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(54) **OPTICAL APERTURE HAVING A NON-CIRCULAR OPENING AND OPTICAL SYSTEM INCLUDING SUCH APERTURE**

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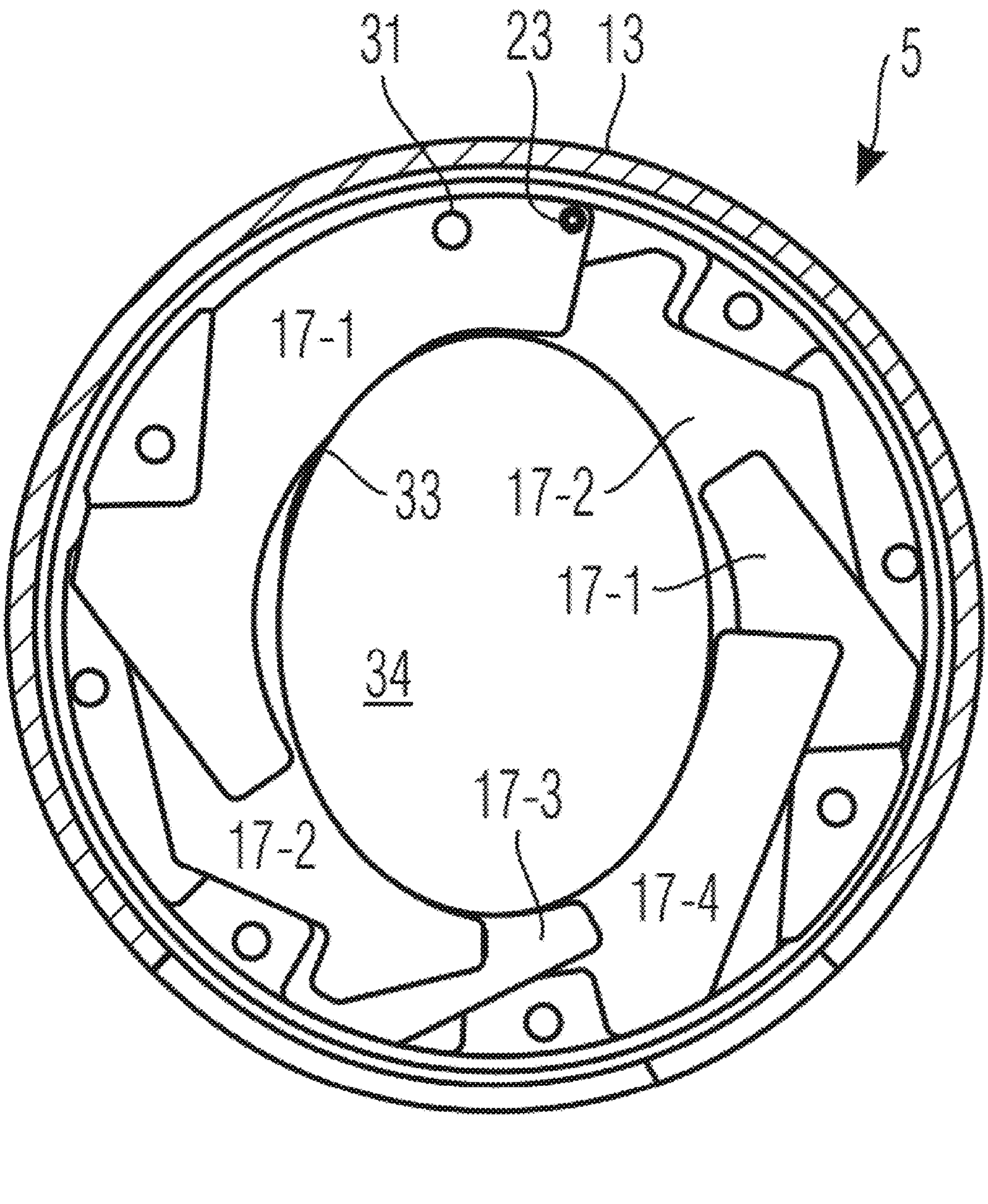
(57) **ABSTRACT**

An aperture having a non-circular aperture comprises a first ring and a second ring rotatable relative to each other, and a plurality of blades, wherein edges of the blades define the aperture. The diaphragm includes a plurality of joints, wherein each joint pivotably connects one blade to the first ring. The diaphragm further comprises a plurality of grooves, wherein a number of the grooves corresponds with the number of the blades, wherein the grooves are provided on the second ring, wherein a connector is provided on each blade, wherein the connector engages with the groove and is moveable along the groove. The joints are positioned at varying distances in the circumferential direction about the rotation axis. Moreover, the edges of the blades defining the aperture have different shapes.



