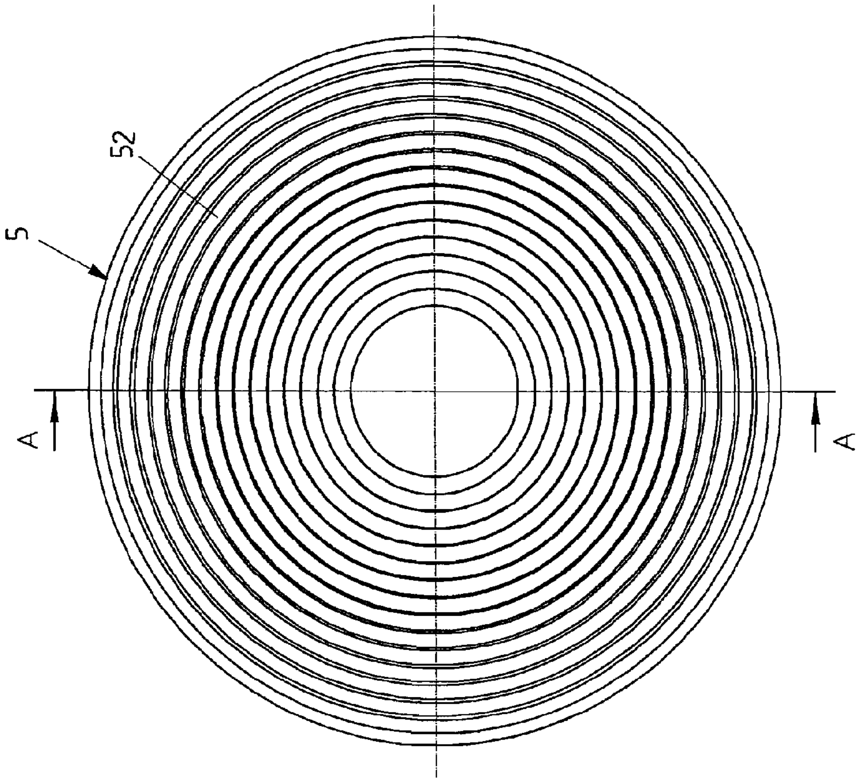


FIG 28

FIG 31

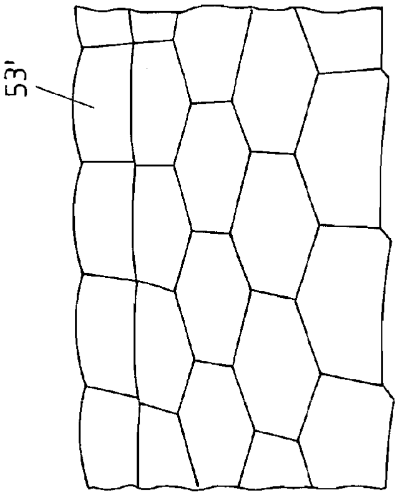
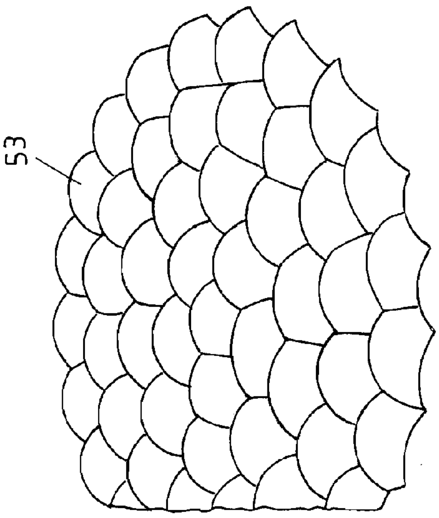


