

**Method for measuring distance, and
a distance measuring instrument**

The invention relates to a method for measuring the distance between an objective and an object, and to
5 a distance measuring instrument which operates according to this method.

In connection with microscopes, in particular, users need to know the distance from their object to the objective of the microscope.

10 The most varied methods have been proposed for this purpose. For example, there are transit-time measurements using pulse-coded laser beams. Various optical methods, such as the split-image method or triangulation method, are also known. Thus, for
15 example, the so-called MKM microscope design from the Zeiss company applies a pulsing laser beam which is directed onto the focus. If the object plane is located in the Z-direction upstream or downstream of the focal plane, the laser luminous point blinks left or right of
20 the optical axis of the microscope. Whereas the first method is electronically complicated and affected by functional errors, the second method requires a substantial optical outlay.

It is therefore the object of the invention to
25 find a new method for measuring distances which is easy to evaluate in optical terms and permits reliable measurement of distances.

The method is implemented according to the invention by means of the features of Claim 1, while
30 the device is designed in accordance with the features of Patent Claim 5.

An important idea is for two essentially parallel beams (as a rule, but not exclusively, these are laser beams) to be directed in the parallel beam
35 path of a microscope onto the objective or through the objective. Even if the focal length of the objective is not known, it can be measured exactly by virtue of the

fact that the two beams - brought to converge at the focus - appear as a single luminous point. The distance from the principal plane of the objective then corresponds to the focal length. If, however, the
5 object plane is not located at the focal point, that is to say is located at a distance differing therefrom, two laser luminous points are seen on the object plane. The distance for the two laser luminous points from one another is a measure of the difference between the
10 focal plane and the object plane. The distance can be determined by computation as a function of the focal length of the objective and the stereobase of the two luminous light sources by the objective. By means of a geometric coding of the laser luminous points, for
15 example in a horizontal or vertical line, by corresponding upstream lenses or masks in the laser beam path, images of such markings are obtained, with the result that a negative or positive distance from the focal plane can be detected as well.

20 Variants of this and further specific designs are described in the dependent claims. Thus, for example, instead of the geometric coding it is possible to provide temporal coding in which, for example, one laser beam lights up on one occasion and then the other
25 lights up with a time shift. It is not imperative according to the invention for the two laser beams actually to be present in parallel upstream of the parallel beam path of the objective. Any desired angular deviations from parallelism are conceivable, if
30 the objective or the microscope is calibrated after installation of the elements producing laser light, and the calibration is taken into account in the calculation. In the case of such a design variant, a specific, defined distance between luminous points in
35 the object plane indicates a focused state of the objective with reference to the object plane.

The accuracy of the measurement of distance according to the invention is influenced by the angle χ which the two beams form with one another.

A good measurement result occurs at $\chi = 90^\circ$.

Also important is the position of the object plane relative to the optical axis. If these are mutually perpendicular, measurement is performed
5 without any problem. There is no need for correction. The measuring points are then situated symmetrically relative to the optical axis. In the case of asymmetry, compensation can be performed computationally by measuring the respective distance of the respective
10 measuring points from the optical axis and calculating back from there to the inclined position of the object plane. The position of the optical axis can be detected optically in this case in a simple way in as far as it is displayed by the point of intersection of the laser
15 beams as soon as it becomes visible. The measuring system can thus be calibrated.

Of course, the optical frequency of the laser beams can be in the visible and also in the invisible region if appropriate detecting means are provided.
20 Thus, for example, in the infrared region it is possible to use CCDs as detection means.

The invention is represented in more detail by way of example with the aid of the drawing, in which:
Figure 1 shows a main objective in a symbolically
25 represented microscope with a laser beam arrangement according to the invention, which is represented in stylized fashion;
Figure 2 shows a variant thereof;
Figure 3 shows a symbolic evaluation circuit;
30 Figure 4 shows the laser beam path downstream of the main objective;
Figure 5 shows a variant with integrated measurement of distance and magnification,
and
35 Figure 6 shows a representation with a non-vertical image-object plane.

Despite the representation of the invention with the aid of a microscope, it is not limited to

microscopy. It can be used in the case of any kind of beam paths with at least one main objective.

Arranged in a microscope 1 with a main objective 18, and eyepiece 8 and an optical axis 11, is a transparent backing plate 10 which supports two deflecting mirrors 12a and 12b. 12a and 12b are aligned in the exemplary embodiment represented, which does not impose limitations. The deflecting mirror 12a is a semitransparent beam-splitting mirror, with the result that a laser beam 2 which is emitted from a laser radiation source 3 arranged, as the case may be, outside the microscope is split into two component beams 2a, 2b.