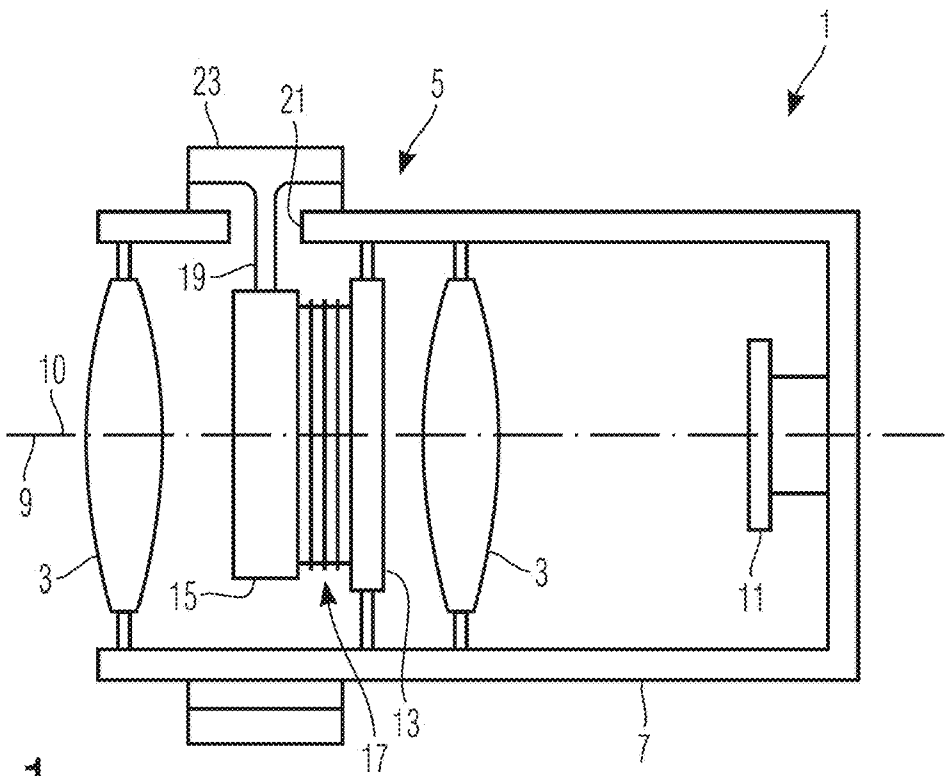


Fig. 1

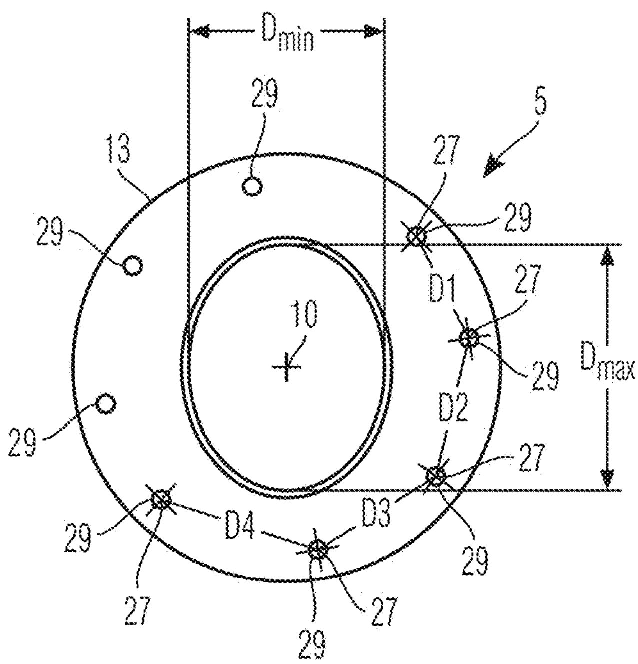


Fig. 2

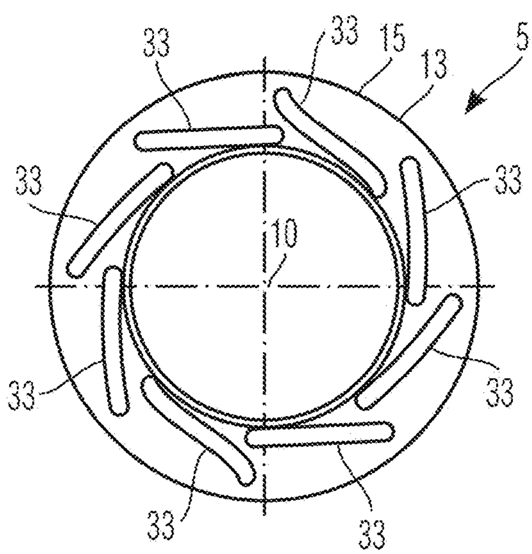


Fig. 3

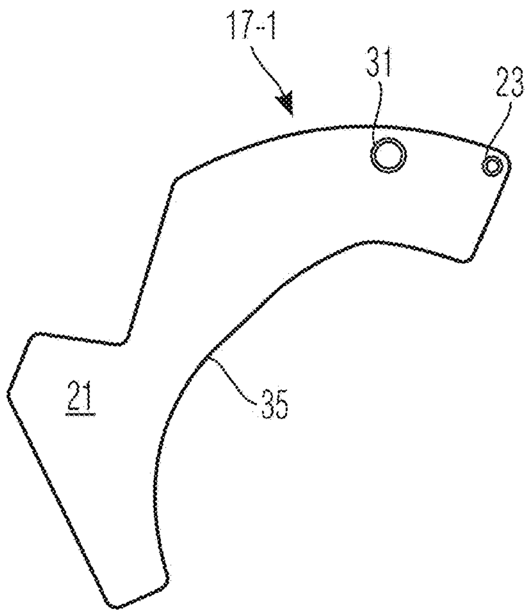


Fig. 4

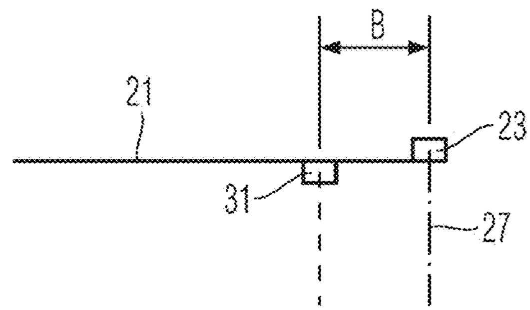


Fig. 5

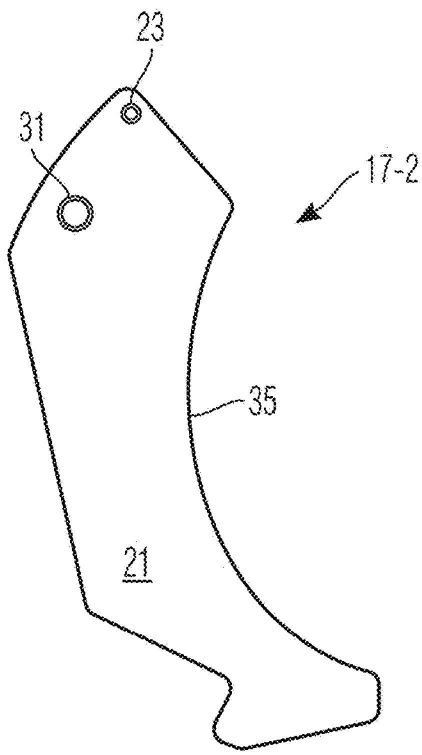


Fig. 6

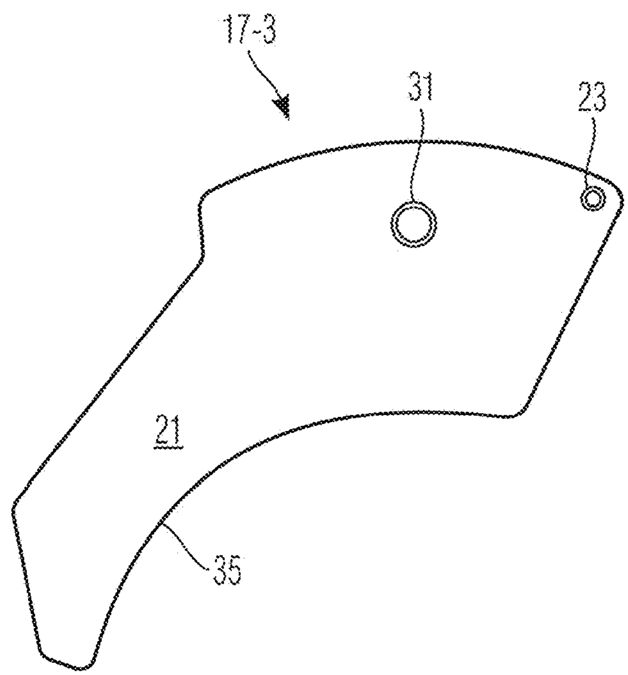


Fig. 7

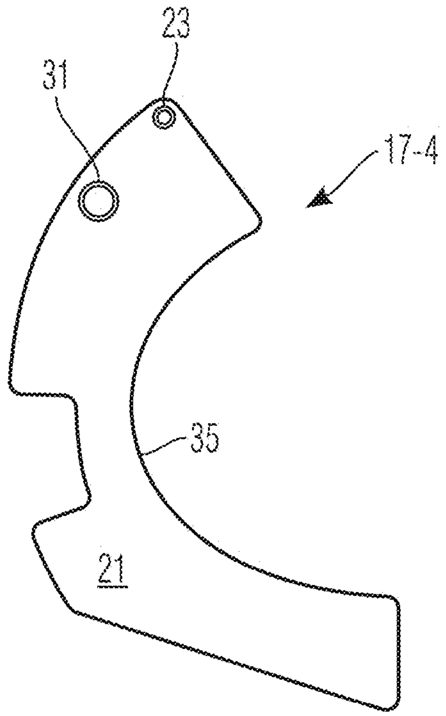


Fig. 8

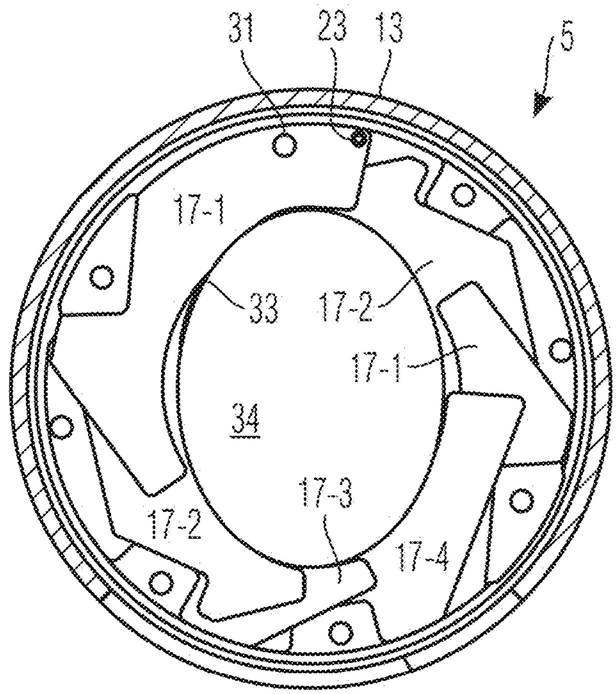


Fig. 9

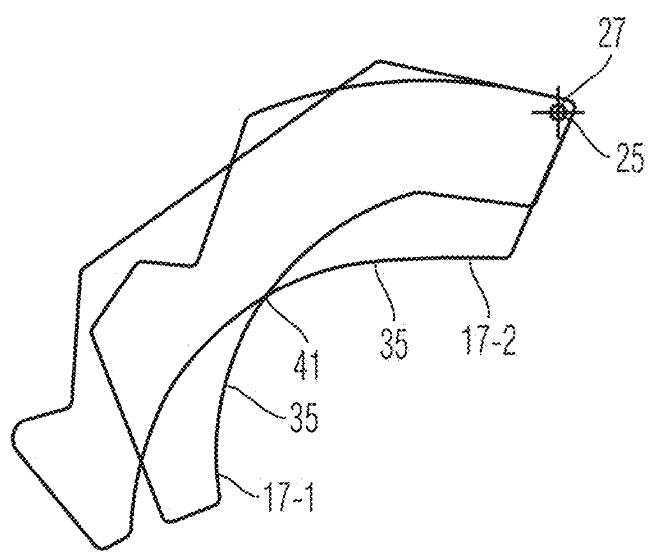


Fig. 10

OPTICAL APERTURE HAVING A NON-CIRCULAR OPENING AND OPTICAL SYSTEM INCLUDING SUCH APERTURE

RELATED APPLICATIONS

