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INT CL⁵ A61B**(54) Ophthalmoscopic attachment for surgical microscopes**

(57) An ophthalmoscopic attachment 1 for a surgical microscope 13 accommodates an optical system 14 which erects an inter-image of the eyeground or areas of the vitreous body produced by one or several ophthalmoscopic lenses 8 and interchanges the optical viewing paths. In so doing, the optical system 14 is located directly behind the produced inter-image where the stereoscopic optical viewing paths are still intertwined. Said optical system 14 is configured either as a triplet with field lenses or as a straight-view inversion prism. A lens 15 which can be moved between the optical system 14 and the end of the attachment 1 adjacent to the main lens 5a, b is used to put the critical section of the eye into focus.

FIG.1

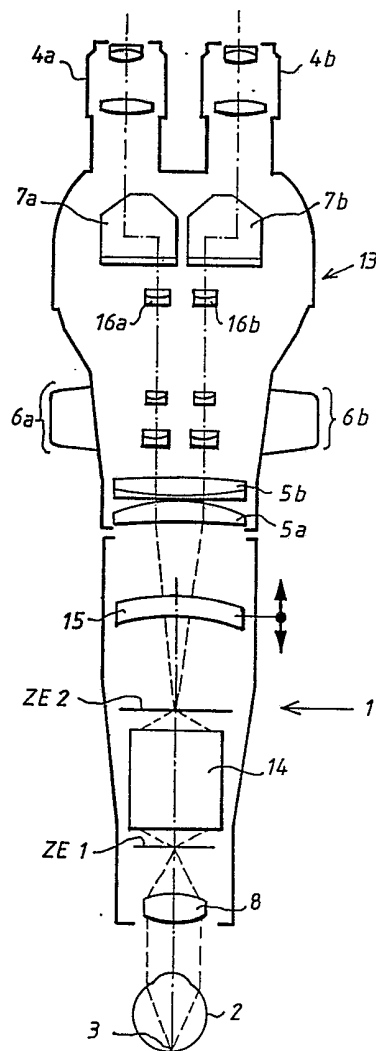
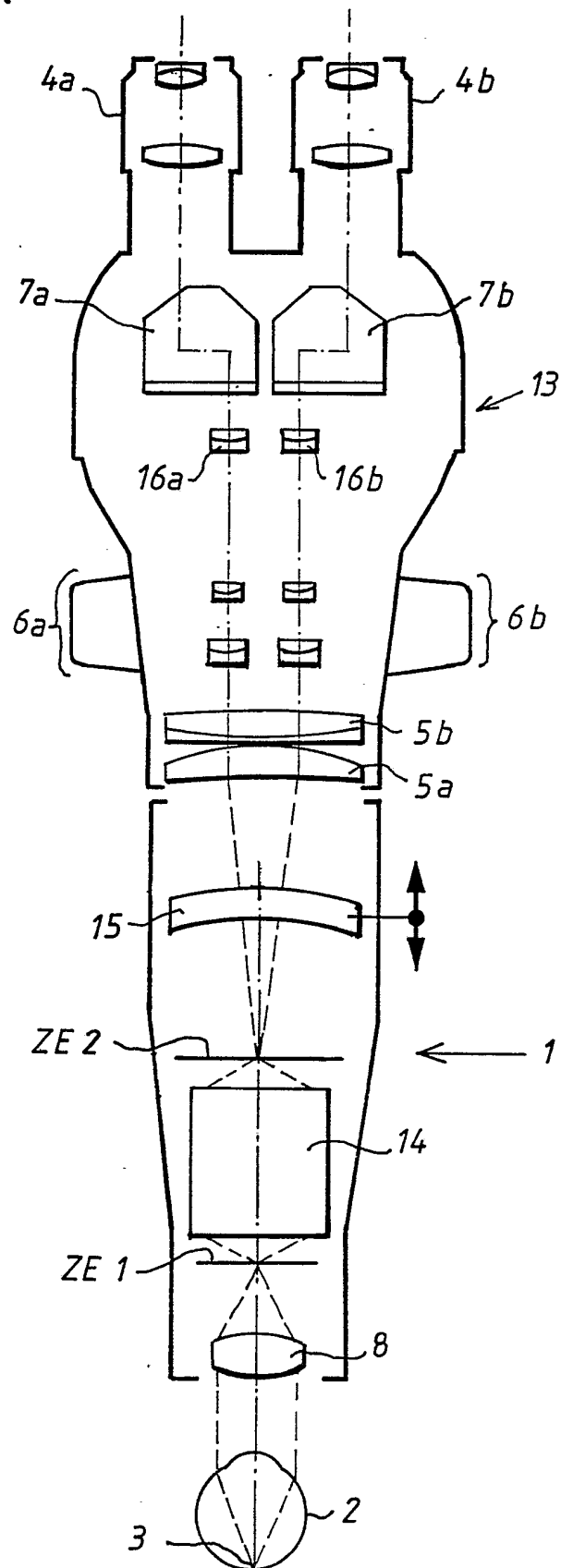
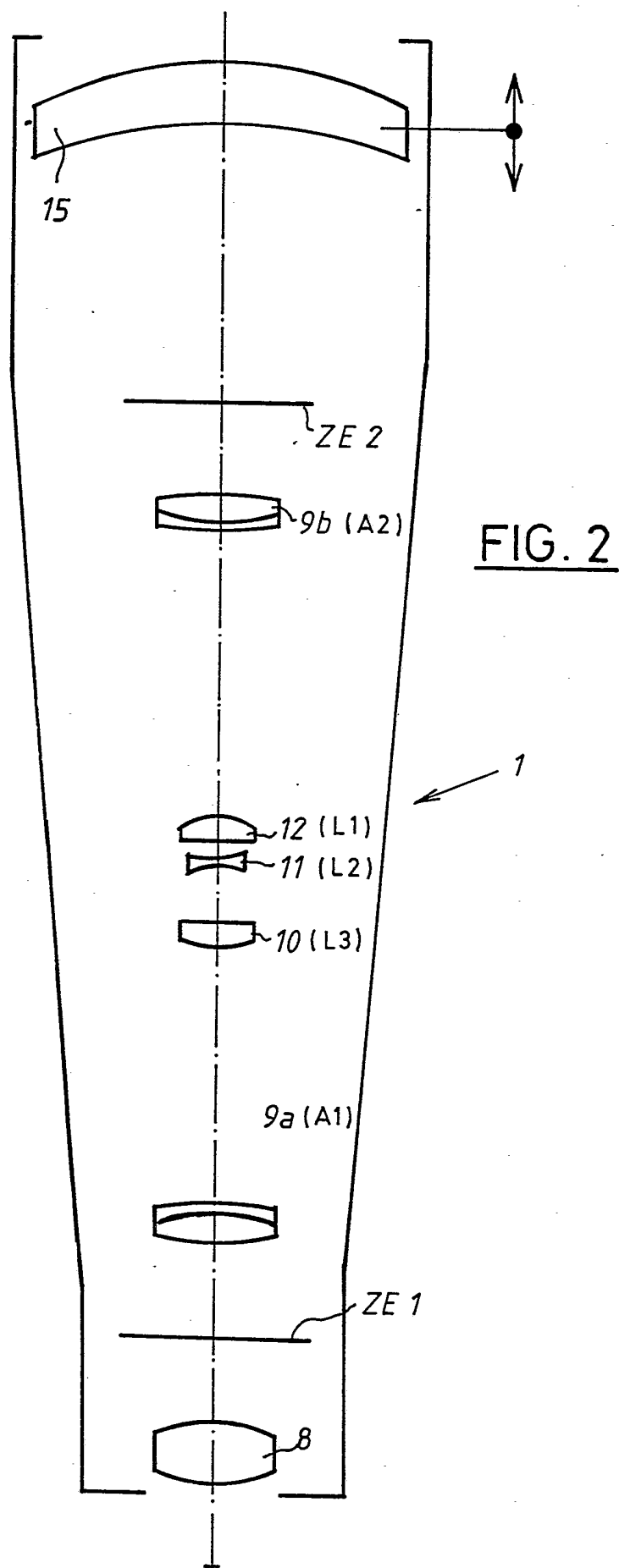
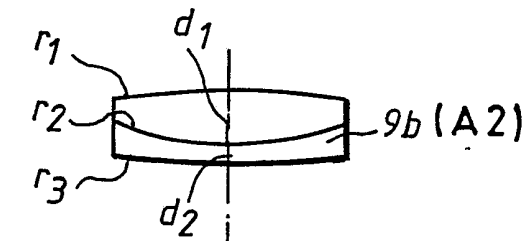
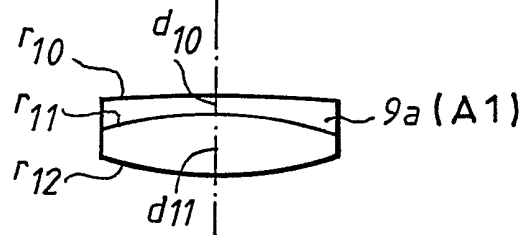
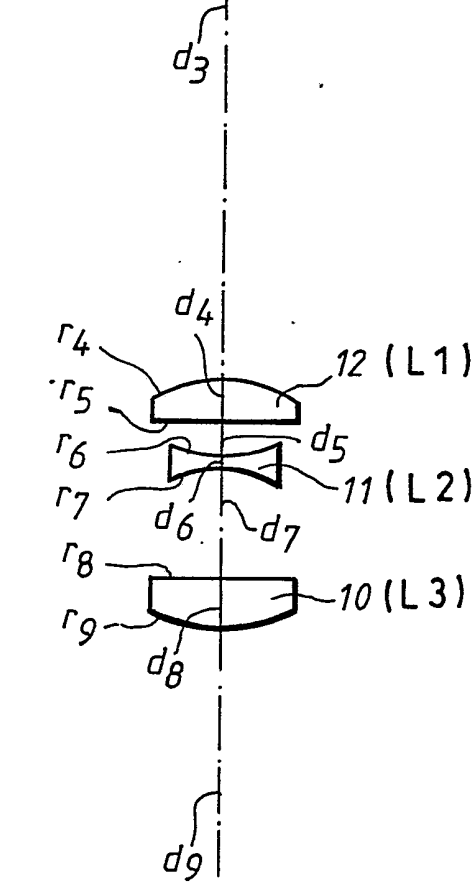


