Optical design and unification of objectives – CCF PlanApo for 28 mm observation in the microscope

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Abstract. The main difference of the planapochromatic objectives is the extended working spectral range. However, other differences also in achieving increased numerical apertures and an extended linear field. The main challenge is the technical possibility of obtaining rational optical designs.

1. Introduction. Figure 1 shows pictures of diatomaceous algae. The photo on the left was obtained by using modern LCF (lateral color free) plan achromatic objective 40x0.70 created within our project. To the right there is the photo taken with use of older Zeiss apochromatic objective 40x0.95. Such color stain in the structure elements in the left image is not a priori present in the object. This stain appeared in the image because of achromatic aberration correction in objective.

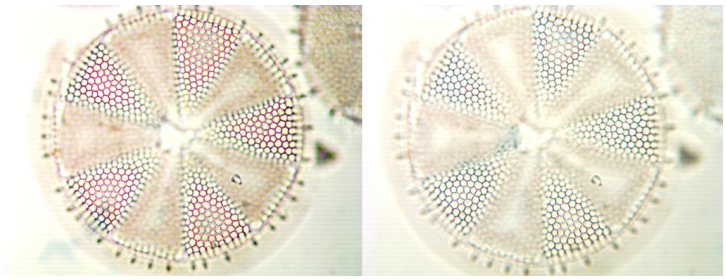


Figure 1. Images of diatomaceous algae use different objective system.

2. Optical designs of different objectives.
Many microscopes operate by the "infinity" principle, when the observed subject is located in the front focal plane of an objective. This microscope provides images using an additional tube system, an image is created in the rear focal plane of this system. In this case an objective optical design is performed for the infinite tube length, and a parametric series of objective focal lengths is determined by the formula $F'_{ob} = \frac{F'_{ts}}{V_{ob}}$, where F'_{ts} is the equivalent focal distance of the tube system, which creates a subject image in its rear focal plane, V_{ob} – linear magnification of objective. Historically, different manufacturers of microscopes have chosen the original dimensional standards for their microscopes. In particular, different values of equivalent focal length have been selected for tube systems. Accordingly, different parametric series of objectives are used. Obviously, it is possible to obtain same magnification in the image plane by different combinations of objectives and tube systems.

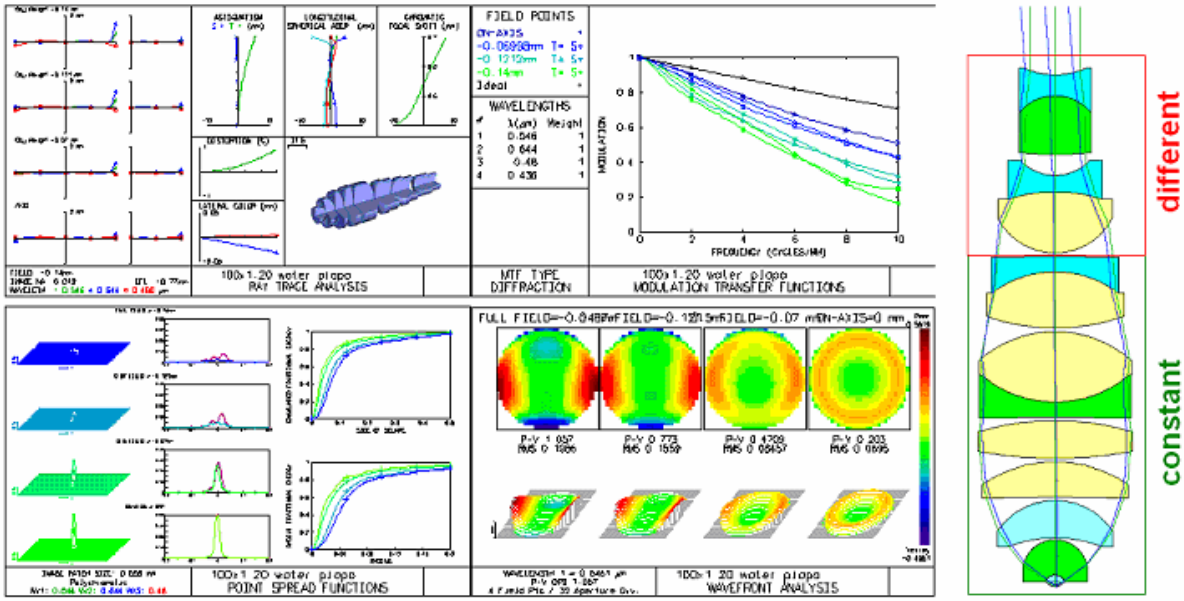


Figure 2. Synthesis different F' plan apochromatic 100x water immersion objective.