[0001] This application is related to the German patent application no. 10 2023 108 644.8 entitled "OPTICAL DIAPHRAGM HAVING A NON-CIRCULAR APERTURE AND OPTICAL SYSTEM HAVING SUCH DIAPHRAGM", the whole content of which is incorporated herein by reference.

TECHNICAL FIELD

[0002] The present invention relates to an optical diaphragm having a non-circular aperture, and to a system having such diaphragm.

DISCUSSION OF THE BACKGROUND

[0003] Optical diaphragms having a circular aperture and having an adjustable diameter are provided in many optical systems, such as movie cameras and still cameras. The diaphragms are used to adjust the depth of focus of an imaging of an object onto a film or image sensor, and to adjust the amount of light reaching the film and image sensor, respectively. When the diaphragm has a smaller diameter of the aperture, the depth of focus is larger and the amount of light is smaller, resulting in the greater exposure time, while the bigger diameter of the aperture results in a smaller depth of focus and a shorter exposure time.

[0004] Some artists appreciate a property of an optical imaging referred to as bokeh which describes the appearance of unsharp or blurred regions in an image. The diaphragm in a lens barrel can be used to control the bokeh in a movie or still camera. It has been found that diaphragms having non-circular apertures can produce a bokeh which is interesting from an artist's point of view.

