Optical designs of the MicroFluar objectives for microscope – a compromise in the aberration correction

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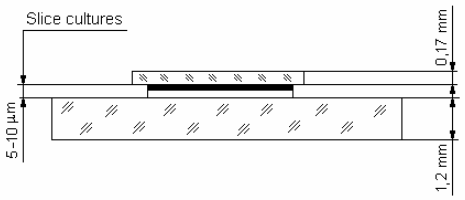
Abstract: The obtaining a compromise aberration correction objectives for visual observation under a biological microscope. Well know, that objective is the most difficult and expensive element of the microscope optical system. This case, using of non so many elements objective give the opportunity to reduce the microscope price. But, the technical parameters of new objectives correspond better results of optical resolution

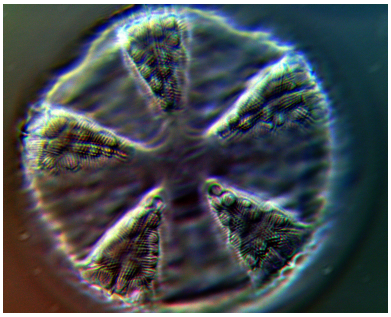
OCIS codes: (180.0180) Microscopy; (220.0220) Optical design and fabrication; (220.3620) Lens system design

1. Introduction: Description of the model specimen

Figure shows the object to be studied with a biological microscope. In a general case, it is a specimen, i.e. a thin slice of matter or a smear glued with one of its side to the object plate with the opposite one glued up with the coverglass.



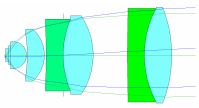
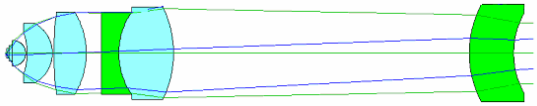
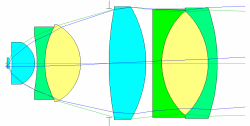
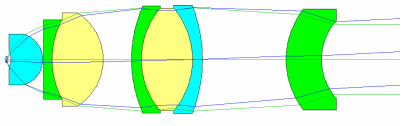
2. Depth of focus in real object



Microscopists are aware that different fragments of an object to be studies are usually located at different heights from the object plate (and coverglass). For a high magnification and high aperture objectives this spread is 5-10 times more than its focal depth. This circumstance requires to review the object "in depth" (by refocusing the microscope). When you achieve exact focusing on a fragment, you may expect that images of other ones (even those located in the vicinity but at other depth) wouldn't be sharp. And it is the point of a wide spread method of visual microscopy, when the researcher selects the "location depth" for the most interesting fragment of the biological culture.

3. Old Zeiss objectives upgrade

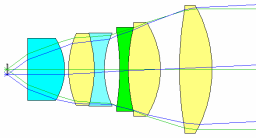
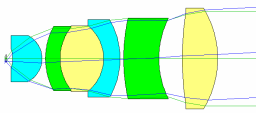
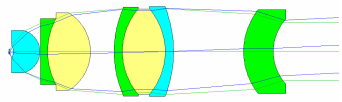
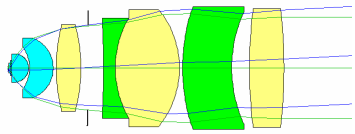
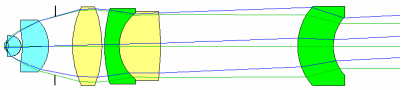
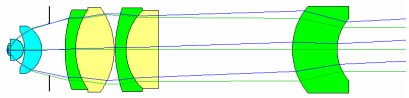
The optical designs of old "Zeiss" achromats and apochromats allow to correct the chromatic focal shift, reduce the secondary spectrum aberration in achromats and correct it in apochromats. But they have not elements for correction of curvature and lateral color. The initial new was to add to the initial classical design of an achromat or apochromat a negative long-focus (near the afocal) concave-convex lens turned with its concavity to the image space and made of the optical "heavy flint" optical glass. This element is used in a number of modern high-magnification objective. Moreover, such component is so universal that achromat and apochromat objectives have been optically designed to achieve much better aberration correction as compared with old achromats and apochromats. Mainly, due to considerable reduction of field curvature and LC aberration. The optical design has not been more complicated with the same number of lenses. The next table illustrates this statement.

Old classical design of objectives	New design of objectives
100x/1.25 oil achromat 	100x/1.30 oil PLAN achromat 
40x/0.95 apochromat 	40x/0.95 PLAN fluor 

4. Practical recommendation of aberration correction

We can develop technical requirements for designing high-aperture achromatic and apochromatic objectives for visual biological microscopy. For 10x objective the aberration must be corrected more carefully. 20x objective can have a high numerical aperture but also certain compromises for correction of such aberrations as field curvature and LC. We believe that 40x objective must be corrected more carefully as to the curvature aberration. When maximum linear magnification (100x immersion objectives) are achieved, the curvature aberration must be reduced by 2 times (relative to classical achromats and Abbe's apochromats).

The next table shows the main technical parameters and basic optical layout of new objectives.
This design for an infinite length of the microscope tube, using additional focusing system F = 200 mm:

Magnification	NA	WD (mm)	F' (mm)	R (μm)	DF (μm)	FOV on object (mm)	FOV on image (mm)	Remark (screw)	The principal optical layout
10x	0.40	3.77	20.0	0.84	2.10	2.2	22	0.8"	
10x	0.60	3.6	20.0	0.56	0.93	2.2	22	M25 or more	
20x	0.80	0.60	10.0	0.42	0.52	1.1	22	0.8" or more	
40x	0.95	0.17	5.0	0.35	0.37	0.55	22	0.8" or more	
50x	1.20 water	0.14	4.0	0.28	0.23	0.44	22	0.8" or more	
50x	1.30 oil	0.16	4.0	0.26	0.20	0.44	22	0.8" or more	
100x	1.20 water	0.12	2.0	0.28	0.23	0.22	22	0.8" or more	
100x	1.35 oil	0.16	2.0	0.25	0.18	0.22	22	0.8" or more	

5. Practical results

It is necessary to make a comment about a possible compromise in correcting curvature aberration and lateral color in a visual observation under a microscope. It has become an important precondition **for the design of new objectives for the microscope, which manufactured and available to microscopists**: