Engineering solutions and synthesis of optics for visualization systems of light microscopes

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Abstract. An overview of existing technical solutions for creating visualization systems for light microscopes is presented. Theoretical and practical aspects of the design of optical systems are considered taking into account the projection of the image of the object on the electronic receiver. The analysis of the basic tendencies in development of modern visualization systems for light microscopes is made. It is necessary to fulfill the basic requirements that ensure correlation when observing images in the eyepieces and using a visualization system. System must to transfer to the receiver linear image of the microscope corresponding to the resolution of the used objective.

1. Introduction. Today, the market offers a very limited number of proposals for imaging and photographing systems from a microscope. The systems can be divided into several types depending on the receiver used and the matching optical scheme:

- video (or digital) eyepiece. Such a design solution allows obtaining a convenient and compact device that can be used instead of the standard eyepiece of the microscope. There is also a monitor.

- based on digital cameras, the so-called "Soaps". In this case, an additional opto-mechanical adapter is required that matches the aberration (aberrations of the camera objective are unacceptably large for microscopy) and the overall optical systems of the microscope and camera. There is also a monitor.

- on the basis of a digital photographic camera, more precisely, the so-called Body (without lens). It has obvious advantages in terms of simplicity and reliability in comparison with other systems, since the image on the receiver is transmitted directly from the objective lens of the microscope "as is" without the participation of any additional optics. The optical quality of such a system depends only on the characteristics of the standard objective of the microscope. There is also a monitor.

- based on a visualization system integrated in a microscope, consisting of a digital camera and a monitor in the form of a single structural module fixed to a microscope tripod. There is a fairly "radical" version of such a system, in which there is no possibility of observation through the eyepieces.

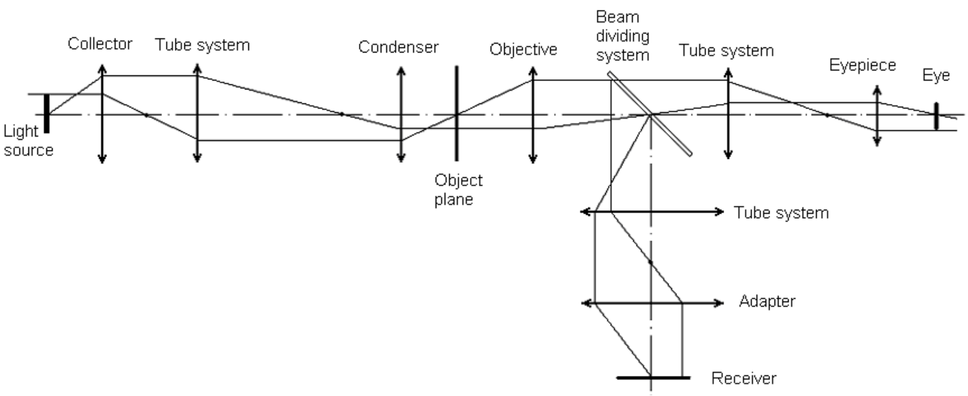

Figure 1. The principal optical scheme of a light microscope with a visualization system.

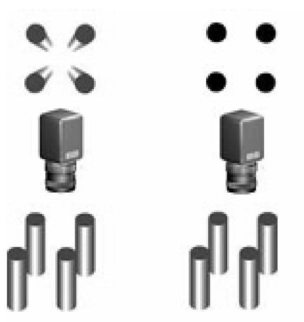

Figure 2. Comparing images obtained with a conventional and telecentric system.

2. Optical designs of different objectives.

We made two optical designs that fit the proposed concept. In the first case, the calculation of the objective lens 20x0.70 is given, the correction type CCF planapochromat. In this case, the projective of the visualization system will also have a CCF degree of correction (i.e. practically free of its own aberrations).

In the second case, the objective is a microfluar 20x0.80, which is characterized by residual aberrations of curvature and lateral (secondary) chromatizm. In this case, the projective must have compensation values of aberrations, for the resulting image quality when working with such an objective will also very good.

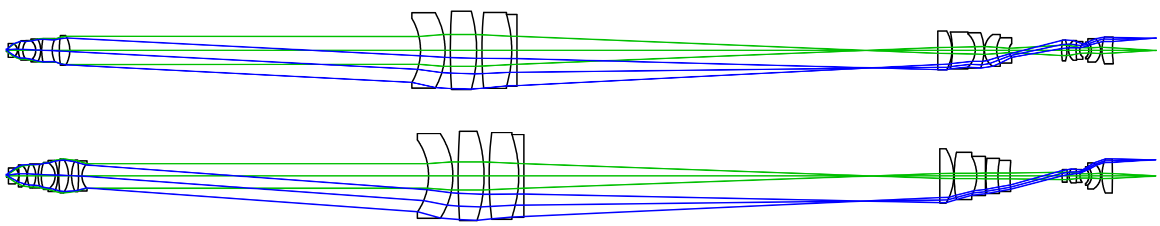

Figure 3. Two optical schemes of a light microscope with a visualization system.

Table 1. Design parameters of two objectives and systems of visualizations.