[0005] However, diaphragms having non-circular apertures of an adjustable diameter are not readily available.

SUMMARY OF THE INVENTION

[0006] Accordingly, it is an object of the present invention, to provide a diaphragm having a non-circular aperture of an adjustable diameter and which is not difficult to manufacture.

[0007] According to the invention, a diaphragm having a non-circular aperture has a first ring, a second ring and a plurality of blades. The blades are mounted between the first ring and the second ring, and edges of the blades define the aperture provided by the diaphragm. The second ring is rotatable relative to the first ring about a rotation axis. The rotation of the two rings relative to each other results in a displacement of the plurality of blades relative to each other, such that the diameter of the aperture provided by the blades can be adjusted by rotating the two rings relative to each other.

[0008] The diaphragm comprises a plurality of joints, wherein a number of the joints corresponds to the number of the blades. Each joint connects one of the blades with the first ring such that the blade is mounted on the first ring to be pivotable about a pivot axis.

[0009] The diaphragm further comprises a plurality of grooves provided in the second ring, wherein the number of grooves corresponds to the number of the blades, and wherein each blade is provided with a connector engaging with one groove and being movable along the groove.

[0010] According to exemplary embodiments, the joints are distributed in the circumferential direction about the rotation axis, wherein distances between adjacent pivot axes of the joints in the circumferential direction about the rotation axis vary between the joints. This means that the joints are not disposed at equal distances about the rotation axis. In the conventional diaphragm having a circular aperture, the pivot axes of the joints are uniformly distributed in the circumferential direction about the rotation axis. Using the arrangement of the joints at varying distances between immediately adjacent joints in the circumferential direction, it is possible to adjust the pivoting motion of the blades upon relative rotation of the two rings such that some of the blades pivot faster or slower than other blades, such that the edges of the blades defining the aperture are located at different distances from the center of the aperture such that the aperture defined by the edges of the blades has a non-circular shape.

[0011] The varying distances between the pivot axes of adjacent joints in the circumferential direction can be designed such that a ratio between a largest distance among the distances between circumferentially adjacent pivot axes and a smallest distance among the distances between the circumferentially adjacent pivot axes is greater than 1.05 and in particular greater than 1.10.

[0012] According to exemplary embodiments, shapes of the edges of the blades defining the shape of the aperture in at least one rotational position of the first ring relative to the second ring vary between blades. This means that the edge of the blade defining the aperture does not have a same shape between the plurality of edges of the blades. In the conventional diaphragm having a circular aperture, the edges of all blades have a same shape. In the present embodiment, the shapes of the edges defining the aperture are designed such that the varying curvatures of the edges define the non-circular aperture. Moreover, the edges of the blades have different portions contributing to defining the aperture at different rotational positions between the two rings. The different portions may have different curvatures, such that a given blade defines a small aperture with a portion of its edge having a greater curvature than another portion of the same edge defining the greater aperture.

[0013] The different shapes of the blades can be, for example, designed such that there is at least one pair of blades for which the following is fulfilled: if the blades of the pair of blades are stacked with their main surfaces on a plane such that the pivot axes of the joints of the two blades coincide, and such that, when seen in an elevational view on this plane, the edges of the blades intersect at a given location, there is another location along the edges, where a distance between the edges of the blades is greater than 0.05 times a maximum diameter of the aperture, and in particular 1.10 times the maximum distance of the aperture.

[0014] According to exemplary embodiments, the grooves have varying shapes. This means that all grooves do not have the same shape. In the conventional diaphragm having a circular aperture, all grooves have a same shape.

[0015] By designing the grooves to have different shapes, the pivoting movement of the blades upon rotation of the two rings relative to each other can be achieved such that some blades move faster or slower than other blades, such that the edges of the blades defining the aperture are arranged at different distances from the center of the aperture, such that the aperture defined by the edges of the blades has a non-circular shape.

[0016] The different shapes of the grooves can be, for example, designed such that there is at least one pair of grooves for which the following is fulfilled: when the grooves are projected onto a drawing plane such that endpoints of the grooves coincide and edges of the groove intersect, there is a portion of the grooves where a distance between the edges of the two grooves is greater than 1.05 times a length of the two grooves and in particular 1.10 times the length of the two grooves.

[0017] The shape of the non-circular aperture may approach an elliptical shape. This means that the aperture of the diaphragm has a large diameter and a small diameter, wherein the large diameter and the small diameter are measured in different directions. A ratio between the length of the large diameter and the length of the small diameter can be regarded as the ellipticity of the aperture even if the shape of the aperture does not exactly correspond to the elliptical shape. According to exemplary embodiments, the ellipticity of the aperture is, at all rotational positions of the second ring relative to the first ring, greater than 1.2, greater than 1.4, greater than 2.0, greater than 2.4 or even greater.

