

Objective having at least a first and a second optical assembly

The present invention relates to an objective having at least a first and a second optical assembly. This type of objectives also include, in particular, the so-called F-theta objectives
5 which are provided, for example, for focusing high-power lasers as may be used in a scanning apparatus for laser material processing.

Laser and material processing applications demand ever higher optical qualities of the optical systems used and a high degree of production stability, that is to say a low deviation in the
10 optical performance of the systems produced in relation to one another.

Manufacturing tolerances of the components used generally lead to aberrations and a reduction in the optical quality. Primarily in the field of UV and solid quartz optical systems, this leads to noticeably poorer quality and increased expenditure on post-processing. The mounting
15 technology is a central factor, particularly in the case of F-theta objectives. The current requirements in respect of quality can no longer be ensured with standard technologies from the prior art.

Standard F-theta mounting technologies are distinguished by so-called filling mounting. The
20 principle of filling mounting is based on the concept of the self-centring of lenses and spacer rings. When using, for example, meniscus lenses (identified by "M" in figure 1) which have a first surface and at least one second surface which have approximately the same radius of curvature, this can lead to problems since these meniscus lenses do not have a centring effect and roll away owing to the respective supports. This can result in an assembly status which is decentred
25 to the maximum extent. Similar problems can occur when planoconvex or planoconcave lenses (identified by "P" in figure 1) are used. The planar side of these lenses cannot be centred by means of the described filling mounting technology. Only lenses with an adequate curvature (identified by "G" in figure 1) of both sides have a sufficiently high self-centring effect.

30 The technology of the adjusting rotary mounts with sliding lenses (high-precision special objectives) is expensive, complicated and takes up a large amount of space. As a result, the said technology is not suitable for the mass market. When fitting F-theta objectives, the lenses are inserted into so-called tube mounts (tubes) and shaped by means of spacers (rings or spacers)

depending on the desired lens unit and parameters. The substantially cylindrical tubes and the spacers are inserted into the mount housing (housing) and fitted one after the other. Defects due to improper assembly or due to irregularities in the spacers etc. can occur in the process, this ultimately leading to adjustment defects and therefore to image defects etc. as a further consequence. These defects are transmitted from lens to lens through the entire lens unit of the objective.

Embodiments of the invention seek to provide a solution for constructing and fitting an objective which has lenses with a low degree of self-centring, that is to say lenses with a first surface and at least one second surface which have approximately the same radius of curvature, such that assembly defects can be minimized or possibly even compensated for.

According to a first aspect of the present invention, there is provided a lens system comprising:
a first optical assembly which is mounted in a first objective housing and comprises at least one first lens, wherein the first lens has at least a first surface and a second surface with approximately the same radii of curvature; and
a second optical assembly which is mounted in a second objective housing and comprises at least one lens, wherein the first and the second objective housing are connected to one another in a connecting region,
wherein that lens in the first objective housing which is directly adjacent to the connecting region is the first lens, and
wherein the connecting region is configured to allow a spacer element to be installed between the first objective housing and the second objective housing in order to change an axial distance between the first objective housing and the second objective housing.

The approach described here is based on the knowledge that there is no or at least a very poor degree of self-centring in the case of lenses with a first surface and a second surface which have approximately the same radius of curvature. The solution is distinguished in that, owing to the two-part design of the objective housing, the connecting region which is produced as a result can be used in order to equalize or compensate for existing manufacturing defects.

According to the invention, the technical feature "approximately the same radius of curvature" is understood to mean that the radii of curvature differ by a maximum of 10 per cent, preferably by less than 5 per cent, particularly preferably by less than 1 per cent.

- 5 In a further embodiment, the first lens is in the form of a meniscus lens with a concave surface as the first surface and a convex surface as the second surface.

According to a second aspect of the present invention, there is provided a lens system comprising:

- a first optical assembly which is mounted in a first objective housing and comprises at
10 least one first lens, wherein the first lens comprises a planoconvex or planoconcave lens; and
a second optical assembly which is mounted in a second objective housing and
comprises at least one lens, wherein the first and the second objective housing are connected
to one another in a connecting region,
wherein that lens in the first objective housing which is directly adjacent to the
15 connecting region is the first lens, and
wherein the connecting region is configured to allow a spacer element to be installed
between the first objective housing and the second objective housing in order to change an
axial distance between the first objective housing and the second objective housing.

- 20 Meniscus and planoconvex or planoconcave lenses are particularly well suited for use in laser material processing.

- In a further embodiment, the first objective housing is detachably connected, in particular
screwed, to the second objective housing. The first objective housing can be disconnected from
25 the second objective housing particularly quickly by virtue of a detachable connection, in
particular by virtue of a screw connection.

The distance between the first and the second objective housing can be controlled by installing the means between the first objective housing and the second objective housing. Therefore, any imaging defects can be corrected.

5

In a further embodiment, there are means in order to connect the first objective housing to the second objective housing in a first position and at least one second position which differs in azimuth from the said first position. In particular, asymmetric aberrations can be compensated for by rotating the two housing parts with respect to the original position.

10

According to a third aspect of the present invention, there is provided an optical system for laser material processing, wherein the arrangement comprises:

a laser beam source for emitting a light bundle; and

the lens system as defined in the first or second aspects above for focusing the light bundle

15

onto a processing plane.