FIG.1



FIG. 3

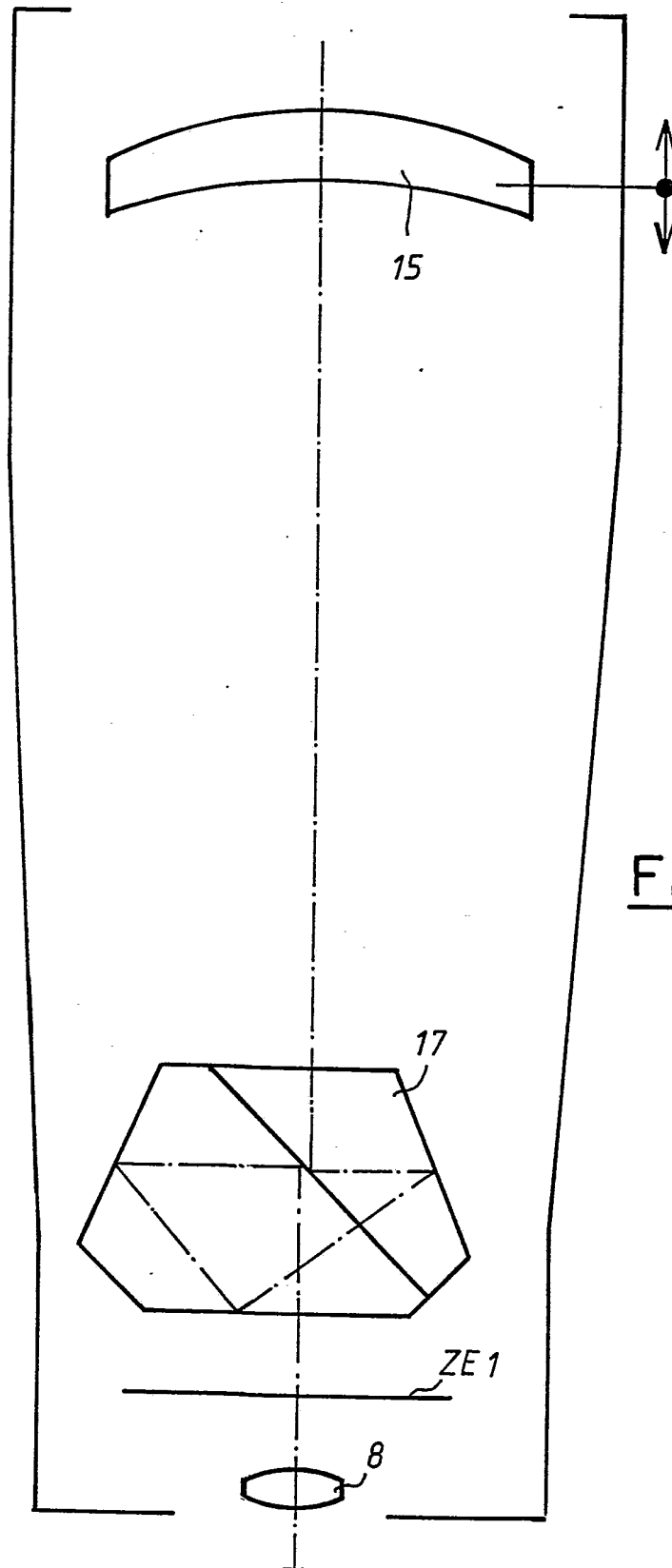


FIG. 4

Specification:

Ophthalmoscopic Attachment for a Surgical Microscope

The invention herein relates to an ophthalmoscopic attachment for a surgical microscope in accordance with the preamble of Claim 1.

In order to be able to view the fundus of the vitreous body of the human eye or regions near the fundus an inter-image of the viewed part of the eye is generated by means of an ophthalmoscopic lens, which said inter-image is viewed by means of a surgical microscope. The image viewed in this manner is inverted vertically and laterally, and is pseudo-stereoscopic, i.e. depth perception is inverted in front and in back. In order to be able to perform microsurgery, however, a stereoscopically correct image must be "right side up". Along with the required image erection the two viewed optical paths must be interchanged (pupil interchange) in order to prevent the occurrence of the pseudo-stereo effect which would otherwise occur during stereoscopic viewing.

Image erection and pupil interchange may take place by means of a prism system which is additionally provided between the binocular tubes and magnification changers on the surgical microscope. Such a prism system is described, for example, in DE-OS 35 07 458. This additional module increases the working distance between the eye of the patient and the pupil of the viewer. However, for ergonomic and practical reasons such a change of the working distance is undesirable in medical applications. Furthermore, such a prism system represents a complex solution when another viewer is supposed to work on a second binocular tube. Said second tube would then require an appropriate second such prism system.

DE-OS 35 39 009 and DE Utility Model G 89 02 035.9 suggest another possible solution. In this case the ophthalmoscopic lens and a system for reversing the generated inter-image area accommodated in an attachment on the surgical microscope. In this case an appropriate prism system is located directly in front of the main lens of the surgical microscope. In this case the section of the eye of interest is focused with the actual surgical microscope which has a two-element main lens; in this case one lens module can be shifted relative to the other. Therefore, each time this attachment is installed or interchanged, the surgical microscope must be re-focused, which is quite a problem during surgery. Another disadvantage of providing an inversion system directly in front of the main lens is that at this point partially still over-lapping divergent optical paths are separated spatially completely by two separate inversion systems. As a result of this, these two optical paths are partially blocked out, i.e., the result are image errors in the surgical microscope (vignetting). Such a system has the additional disadvantage that the two-element main lens of the used surgical microscope results in a greater length of this module of the system which does not meet the surgeon's requirement of the largest possible operating range.