[0018] According to exemplary embodiments herein, the ellipticity of the aperture, which can be greater than 1.2, is substantially the same for all rotational positions of the second ring relative to the first ring. This means that the ellipticity does not vary by more than 20% over all rotational positions of the first ring relative to the second ring. In particular, a ratio between the largest ellipticity of all rotational positions of the first ring relative to the second ring and a smallest ellipticity of all rotational positions of the first ring relative to the second ring can be smaller than 1.2 and in particular smaller than 1.1.

[0019] According to exemplary embodiments, a number of the blades of the diaphragm is six or greater than six. For example, eight, ten, twelve, fourteen or more blades can be provided. The number of blades can be an even number or an impair number.

[0020] According to exemplary embodiments, the diaphragm is designed such that an orientation of the large diameter of the aperture at a given rotational position of the first ring relative to the second ring does not change by more than 10° over all rotational positions.

[0021] Embodiments of the invention further provide an optical system having plural lenses providing a beam path of the optical system. This optical system also includes the above described diaphragm with its aperture in its beam path. By rotating the second ring relative to the first ring, the positions of the blades can be changed in order to change the diameter of the aperture resulting in a change in the configuration of the bundle of light rays traversing the optical system.

[0022] The geometrical configuration of the diaphragm can be defined by parameters. Some of these parameters can be used as free parameters in a suitable optimization method in order to be optimized to determine parameters of the diaphragm having desired geometric properties. It is thus possible to manufacture the diaphragm providing the desired properties using the determined parameters. The free parameters used in the optimization may in particular include the distances between the pivot axes, parameters describing the shapes of the edges of the blades defining the aperture in at least one rotational position of the first ring relative to the second ring, and parameters describing the shapes of the grooves.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] Embodiments of the invention will be illustrate with reference to the drawings below.

[0024] FIG. **1** shows an optical system having a diaphragm according to an embodiment;

[0025] FIG. **2** is an elevational view of a first ring of the diaphragm shown in FIG. **1**;

[0026] FIG. **3** is an elevational view of a second ring of the diaphragm shown in FIG. **1**;

[0027] FIG. **4** is an elevational view of a blade having a first shape of the diaphragm shown in FIG. **1**;

[0028] FIG. **5** is a side view of the blade having the first shape shown in FIG. **4**;

[0029] FIG. **6** is an elevational view of a blade having a second shape of the diaphragm shown in FIG. **1**;

[0030] FIG. **7** is an elevational view of a blade having a third shape of the diaphragm shown in FIG. **1**;

[0031] FIG. **8** is an elevational view of a blade having a fourth shape of the diaphragm shown in FIG. **1**;

[0032] FIG. **9** is an elevational view of the diaphragm shown in FIG. **1** when the second ring is removed; and

[0033] FIG. **10** is an illustration of different shapes of the blade of the first shape shown in FIG. **4** and of the blade of the second shape shown in FIG. **6**.

DESCRIPTION OF EMBODIMENTS

[0034] FIG. **1** is a schematic sectional view of an optical system **1** having a plurality of optical lenses **3** and a diaphragm **5** mounted in a housing **7**. The lenses **3** and the diaphragm are disposed along a beam path and centered relative to an optical axis **9**. The optical system **1** further comprises a light-sensitive image sensor **11** mounted on the housing **7** such that the optical system **1** provides a camera.

[0035] The diaphragm **5** comprises a first ring **13** and a second ring **15** on which a plurality of blades **17** are mounted, wherein the blades **17** define an aperture of the diaphragm **5**. The first ring **13** is mounted on the housing **7** to be fixed in the circumferential direction about the optical axis **9**, while the second ring **15** can be rotated relative to the first ring **13** about a rotation axis **10** which coincides with the optical axis **9** of the optical system **1**. For this purpose, a projection **19** fixed to the second ring traverses a groove **21** in the housing **7** and carries an outer ring **23**. The user of the optical system **1** may grasp the outer ring **23** and rotate the outer ring **23** relative to the housing **7** in order to achieve the rotation of the second ring **15** of the diaphragm **5** relative to the first ring **13** of the diaphragm **5**.

[0036] Details of the diaphragm **5** will be illustrated below with reference to FIGS. **2** to **9**, wherein FIG. **2** is an elevational view of the first ring **13**, FIG. **3** is an elevational view of the second ring **15**, FIGS. **4** to **8** illustrate shapes of the blades **17**, and FIG. **9** shows the partially mounted diaphragm **5**.