FIG 30



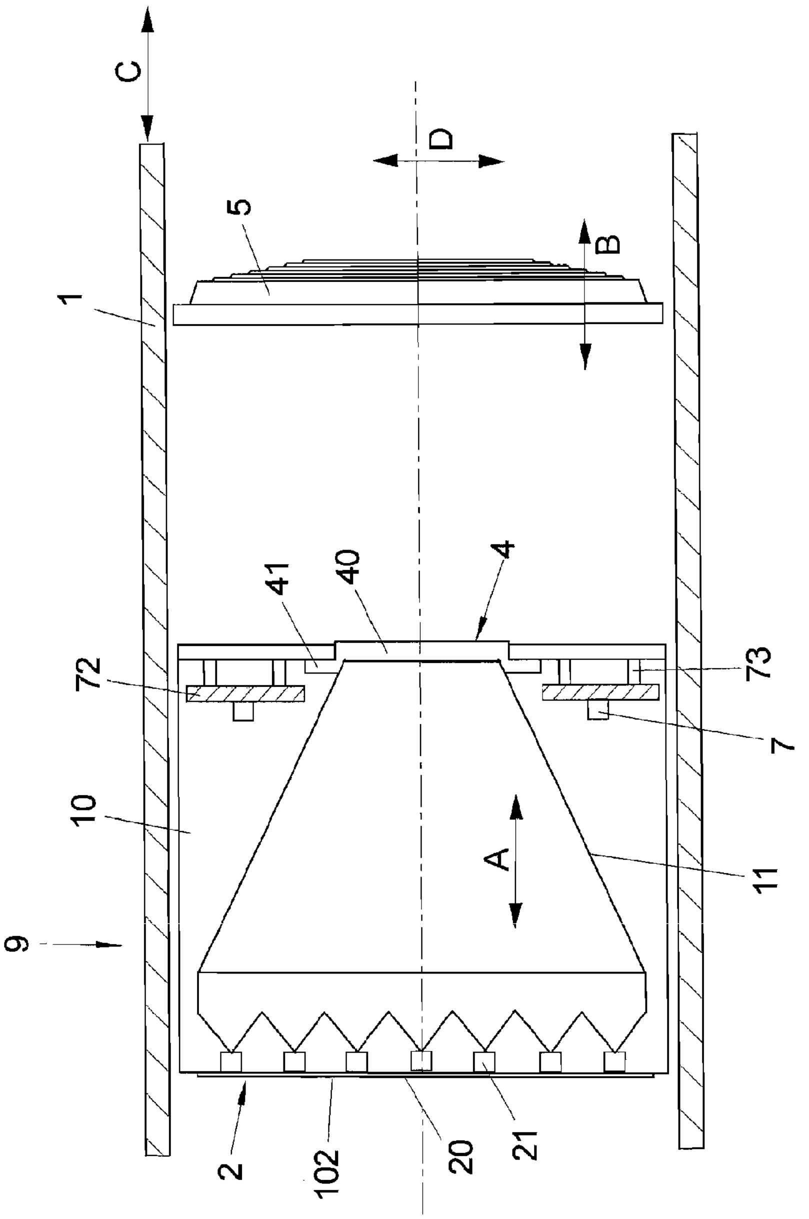


FIG 32

FIG 33

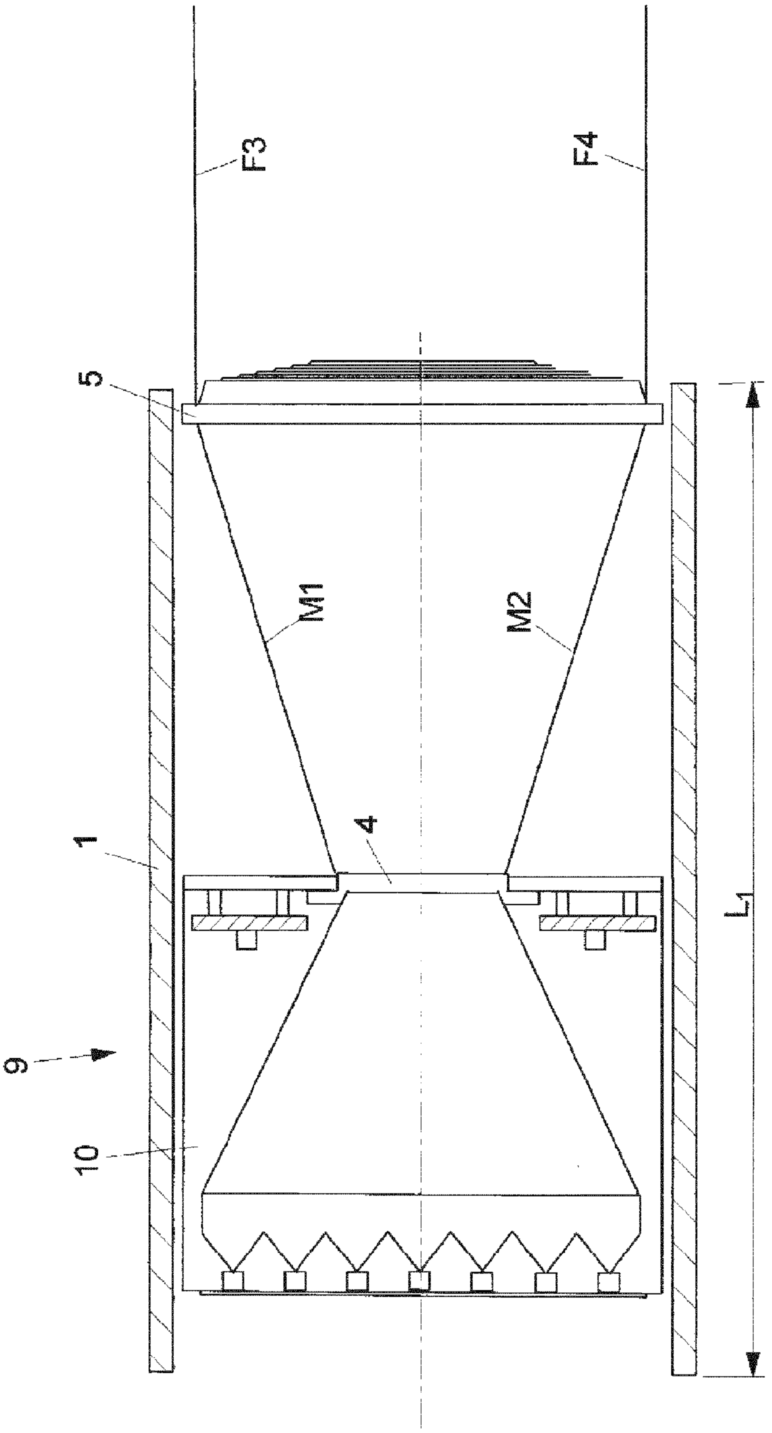