Therefore, the problem to be solved by the present invention is to provide an ophthalmoscopic attachment for a surgical microscope, which said attachment permits the vertical inversion of an inter-image produced by an ophthalmoscopic lens which interchanges the optical viewing paths and the optional use of a conventional surgical microscope in a conventional manner or as ophthalmoscope, without requiring changes on the surgical microscope. In so doing, the ophthalmoscopic attachment must assure that an inter-image without image errors can be viewed through the surgical

microscope. Furthermore, this attachment should permit stereoscopic viewing by another viewer, merely requiring another binocular tube.

This problem has been solved by an ophthalmoscopic attachment in accordance with the characterizing portion of Claim 1.

The ophthalmoscopic attachment of the invention herein accommodated an optical system which produces the desired image erection of the inter-image produced by an ophthalmoscopic lens or an ophthalmoscopic lens system in a first inter-image plane. In addition, the optical system interchanges the optical viewing paths (pupil interchange). Image erection and pupil interchange in this case occur directly behind the first inter-image plane where the stereoscopic optical viewing paths do not yet run completely separately but are still intertwined with each other. The erected, unreversed image may then be viewed stereoscopically correct with the conventional surgical microscope without requiring additional adjustments of said surgical microscope. Furthermore, said attachment accommodates a focusing lens between the relevant optical system and the end of the attachment, adjacent to the main lens. Said focusing lens may be moved along the optical axis. This lens is used to focus on the critical section of the eye. In so doing, the focus is adjusted on the inventive attachment without requiring an adjustment on the actual surgical microscope. The viewing mode through the surgical microscope, i.e., the surgical microscopic with the ophthalmoscopic attachment, may be changed rapidly by the operator without requiring time-consuming focus adjustments on the surgical microscope each time the viewing mode is changed. With the use of an appropriate pivoting mechanism for the inventive attachment, the viewing mode may be changed rapidly. Therefore, the operating distance between the patient's eye and the viewer's

eye remains constant even when the inventive attachment is installed. Therefore, this attachment can be optionally used with any conventional surgical microscope. When additional viewers are involved, only a single such attachment is required. In this case additional viewers use additional binocular tubes and the same main-lens. Image erection and pupil interchange are effected either by the optical system, which consists of two field lenses and a triplet, or by a straight-view inversion prism located in the inventive attachment.

Two examples of embodiments of the invention will be explained in detail hereinafter by means of the enclosed drawings Figs. 1 - 4.

Figure 1 shows a surgical microscope with the inventive ophthalmoscopic attachment, whereby the optical system for image erection and pupil interchange is configured as a lens system,

Figure 2 shows said inventive ophthalmoscopic attachment of Figure 1 with the corresponding lens system,

Figure 3 is a sectional view of the lens system of Figure 2 with the relevant identification of the lens radii, lens thicknesses and lens distances,

Figure 4 shows the inventive ophthalmoscopic attachment accommodating a straight-view inversion prism for image erection and pupil interchange.

Figure 1 shows a surgical microscope (13) which comprises, in front of the main lens (5a, b), the inventive ophthalmoscopic attachment (1) accommodating an optical system (14) for image erection and pupil interchange. The ophthalmoscope attachment

(1) has on the side facing the eye (2) an ophthalmoscopic lens (8) which produces in the first inter-image plane ZE1 a vertically and laterally inverted image of the viewed fundus (3). By means of the adjoining optical system (14) (in this example of embodiment a lens arrangement) the image is erected and projected unreversed in a second inter-image plane ZE2. The image in said inter-image plane ZE2 is viewed through the actual surgical microscope (13). In so doing, this surgical microscope (13) is constructed in a manner known per se. Hence, the magnification controls (6a, b), as well as the tube lenses (16a, b) and the inversion prisms (7a, b) for the two separate optical paths, are located behind one main lens (5a, b). Stereoscopic viewing takes place through the binocular tubes (4a, b). The use of one main lens (5a, b) for both optical viewing paths is not specific to the present invention. It is also possible to provide a separate lens for each of the two optical viewing paths.