The invention will be explained in more detail by way of example with reference to the appended drawings, in which:

Fig. 1 shows a schematic illustration of the self-centring process for various types of lenses;
5 and

Fig. 2 shows a schematic illustration according to an exemplary embodiment of the present invention; and

Fig. 3 shows a schematic illustration according to an exemplary embodiment of the present invention.

10

In the following description of preferred exemplary embodiments of the present invention, identical or similar reference symbols are used for the elements which are illustrated in the various figures and act in a similar manner, wherein these elements are not repeatedly described.

15

Fig. 2 shows a schematic illustration of a possible implementation of an objective 1 according to the invention. The objective 1 forms a light bundle L, for example a laser bundle from a laser beam source, not illustrated in more detail, onto a processing plane BE.

20 The figure shows the objective housing parts 2 and 3 which are connected in a connecting region V. According to the exemplary embodiment, the two housing parts are screwed together by means of screws 8, wherein only one screw can be seen in the sectional illustration. The first objective housing 2 comprises a first lens which is in the form of a meniscus lens 4 and a further lens 5. These two lenses form a first optical assembly. The second objective housing 3
25 comprises a lens 6 and a further lens 7, wherein the precise function of these two lenses is not intended to be discussed in more detail. These two lenses form a second optical assembly.

As is clear from Figure 2, the meniscus lens 4 comprises a concave surface 4A and a convex surface 4B, wherein the radii of curvature of these two surfaces are approximately the same.

30 The meniscus lens 4 is that lens from the first optical assembly which directly adjoins the connecting region V. Therefore, it is possible to set the air space between the lenses 4 and 7 in a simple and quick manner by, for example, inserting spacer elements between the first objective

housing and the second objective housing. Owing to a measure of this kind, additional decentring states as in filling mounting technology cannot occur.

Fig. 3 shows a further embodiment of the present invention. Figure 3 shows, in the right-hand region, the second objective housing 3 which has eight threaded bores 8o in this embodiment.

The azimuth orientation of the two objective housings in relation to one another - for example even in smaller than 90° steps - can be changed owing to the provision of a plurality of threaded bores in the second housing part 3. The number of bores and therefore the possibilities for changing the objective housings in relation to one another is unlimited in terms of technical and technological expediency.

The external view of the assembled objective 1 with the two objective housings, that is to say the first objective housing 2 and the second objective housing 3, is shown in figure 3 (left-hand region) with visible connecting screws 8.

Objectives of this kind, in particular F-theta objectives, are suitable for use in micromaterial processing for medium and high powers in the kilowatt range. The F-theta objectives are distinguished in that they have a particularly long service life and allow high-precision laser material processing. They can be used, for example, for microstructuring, marking and inscribing different materials.

The F-theta objectives are specially developed and used for applications with high-power lasers and short pulses. The said objectives are, in particular, minimally absorbing solid quartz objectives for particularly high laser powers. The objectives are diffraction-limited and are distinguished by high imaging quality. In addition, they provide a considerably higher damage threshold and a high spot consistency over the entire scanning range. They guarantee a minimal focus shift in high-power lasers.

High-precision objectives with a long service life can be produced owing to special, low-contamination mounting technologies, avoidance of adhesive and lubricant and assembly in a certified cleanroom.

The two objective housings are composed at least partially of aluminium, brass and/or stainless steel, wherein good processability is advantageous. The robustness of the two objective housings to mechanical and/or thermal loading, but also the weight, is likewise important for the choice of material. In particular, a plurality of component housings, possibly with different material units, can therefore also be connected to one another, in particular screwed together.

Where an exemplary embodiment comprises an "and/or" conjunction between a first feature and a second feature, this is intended to be read to mean that the exemplary embodiment has both the first feature and the second feature in accordance with one embodiment and either just the first feature or just the second feature in accordance with a further embodiment.

Patent claims

1. A lens system comprising:
 - a first optical assembly which is mounted in a first objective housing and comprises at least one first lens, wherein the first lens has at least a first surface and a second surface with approximately the same radii of curvature; and
 - a second optical assembly which is mounted in a second objective housing and comprises at least one lens, wherein the first and the second objective housing are connected to one another in a connecting region,
 - wherein that lens in the first objective housing which is directly adjacent to the connecting region is the first lens, and
 - wherein the connecting region is configured to allow a spacer element to be installed between the first objective housing and the second objective housing in order to change an axial distance between the first objective housing and the second objective housing.
2. The lens system according to Claim 1, wherein the first lens comprises a meniscus lens with a concave surface as the first surface and a convex surface as the second surface.
3. A lens system comprising:
 - a first optical assembly which is mounted in a first objective housing and comprises at least one first lens, wherein the first lens comprises a planoconvex or planoconcave lens; and
 - a second optical assembly which is mounted in a second objective housing and comprises at least one lens, wherein the first and the second objective housing are connected to one another in a connecting region,
 - wherein that lens in the first objective housing which is directly adjacent to the connecting region is the first lens, and
 - wherein the connecting region is configured to allow a spacer element to be installed between the first objective housing and the second objective housing in order to change an axial distance between the first objective housing and the second objective housing.

4. The lens system according to any one of the preceding claims, wherein the first and the second objective housing are detachably connected to one another, in particular screwed together.

5

5. The lens system according to any one of the preceding claims, further comprising connecting means arranged to connect the first objective housing to the second objective housing in a first position and at least one second position which differs in azimuth from the said first position.

10

6. An optical system for laser material processing, wherein the arrangement comprises:

5 a laser beam source for emitting a light bundle; and

the lens system according to any one of the preceding claims for focusing the light bundle onto a processing plane.