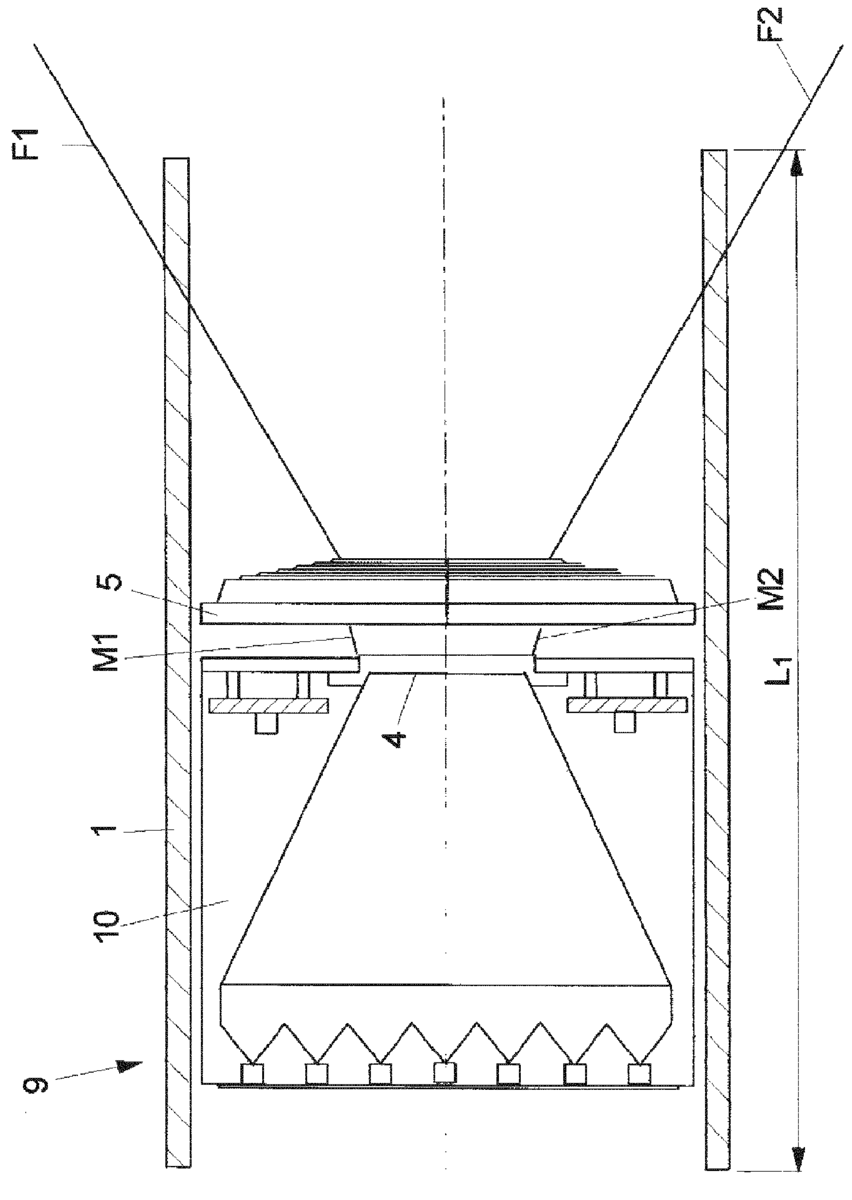