Furthermore, Figure 1 shows a lens (15) which is mounted between the optical system (14) and the end of the attachment (1) adjacent to the main lens (5a, b) so that it may be moved along the optical axis. By means of this lens (15) it is possible to focus on the critical section of the eye (2) without requiring a change on the actual surgical microscope (13). By means of a pivoting device (which is not illustrated in Figure 1) it is possible to use the surgical microscope optionally in a conventional manner, as well as in eye surgery.

Figure 2 shows the inventive ophthalmoscopic attachment (1) which accommodates the optical system for image erection and pupil interchange; in this example of embodiment said attachment is configured as an optical system with several lenses (9a, 10, 11, 12, 9b). The ophthalmoscopic lens (8)

located on the side of the attachment (1) facing the patient's eye produces in the inter-image plane ZE1 a vertically and laterally reversed image of the viewed part of the eye. Said image is erected on a scale of 1:1 by the subsequent five lenses (9a, 10, 11, 12, 9b) and projected unreversed in the inter-image plane ZE2. The actual image formation occurs by means of a triplet which comprises two lenses exhibiting positive refractive power (L3:10, L1:12) and one interposed lens exhibiting negative refractive power (L2:11). Two additional lenses (A1:9a; A2:9b) act as field lenses. A lens (15) is moved along the optical axis inside the attachment (1) whereby the critical section of the eye is put into focus. The image produced in the inter-image plane ZE2 is viewed with the surgical microscope (13).

In order to be able to fit the optical system into an appropriate attachment which is dimensionally not too long the individual elements of said optical system can be accommodated inside said attachment not in a linear manner but such that the optical projection path is deflected.

Considering a lens system which consists of a triplet (L1:f₁; L2:f₂; L3:f₃) and two field lenses (A1:9a; A2:9b) and which has been color-corrected for the wavelength ranges 436 nm, 480 nm, 546 nm and 644 nm in the visible spectral region, the focal length ratios which can be realized with a focal length of the main lens of 200 mm are within the following ranges:

$$\begin{aligned} f_3 : f_1 &= [0.9 \dots 2.0] \\ - f_2 : f_1 &= [0.4 \dots 0.6] \end{aligned}$$

Within these ranges an acceptable length of the ophthalmoscopic attachment can be attained, thereby offering

a large operating area beneath the surgical microscope. In addition, the optical system assures a high-quality image.

Examples of embodiment and their corresponding data sets are listed in Tables 1 through 3. Variation of the individual parameters of these data sets may lead to comparably good imaging results.

Figure 3 shows a sectional view of the optical system of Figure 2 identifying the lens radii (r_i), lens thicknesses (d_i), and lens distances (d_i), as used in the data sets of Tables 1 through 3.

Figure 4 shows a second example of embodiment of the inventive attachment (1) which accommodates an optical system for image erection and pupil interchange which, in this case, is configured as a straight-view inversion prism system (17). The inter-image of the fundus or areas near the fundus of the vitreous body of the eye is erected by a straight-view Schmidt-Pechan prism having a roof (17) directly behind the first inter-image plane ZE1, and the optical viewing paths are interchanged. It is also possible to use a mirror system fulfilling essentially the same function. The position of the inversion prism (17) at the point where the stereoscopic optical paths are intertwined permits a very compact construction of the invention prism (17) or the inventive attachment (1) because the total optical path exhibits its smallest expansion at this point. Furthermore, the inventive attachment (1) accommodates a focusing lens (15) between the inversion prism (17) and the end of the attachment adjacent to the main lens (9a, b). Said focusing lens (15) can be moved along the optical axis and is used to focus on the critical section of the eye.