[0037] The diaphragm **5** has eight blades **17**. The blades **17** different with respect to their shapes, wherein four different shapes are provided. An elevational view of a blade **17-1** of a first shape is shown in FIG. **4** while FIG. **5** shows a side view thereof. An elevational view of a blade **17-2** of a second shape is shown in FIG. **6**; an elevational view of a blade **17-3** of a third shape is shown in FIG. **7**, and an elevational view of a blade **17-4** of a fourth shape is shown in FIG. **8**. The side views of the blade **17-2** of the second shape, the blade **17-3** of the third shape and the blade **17-4** of the fourth shape are not shown in the figures since they are similar to the side view of the blade **17-1** of the first shape shown in FIG. **5**.

[0038] The blades **17-1**, **17-2**, **17-3** and **17-4** are each made of a thin metal sheet. A first stud **23** projects from one face of the blade **17**. The stud **23** is one component of a joint **25** mounting the blade **17** on the first ring **13** such that the blade **17** is pivotable relative to the first ring **13** about a pivot axis **27**. In the diaphragm **5**, the studs **23** engage with holes **29** provided in the first ring **13**.

[0039] A stud **31** projects from the face of the sheet **21** opposite to the stud **23**, and is provided at a distance B from the stud **23**. In the diaphragm **5**, the stud **31** engages with a groove **33** provided on the second ring **15**. The studs **13** provide connectors between the blades **17** and the second ring **15**, wherein the connector is fixed to the blade **17**, engages with the groove **33** and is movable along the groove **33**. By rotating the second ring **15** relative to the first ring **13**, the studs **13** are moved along the grooves **33**, resulting in the blades being pivoted about their pivot axes **27**. This also results in displacing of edges **35** of the blades **17** relative to the rotation axis **10**. The edges **35** are those edges of the blades **17** defining an aperture **34** of the diaphragm **5** in at least one rotational position of the first ring **13** relative to the second ring **15**.

[0040] FIG. **9** shows the partially mounted diaphragm **5** including the first ring **13**, a portion of the blades **17**, wherein the second ring **15** is removed, wherein one of the blades **17-3** is removed, and wherein one of the blades **17-4** is removed.

[0041] The blades **17** of different shapes have edges **35** of different shapes, while blades **17** of a same shape have edges **35** of a same shape. The differences between blades **17** of different shapes and the shapes of the edges **35** thereof will be described with reference to FIG. **10** below. FIG. **10** shows the blade **17-1** of the first shape and the blade **17-2** of the second shape stacked above each other such that the pivot axes **27** of the joints **25** thereof coincide and such that the edge **35** of the blade **17-1** and the edge **35** of the blade **17-2** intersect at a point **41**. It is apparent from FIG. **10** that the edges **35** of the two blades **17-1** and **17-2** have increasing distances from each other when the distance from the point **41** increases. Specifically, a distance between the two edges **35** of the two blades **17-1** and **17-2** will become greater than 0.05 a maximum diameter Dmax of the aperture **34**, and in particular greater than 1.1 times the maximum diameter Dmax of the aperture **34**.

[0042] All pairs of the blades **17-1**, **17-2**, **17-3** and **17-4** of the first, second, third and fourth shapes, respectively, can be stacked, as described above, to recognize the different shapes of the edges **35** defining the aperture **34** in at least one rotational position of the second ring **15** relative to the first ring **13**.

[0043] The diaphragm **5** comprises two blades **17-1** of the first shape, two blades **17-2** of the second shape, two blades **17-3** of the third shape and two blades **17-4** of the fourth shape, such that the total number of blades **17** is an even number and so that the number of the blades **17** having edges **35** of a same shape is an even number. Thus, two, four or six blades may have edges of a same shape. However, there are at least two, three, four or more blades of the diaphragm having edges of different shapes. It is, however, not required to have an even number of blades having edges of a same shape. It is possible that only one blade or three blades have edges of a same shape, and also the total number of blades of the diaphragm can be an impair number.

[0044] Apart from the blades **17** differing with respect to the shapes of the edges **35**, the blades also differ with respect to positions of attachment of the blades on the first ring **13** by the joints **25**.

[0045] The joints **25** of the blades **17** are not provided at equal distances in the circumferential direction on the first ring **13**. Specifically, the holes **29** engaged by the studs **23** to provide the joints **25** are arranged with different distances in the circumferential direction about the rotation axis **10**. FIG. **2** shows four different distances D1, D2, D3, and D4 between the pivot axes **27** of the individual joints **25**. The arrangement of the pivot axes is symmetric relative to the rotation axis **10**. In the illustrated example: D1=10.25 mm, D2=13.06 mm, D3=12.95 mm and D4=15.51 mm. A ratio between the greatest distance D4 among these distances and the smallest distance D1 among these distances is 1.51, which is greater than 1.05 and in particular greater than 1.10. In the most open position of the diaphragm, the largest diameter Dmax of the elliptical aperture is 24 mm, and the smallest diameter Dmin of the elliptical aperture is 18 mm. The ellipticity of the aperture **35**, which is the ratio of Dmax and Dmin is, in the illustrated example, 1.33 which is greater than 1.2.