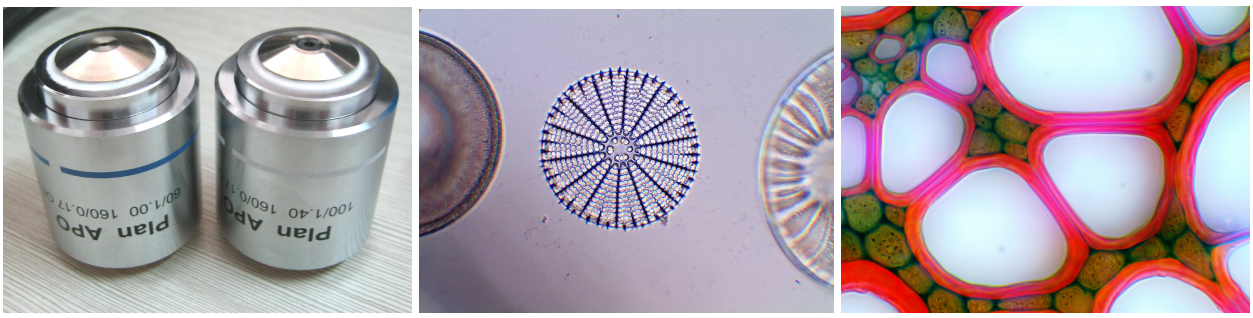
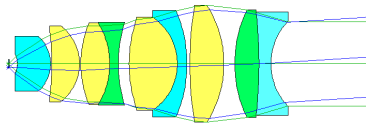
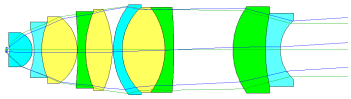
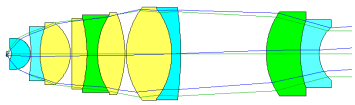
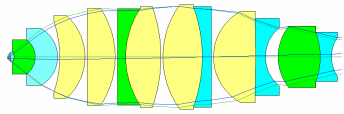
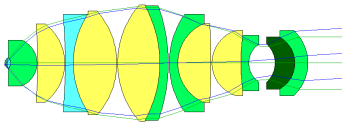
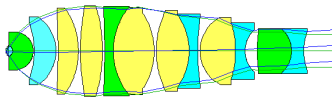
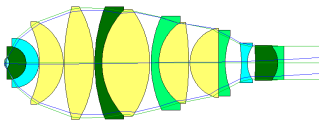


Figure 3. Picture of two objectives and photos of two objects from planapochromatic objective 60x1.0 oil immersion.

Table 1. Main technical parameters and the basic optical layouts of the objectives.

Magnification (V_{ob})	NA	WD (mm)	R (μm)	DF (μm)	FOV on object (mm)	FOV on image (mm)	The principal optical layout	Note
20x	0.70	1.0	0.48	0.68	1.4	28		F'_{ts}=164 F'_{ts}=180 F'_{ts}=200
40x	0.90	0.20	0.38	0.41	0.70	28		F'_{ts}=164 F'_{ts}=180 F'_{ts}=200
60x	0.92	0.18	0.37	0.40	0.47	28		F'_{ts}=164 F'_{ts}=180 F'_{ts}=200
60x	1.00 Oil	0.18	0.33	0.33	0.47	28		Finity 160 F'_{ts}=164 F'_{ts}=180 F'_{ts}=200
60x	1.20 Oil	0.18	0.28	0.23	0.47	28		F'_{ts}=164 F'_{ts}=180 F'_{ts}=200
100x	1.20 Water	0.09	0.28	0.23	0.28	28		Finity 160 F'_{ts}=164 F'_{ts}=180 F'_{ts}=200
100x	1.40 Oil	0.11	0.24	0.17	0.28	28		Finity 160 F'_{ts}=164 F'_{ts}=180 F'_{ts}=200

3. CONCLUSION. Using original methods for creation of unified designs for plan apochromatic microscope objectives significantly reduces the cost of production and the cost of objectives.

We developed the optical design for microscope objectives with independent aberration correction and linear field of view of 28 mm. This approach provides an opportunity for supplying new objectives for different models of microscopes.