Claims:

1. Ophthalmoscopic attachment (1) for a surgical microscope (13) consisting of a main lens (5a, b) and one or several stereoscopic viewing tubes (4a, b), characterized in that
 - said attachment (1) accommodates one or several ophthalmoscopic lenses (8) for producing an image of the fundus or of areas of the vitreous body of the eye,
 - an optical system (14; 9a, 10, 11, 12, 9b; 17) is located behind said ophthalmoscopic lens (8) or said ophthalmoscopic lenses for erecting the image and interchanging the optical viewing paths,
 - a lens (15), which can be moved along the optical axis and is used to focus on the critical part of the eye, is positioned between said optical system (14; 9a, 10, 11, 12, 9b; 17) and the end of said ophthalmoscopic attachment (1) adjacent to the main lens (5a, b).
2. Ophthalmoscopic attachment (1) in accordance with Claim 1, characterized in that the optical system is configured as an optical system which consists of two field lenses (9a, b) and, positioned between the latter, a triplet of two lenses displaying positive refractive power (10, 12) and one lens (11) displaying negative refractive power interposed between the latter two.
3. Ophthalmoscopic attachment (1) in accordance with Claims 1 and 2, characterized in that said optical system (9a, 10, 11, 12, 9b) produces an image of the inter-image produced by the ophthalmoscopic lens (8) at an object-to-image ratio of 1:1.

4. Ophthalmoscopic attachment (1) for a surgical microscope with a main lens having a focal length of 200 mm in accordance with Claims 1 through 3, characterized in that, with the use of a color-error-corrected lens system consisting of a triplet (10, 11, 12) and two field lenses (9a, 9b), the focal length ratios ($f_3 : f_1$) and ($-f_2 : f_1$) of the triplet lenses (L1, 12, f_1 ; L2 : 11, f_2 ; L3 : 10, f_3) are within the following ranges:

$$\begin{aligned} f_3 : f_1 &= [0.9 \dots 2.0] \\ -f_2 : f_1 &= [0.4 \dots 0.6] \end{aligned}$$

5. Ophthalmoscopic attachment (1) in accordance with Claims 1 through 4, characterized in that the lenses (9a, 10, 11, 12, 9b) of the optical system used produce the data for lens radii (r_i), lens thicknesses (d_i), lens distances (d_i), the indices of refraction (n) (546 nm), and the Abbe Numbers (ν_e) for different types of glass or values which result in a comparable high-quality image by varying the individual parameters based on said data set as listed in Table 1.

Table 1

$(f_3 : f_1 = 2.0, -f_2 : f_1 = 0.545)$

Lens	Radius r_i / mm	Thickness d_i / mm	Distance d_i / mm	Refractive Index n (546)	Abbe Number ν_e
	$r_1 = 42.9911$				
		$d_1 = 3.000$		1.68637	44.2
A2	$r_2 = -18.9821$				
		$d_2 = 1.000$		1.81265	25.2
	$r_3 = -59.2871$				
			$d_3 = 30.750$		
	$r_4 = 6.4576$				
L1		$d_4 = 2.500$		1.80730	46.1
	$r_5 = -140.0550$				
			$d_5 = 1.948$		
	$r_6 = -8.7323$				
L2		$d_6 = 0.600$		1.81265	25.2
	$r_7 = 5.7935$				
			$d_7 = 6.175$		
	$r_8 = 925.3580$				
L3		$d_8 = 2.500$		1.80730	46.1
	$r_9 = -12.3903$				
			$d_9 = 27.530$		
	$r_{10} = 86.8200$				
		$d_{10} = 1.000$		1.81265	25.2
A1	$r_{11} = 17.1400$				
		$d_{11} = 3.000$		1.68637	44.2
	$r_{12} = -31.4353$				

6. Ophthalmoscopic attachment (1) in accordance with Claims 1 through 4, characterized in that the lenses (9a, 10, 11, 12, 9b) of the optical system used produce the data for lens radii (r_i), lens thicknesses (d_i), lens distance (d_i), the indices of refraction (n) (546 nm), and the Abbe Numbers (ν_e) for different types of glass or values which result in a comparable high-quality image by varying the individual parameters based on said data set as listed in Table 2.