FIG 34



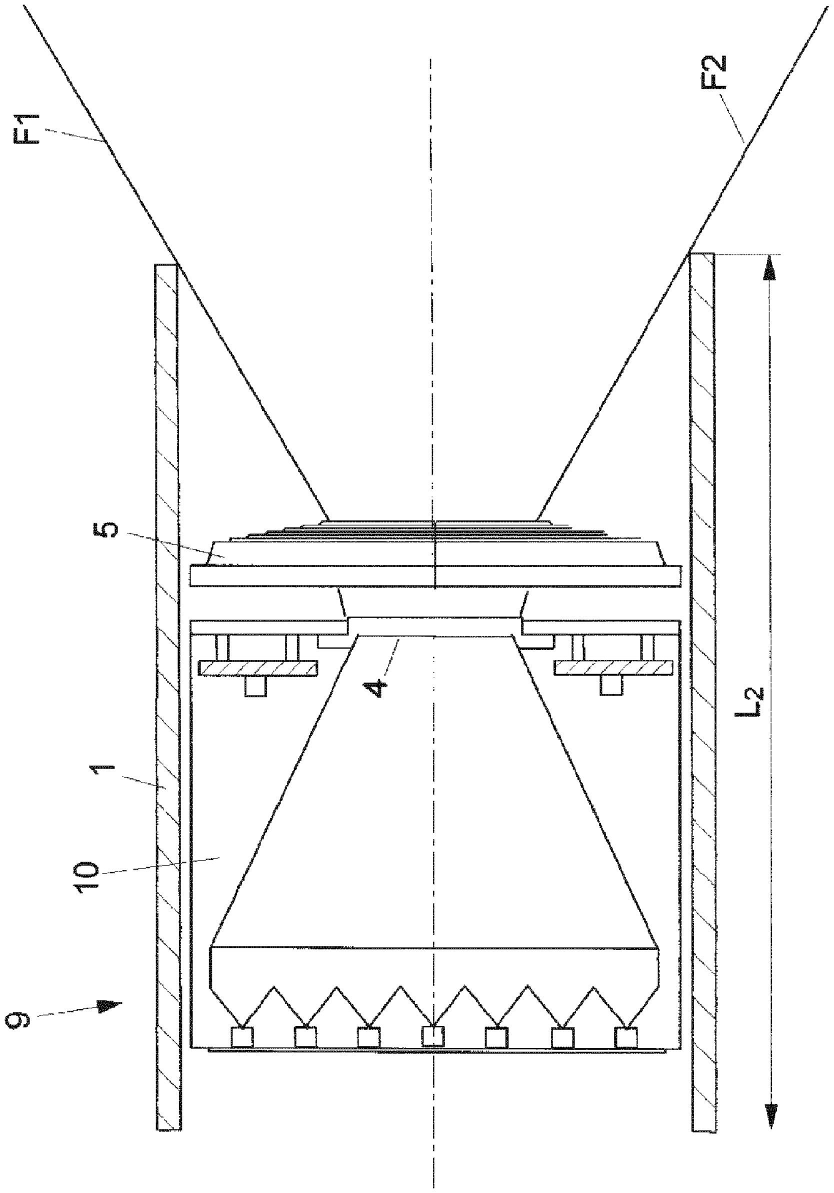


FIG 35