Lens: 20/0.80+tubsys+adapter

Object num aper 0.800000 Object height 0.500000 Primary wavln 0.546070

SRF	RADIUS	THICKNESS	APERTURE RADIUS	GLASS	SPECIAL
OBJ	0.000000	0.010000	0.500000	AIR	
AST	0.000000	0.170000	0.510000 A	K9	
2	0.000000	1.003200	0.620000	AIR	
3	-4.564000	5.000000	1.580000	H-LAK2	
4	-4.368000	0.580000	3.910000	AIR	
5	11.250000	2.500000	5.440000	ZF6	
6	8.395000	7.400000	5.250000	CAF2	
7	-7.060000	2.800000	5.550000	H-LAK2 P	
8	-12.953000	0.600000	6.540000	AIR	
9	31.220000	6.000000	6.820000	ZF3	
10	14.791000	4.000000	6.680000	AIR	
11	53.270000	6.000000	7.870000	CAF2	
12	-16.200000	200.000000	8.500000	AIR	
13	-36.100000	14.000000	18.320000	H-K9	
14	-43.560000	3.000000	21.360000	AIR	
15	377.100000	15.000000	21.940000	CAF2	
16	-81.500000	3.000000	22.230000	AIR	
17	221.300000	17.000000	21.590000	CAF2 P	
18	-72.000000	3.000000	20.410000	H-LAK2 P	
19	0.000000	240.000000	20.230000	AIR	
20	0.000000	8.000000	10.910000	H-FK71	
21	-22.000600	0.300000	11.010000	AIR	
22	-48.729200	13.000000	10.440000	H-FK71 P	
23	-12.883700	5.000000	9.390000	H-LAK3	
24	-27.131600	0.300000	10.070000	AIR	
25	11.101200	7.000000	9.100000	H-FK71 P	
26	13.802200	7.000000	7.120000	H-ZF7LA	
27	5.559200	30.000000	3.890000	AIR	
28	37.607000	3.000000	5.770000	H-LAK2	
29	-22.810400	1.000000	5.910000	AIR	
30	7.278900	4.300000	5.670000	H-FK71 P	
31	53.255600	2.000000	4.990000	ZF1	
32	4.913900	5.200000	3.800000	AIR	
33	-5.572300	1.500000	4.090000	H-LAK4L	
34	-6.512900	5.200000	4.720000	H-FK71 P	
35	-9.169000	0.800000	6.610000	AIR	
36	20.114600	6.000000	7.670000	H-LAK3 P	
37	55.382000	24.994763 S	7.330000	AIR	
38	0.000000	0.000000	7.330000	AIR	
IMS	0.000000	0.000000	7.330000		

Lens: PLAPO 20/0.70+tubsys+adapter

Object num aper 0.700000 Object height 0.700000 Primary wavln 0.546070

SRF	RADIUS	THICKNESS	APERTURE RADIUS	GLASS	SPECIAL
OBJ	0.000000	0.010000	0.700000	AIR	
AST	0.000000	0.170000	0.630000 A	K9	
2	0.000000	1.305400	0.720000	AIR	
3	-3.500000	5.510000	1.610000	H-LAK3	
4	-6.109000	0.200000	4.540000	AIR	
5	-41.350000	4.600000	5.550000	CAF2	
6	-7.900000	0.200000	6.300000	AIR	
7	17.320000	4.800000	6.790000	CAF2 P	
8	-12.886000	1.400000	6.700000	ZBAF4	
9	22.180000	1.800000	6.840000	AIR	
10	22.590000	8.000000	7.440000	CAF2 P	
11	-9.330000	1.600000	7.700000	H-LAK3 P	
12	-22.000000	0.500000	8.850000	AIR	
13	65.350000	5.600000	9.480000	CAF2 P	
14	-18.232000	1.800000	9.700000	AIR	
15	20.430000	4.000000	8.930000	H_F2	
16	-79.360000	2.000000	8.570000	H-QK3	
17	10.130000	200.000000	7.090000	AIR	
18	-36.100000	14.000000	20.580000	K9	
19	-43.560000	3.000000	24.120000	AIR	
20	377.100000	15.000000	25.050000	CAF2	
21	-81.500000	3.000000	25.440000	AIR	
22	221.300000	17.000000	24.680000	CAF2	
23	-72.000000	3.000000	23.570000	H-LAK2	
24	0.000000	240.000000	23.380000	AIR	
25	0.000000	8.000000	15.380000	H-FK71	
26	-28.916000	0.300000	15.430000	AIR	
27	70.468400	13.000000	13.530000	H-FK71 P	
28	-22.894200	5.000000	11.110000	H-LAK3	
29	0.000000	0.300000	10.220000	AIR	
30	81.833500	7.000000	10.040000	H-FK71 P	
31	50.546100	7.000000	8.800000	H-ZF7LA	
32	105.863800	30.000000	7.670000	AIR	
33	219.518000	3.000000	3.190000	H-LAK2 P	
34	-28.482600	1.000000	3.600000	AIR	
35	7.124700	4.300000	4.020000	H-FK71 P	
36	-45.583400	2.000000	3.720000	ZF1	
37	5.842500	5.200000	3.460000	AIR	
38	-5.811300	1.500000	4.370000	H-LAK4	
39	-7.253300	5.200000	5.220000	H-FK71 P	
40	-8.706500	0.800000	7.360000	AIR	
41	25.240600	6.000000	9.710000	H-LAK3 P	
42	-567.556000	24.989229 S	9.690000	AIR	
43	0.000000	0.000000	9.690000	AIR	
IMS	0.000000	0.000000	9.690000		

3. Conclusion. Some suggestions for the creation of visualization systems for light microscopes are presented. The principal possibility of creating telecentric projection systems in a light microscope is shown. Presented optical designs of such systems. It is shown that the projection telecentric systems for visualization purposes can have both an independent degree of aberration correction and a compensating one. The use of the proposed concept of constructing a visualization system, as well as some practical technical solutions, can improve the quality of microscope research.