[0046] Also the grooves **33** engaged by the studs **31** have different shapes for blades **17** of different shapes, as shown in FIG. **3**.

[0047] By providing the blades **17** with edges **35** of different shapes defining the aperture **34**, by providing different distances between adjacent joints in the circumferential direction about the rotation axis **10**, and also by providing different shapes of the grooves **23**, it is possible to design the diaphragm such that the aperture has, irrespective of the size of the aperture, an elliptical shape, wherein the orientation of the main axis of the ellipse relative to the first ring **13** is substantially the same for all positions of the aperture.

1. A diaphragm having a non-circular aperture, comprising:

a first ring and a second ring rotatable relative to the first ring about a rotation axis;

a plurality of blades wherein edges of the blades define the aperture of the diaphragm wherein a number of the blades is greater than or equal to six;

a plurality of joints, wherein a number of the joints corresponds to the number of the blades, wherein each joint connects one of the blades to the first ring such that the blade is pivotable relative to the first ring about a pivot axis;

a plurality of grooves, wherein a number of the grooves corresponds to the number of the blades, wherein the grooves are provided on the second ring, wherein a connector is provided on each blade, wherein the connector engages with one of the grooves and is moveable along the groove;

wherein the joints are distributed around the rotation axis, wherein distances between pivot axes vary between joints adjacent to each other in the circumferential direction about the rotation axis, and/or wherein the edges of the blades defining the aperture of the diaphragm in at least one rotational position of the first ring relative to the second ring differ with respect to their shapes.

2. The diaphragm according to claim **1**,

wherein a ratio between a largest distance among the distances between the pivot axes of adjacent joints in the circumferential direction about the rotation axis and a smallest distance among the distances between pivot axes of adjacent joints in the circumferential direction about the rotation axis is greater than 1.05.

3. The diaphragm according to claim **1**,

wherein there is at least one pair of blades which fulfills:

when the blades of the pair are stacked such that the pivot axes of the joints of the two blades coincide, and such that, when seen in an elevational view of the faces of the blades, the edges of the blades intersect at a location, there is a distance between the edges of the two blades at a distance from this location greater than 0.05 times a maximum diameter of the aperture.

4. The diaphragm according to claim **1**,

wherein the edges of the blades defining the aperture of the diaphragm in at least one rotational position of the first ring relative to the second ring have different shapes, and

wherein a number of the blades having a same shape of their edges is an even number.

5. The diaphragm according to claim **1**,

wherein the shapes of the grooves vary.

6. The diaphragm according to claim **1**,

wherein the joints include at least one first stud provided on the blade, and a hole provided on the first ring, wherein the first stud engages with the hole provided on the first ring.

7. The diaphragm according to claim **1**,

wherein the connector includes a second stud fixed to the blade and engaging with the groove.

8. The diaphragm according to claim **1**,

wherein, in a given rotational position of the first ring relative to the second ring, an ellipticity of the aperture is given by a ratio between a large diameter of the aperture at the given rotational position and a small diameter of the aperture at the given rotational position, and

wherein the ellipticity of the aperture is, at all rotational positions of the first ring relative to the second ring, greater than 1.2.

9. The diaphragm according to claim **8**,

wherein a ratio between the greatest ellipticity among all rotational positions of the second ring relative to the first ring and the smallest ellipticity among all rotational positions of the second ring relative to the first ring is smaller than 1.2.

10. The diaphragm according to claim **1**,

wherein an orientation of a large diameter of the aperture at a given rotational position of the second ring relative to the first ring doesn't change by more than 10° over all rotational positions.

11. Optical system, comprising:

plural lenses and

a diaphragm positioned along a beam path of the optical system,

wherein the diaphragm comprises:

a first ring and a second ring rotatable relative to the first ring about a rotation axis;

a plurality of blades wherein edges of the blades define the aperture of the diaphragm wherein a number of the blades is greater than or equal to six;

a plurality of joints, wherein a number of the joints corresponds to the number of the blades, wherein each joint connects one of the blades to the first ring such that the blade is pivotable relative to the first ring about a pivot axis;

a plurality of grooves, wherein a number of the grooves corresponds to the number of the blades, wherein the grooves are provided on the second ring, wherein a connector is provided on each blade, wherein the connector engages with one of the grooves and is moveable along the groove;

wherein the joints are distributed around the rotation axis, wherein distances between pivot axes vary between joints adjacent to each other in the circumferential direction about the rotation axis, and

wherein the edges of the blades defining the aperture of the diaphragm in at least one rotational position of the first ring relative to the second ring differ with respect to their shapes.

* * * * *