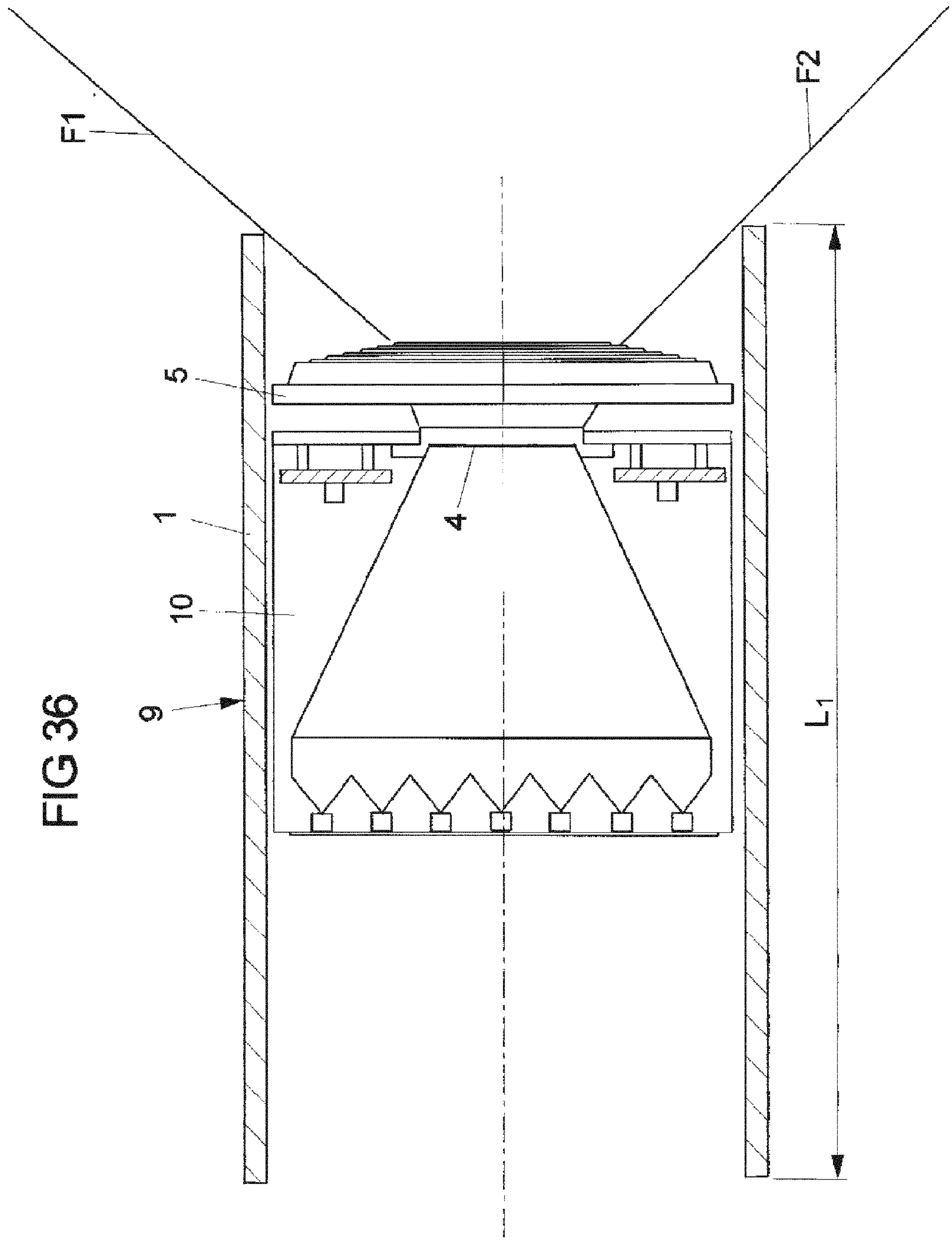


FIG 36

FIG 37

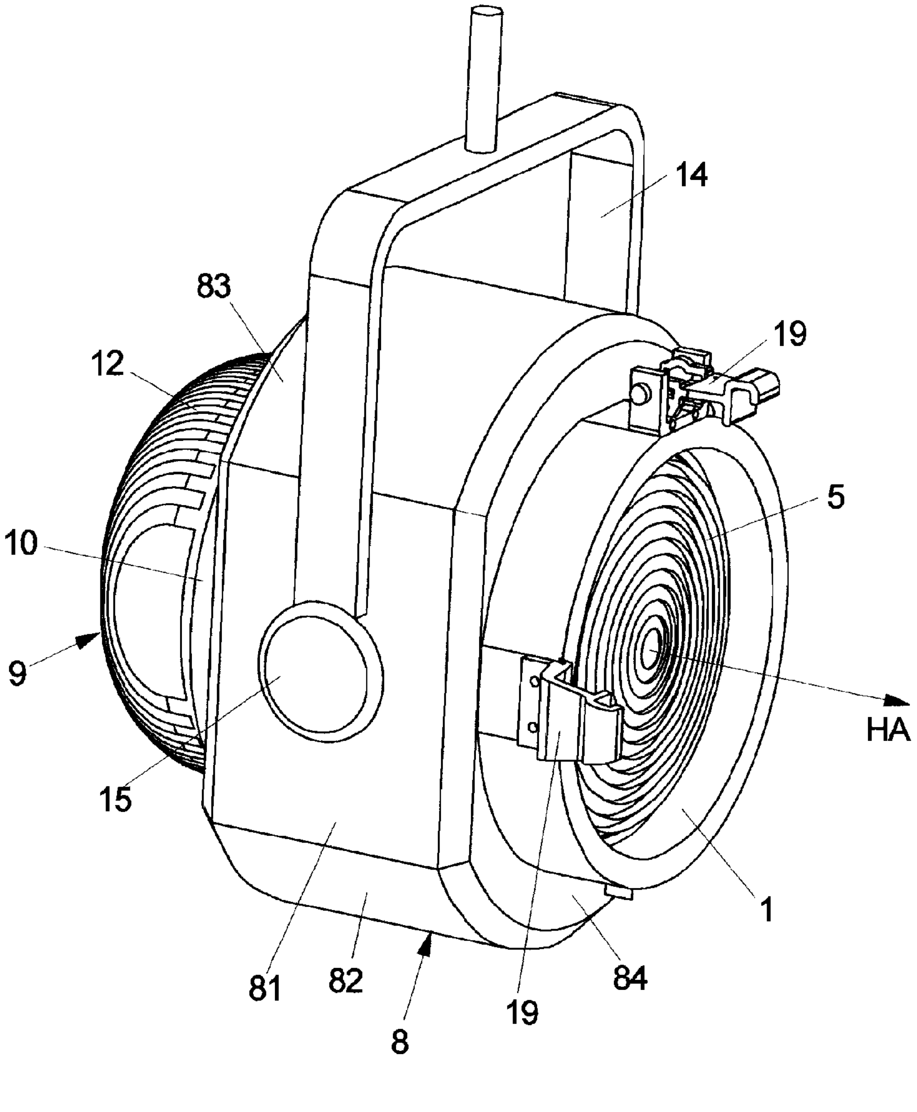