Arranged downstream of the deflecting mirrors 12a, 12b are stops 9a and 9b which code the laser component beams 2a and 2b optically. Upon traversing the main objective 18, the parallel laser component beams 2a and 2b are angled away in the direction of the focal point 5, located in the focal plane A, of the main objective 18. If an object 6 is located outside the focal plane A, the laser component beams 2a and 2b produce two luminous markings 20a and 20b on the object 6. The distance 13 between the two luminous markings 20a and 20b is a measure of the distance Z between the principal plane 7 of the main objective 18 and the object 6 or the difference f (focal length) minus Z.

Figure 2 shows a variant for time-coded component beam paths 2a and 2b which are produced by virtue of the fact that the laser beam is deflected by two deflecting mirrors 17a and 17b, which are aligned with one another, in the direction of further deflecting mirrors 12c which are not aligned with one another, but are arranged upstream of the main objective 18. In this case, the deflecting mirror 17a is semitransparent. Located between the deflecting mirrors 17 and 12 is a rotating pinhole stop 14 with a hole 16, which is set rotating by a drive 15. Only when the hole coincides with a component beam path 2a or 2b can the latter be focused by the main objective 18.

Instead of the pinhole stop 14 represented, it is also possible, of course, to use all the shutters known in the prior art. As an alternative, it is also possible to use two pulsed lasers. Instead of a
5 geometric or a pulsed coding, it is also possible, of course, to provide a color coding. The variants represented in Figures 1 and 2 are also theoretically suitable for reading out distance with the naked eye. Thus, for example, it is possible to provide in the
10 viewing beam path a scale which permits the user, who looks through the eyepiece 8, to measure the distance between the two luminous points 20a and 20b.

However, the readout electronic system represented in Figure 3 is preferred. Figure 3 is
15 represented as a detail of the design according to Figure 1. A planar transparent optics holder 24 supports approximately centrally a deflecting mirror 25 which projects a portion of the beam coming from the object 6 onto a spatially sensitive optoelectronic
20 detector 27, for example a CCD, via an imaging system 26. The optics holder 24 is fitted immediately downstream of the main objective 18 in the parallel beam path. In this way, the optical images 20b and 20a shining on the object 6 can be imaged on the detector
25 27. A display 21 for indicating the Z-distance is, for example, connected to an evaluation unit 19 with evaluation software and a corresponding computer. However, it is also possible on the output side to connect to the evaluation unit 19 components which
30 control the microscope such as, for example, an autofocus 22 or an output 23 for stereotactic applications, in particular for determining the relative positions of the microscope 1 and the object 6.

35 The optics holders 10 and 24 and the small deflecting elements 12a, b, c, 17a, b can be gathered from the teaching of Patent Applications PCT/EP 95/01311 and PCT/EP 95/01301. Of course, all other conventional methods for reflecting information

into or extracting information from a beam path are within the scope of the invention. However, the method with the transparent optics holders is preferred.

It is not imperative for a parallel beam path to prevail upstream of the main objective 18, it is also possible for the laser beams to go through the main objective 18 at any desired angle, if subsequently calibration is carried out and it is established that a specific distance 13 of the luminous points in the object plane corresponds to a focused state of the main objective 18 with reference to the object plane.

The symbolic representation of Figure 4 shows the following: a point T which is to be observed is visible upstream of the focal point F. The laser beam S1 produces a point P(S1) in the plane B. The laser beam S2 produces a point P(S2). P(S1) differs from P(S2). The distance of the observed point T from the focal plane A is yielded from the distance 13 of the two points. If the position of the two points relative to one another is now considered, it is possible to state whether the distance between T and A received a positive or negative sign. If the observed point T is upstream of the focal point F, P(S1) is seen to the right of P(S2) through the microscope 1, and, if vice versa, the observed point T' is located downstream of the focal point F. What is decisive in this observation is that these two points P(S1) and P(S2) can be picked up separately, that is to say they must be coded. As mentioned, it is possible for them to be geometrically coded, with the result that it is therefore possible to distinguish P(S1) and P(S2) from one another, or for them to be coded appropriately in terms of time by knowing exactly when P(S1) lights up and when P(S2) lights up. This information is input into a computer or into a method, in order to calculate therefrom the position upstream or downstream of the focal point.

Figure 5 shows a variant which not only permits the Z distance to be measured but, moreover, permits a measurement of amplification (T-measurement) via beam

5 splitters 12c, d. For this purpose, the laser beam 2 is additionally split into the component beams S2' and S2", which form a defined angle α with one another. The component beams S2' and S2" are guided through the further optical system (not represented in Figure 5) of the microscope 1 and evaluated for the purpose of determining the magnification of the microscope 1. The evaluation is described in more detail in PCT/EP 95/01311. In particular, reference is made there to Figures 1-7 and the description on pages 8-15. All the variants specified there can be used meaningfully here as regards picking up the measuring beam and evaluation.