Table 2

$(f_3 : f_1 = 1.66, -f_2 : f_1 = 0.56)$

Lens	Radius r_i / mm	Thickness d_i / mm	Distance d_i / mm	Refractive Index n (546)	Abbe Number ν_e
	$r_1 = 42.9911$				
		$d_1 = 1.696$		1.68637	44.2
A2	$r_2 = -18.9821$				
		$d_2 = 0.848$		1.81265	25.2
	$r_3 = -59.2871$				
			$d_3 = 32.070$		
	$r_4 = 7.9988$				
L1		$d_4 = 2.500$		1.80730	46.1
	$r_5 = -106.2270$				
			$d_5 = 2.620$		
	$r_6 = -9.5154$				
L2		$d_6 = 0.600$		1.81265	25.2
	$r_7 = 7.7269$				
			$d_7 = 4.940$		
	$r_8 = -148.7780$				
L3		$d_8 = 2.500$		1.80730	46.1
	$r_9 = -11.5635$				
			$d_9 = 28.490$		
	$r_{10} = 86.8223$				
		$d_{10} = 0.848$		1.81265	25.2
A1	$r_{11} = 17.1339$				
		$d_{11} = 1.696$		1.68637	44.2
	$r_{12} = -28.2267$				

7. Ophthalmoscopic attachment (1) in accordance with Claims 1 through 4, characterized in that the lenses (9a, 10, 11, 12, 9b) of the optical system used produce the data for lens radii (r_i), lens thicknesses (d_i), lens distances (d_i), the indices of refraction (n) (546 nm), and the Abbe Numbers (ν_e) for different types of glass or values which result in a comparable high-quality image by varying the individual parameters based on said data set as listed in Table 3.

Table 3

$(f_3 : f_1 = 0.88, -f_2 : f_1 = 0.40)$

Lens	Radius r_i / mm	Thickness d_i / mm	Distance d_i / mm	Refractive Index n (546)	Abbe Number ν_e
	$r_1 = 30.5000$				
		$d_1 = 3.000$		1.68637	44.2
A2	$r_2 = -18.9820$				
		$d_2 = 1.000$		1.81265	25.2
	$r_3 = -59.2870$				
			$d_3 = 31.687$		
	$r_4 = 5.9576$				
L1		$d_4 = 2.500$		1.61521	58.4
	$r_5 = 50.5546$				
			$d_5 = 3.277$		
	$r_6 = -6.0844$				
L2		$d_6 = 1.000$		1.65222	33.6
	$r_7 = 5.4845$				
			$d_7 = 2.333$		
	$r_8 = 17.7756$				
L3		$d_8 = 2.500$		1.61521	58.4
	$r_9 = -8.1069$				
			$d_9 = 23.117$		
	$r_{10} = 86.8200$				
		$d_{10} = 1.000$		1.81265	25.2
A1	$r_{11} = 17.1400$				
		$d_{11} = 3.000$		1.68637	44.2
	$r_{12} = -30.5299$				

8. Ophthalmoscopic attachment (1) in accordance with Claim 1, characterized in that the optical system is configured as a straight-view inversion prism system (17) or as a mirror system performing the same function, effecting image erection and an interchange of the optical viewing paths.
9. Ophthalmoscopic attachment (1) in accordance with Claims 1 and 6, characterized in that the optical system is configured as a Schmidt-Pechan prism having a roof (17) or as a mirror system exhibiting the same beam path.
10. Ophthalmoscopic attachment (1) in accordance with Claim 1 and one or more of the following claims, characterized in that said attachment may be positioned in front of the main lens (5a, b) of a surgical microscope (13) by means of a pivoting device.
11. Surgical microscope with an ophthalmoscopic attachment in accordance with Claim 1 and one or more of the following claims, characterized in that said microscope is used in eye surgery in order to produce an enlarged image of the eyeground (fundus of the eye) or parts of the vitreous body.

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Examiner's report to the Comptroller under
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Search Examiner

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Databases (see over)

(i) UK Patent Office

(ii)

Date of Search

14 JULY 1992

Documents considered relevant following a search in respect of claims

1-11

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
X	GB 2005436 A (CARL ZEISS) - see especially the figure	1 at least
P,X	WO 91/15150 A1 (LEUVEN) 17 OCTOBER 1991 - see especially Figure 3	1 at least
X	US 4989023 (TOPCON) - see especially Figure 1, parts 23, 25, 29	1 at least

Category	Identity of document and relevant passages	Relevant to claim(s)

Categories of documents

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