FIG 38

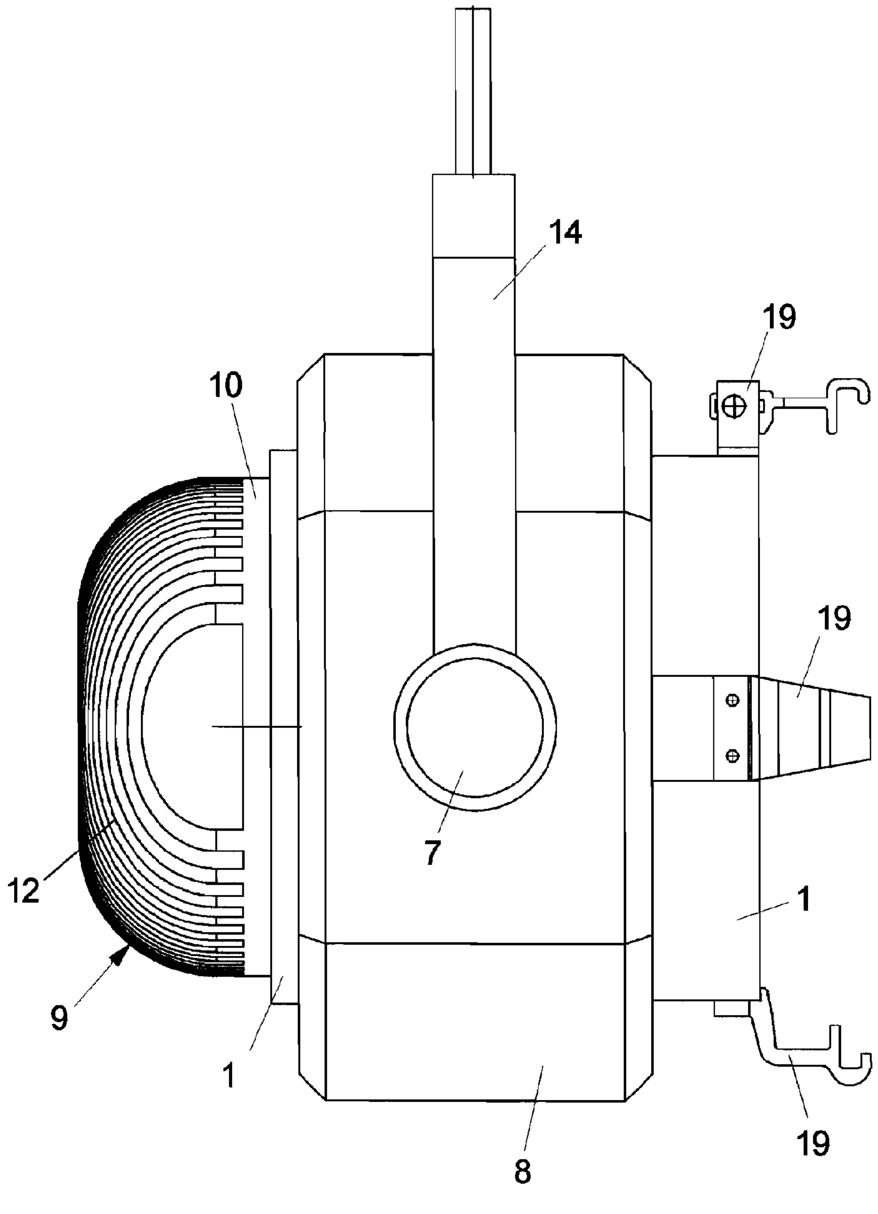


FIG 39