15 Figure 6 shows the problems associated with an inclined object plane with asymmetric distances a1 and a2 from the optical axis 11.

It is advantageous to combine the invention with measurement of magnification, as described, for example, in the abovementioned PCT/EP 95/01311. The information required for this is evident to the person skilled in the art from this PCT application; they are therefore deemed to be disclosed herein.

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List of reference symbols

	A	Focal plane
	B, C	Planes of object surfaces which are situated
5		opposite the main objective 18
	1	Microscope
	2	Laser beam
	2a	Component laser beams
	2b	Component laser beams
10	3	Laser
	5	Focal point
	6	Object
	7	Principal plane of the objective 18
	8	Eyepiece
15	9a	Stop
	9b	Stop
	10	Transparent backing plate
	11	Principal axis of the beam path
	12a	Deflecting mirror, semitransparent
20	12b	Deflecting mirror
	12c	Non-aligned deflecting mirrors
	13	Distance between the luminous markings 20a and 20b which are produced on the object surface
	14	Rotating pinhole stop/shutter wheel
25	15	Drive for pinhole stop
	16	Hole
	17	Deflecting mirror for time coding/beam- splitting device
	17a	Aligned deflecting mirror, semitransparent
30	17b	Aligned deflecting mirror
	18	Main objective
	19	Evaluation unit with evaluation software
	20a	Luminous marking/optical image
	20b	Luminous marking/optical image
35	21	Distance display
	22	Autofocus
	23	Output for stereotactic applications
	24	Optics holder
	25	Deflecting mirror

- 26 Imaging system
- 27 Detector (for example CCD)
- z Distance between object surface and main
 objective 18
- 5 χ Angle between the component laser beams S1, S2
 S1, S2 Component laser beams 2a, 2b after their
 traversal of the main objective 18

**Patent claims**

1. Method for measuring a distance (Z) between the object surface of an object (6) and a main objective (18) with the aid of an optical beam, characterized in
5 that at least two component beams (2a, b) of the beam are directed in the parallel beam path upstream of the main objective (18) to pass through the latter onto the object (6), the image of the intersection of the component beams (2a, b) with the surface of the object
10 (6) being evaluated as a measure for determining the distance (Z) by computer in an evaluation unit (19).
2. Method according to Claim 1, characterized in that the two component beams (2a, b) are produced by splitting a single beam (2) by means of at least one
15 semitransparent mirror (12a; 17a).
3. Method according to Claim 1 or 2, characterized in that each component beam (2a, b) is geometrically coded in a distinguishable fashion, if appropriate via stops (9a, 9b), during the evaluation a right-left
20 change of the projected images of the component beams about the optical axis (11) representing a plus-minus Z-displacement of the object (6) about the focal plane (A).
4. Method according to Claim 1, characterized in
25 that the component beams (2a, b) are coded by color or frequency, or are pulse modulated, color filters or image point integrators consequently being applied in the evaluation.
5. Device for carrying out a method according to
30 one of the preceding claims, characterized in that arranged downstream of the main objective (18) is at least one optical radiation source (3) which transmits at least two component beams (2a, b) through the main objective (18) in the direction of the object (6).
- 35 6. Device according to Claim 5, characterized in that transparent flat optics holders (10, 24) on which there are arranged small semitransparent and/or

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exclusively reflecting deflecting mirrors (12, 25) are provided for including the component beams (2a, b) and/or cutting out a portion of the beam coming from the object (6).

- 5 7. Device according to Claim 5 or 6, characterized in that immediately downstream of the main objective (18) the image information of the two component beams (2a, b) at the object (6) is imaged on a spatially resolving optoelectronic detector (27), the detector
10 (27) being connected to the evaluation unit (19), and the evaluation unit (19) being connected, if appropriate, to a distance display (21) and/or to a device for an autofocus (22), and/or to an output (23) for stereotactic measuring purposes.
- 15 8. Device according to one of Claims 5-7 for carrying out a method using pulse-modulated component beams (2a, b), characterized in that the radiation source (3) is assigned a beam-splitting device (17) upstream of which there is arranged a shutter wheel
20 (14) or a rotatable pinhole stop (14) or LCD shutter elements.
9. Device according to one of the preceding Claims 5-8, characterized in that the light of the component beams (2a, b) is selected to be in the infrared region.
- 25 10. Device according to one of Claims 5 to 9, characterized in that additional beam-splitting mirrors (12c, d) are arranged in the beam path so as to produce two component beams S2' and S2" which can be evaluated with regard to determining the magnification of the
30 optical system (compare PCT/EP/01311).



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