# Optical design of high-aperture lens objectives for NUV and DUV spectral ranges

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**Abstract.** The aspects of the use of dioptric optics for DUV microscopy are considered. The transition to the NUV and DUV range can significantly improve the resolving power of the microscope. Different kinds of crystals can be used as optical materials.

**1. Description.**

A serious argument in constructing a microscope working in NUV and DUV spectral ranges is the need to achieve maximum numerical apertures. Achieving the maximum numerical aperture will ensure maximum resolution of the optics. In this case, it is not possible to use a catoptric or catodioptric optics, since it is characterized by the presence of a central obscuring.

The use of lens (dioptric) systems allows fulfilling the conditions for the realization of the maximum resolution. The main thing in the optical system of such a microscope is the objective, which performs the optical projection of the image of the object into the plane of the image receiver. The objective must have a high transmission not only in the working wavelength, but also in the specified spectral range – for the possibility of using a fluorescence instrument.

Table 1. Relation the theoretical resolution values for a numerical aperture NA=0.95 and NA=1.25 water immersion depending on the wavelengths.

| Wavelengths (nm) | 244 | 193.4 | 121.6 | 106 |
|---|---|---|---|---|
| Resolution value (nm) NA=0.95 | 157 | 124 | 78 | 68 |
| Resolution value (nm) NA=1.25 water | 119 | 94 | not possible now | |

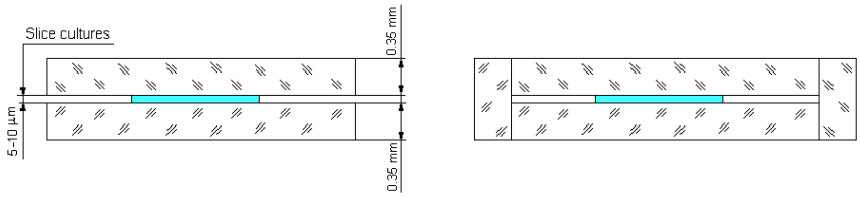
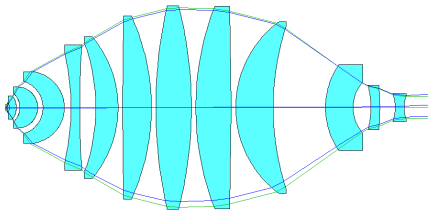
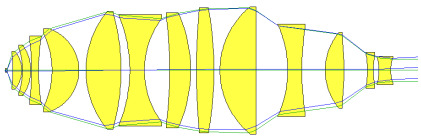
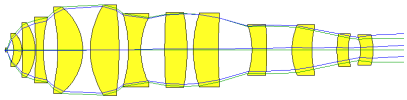



Figure 1. Two types of coverglass and specimen glass “constructions”.

Table 2. Main technical parameters and basic optical layout of objectives.

| Magnification / F’ | NA | “Glass” | λ (nm) | WD (mm) | R (nm) | FOV on object (mm) | FOV on image (mm) | The principal optical layout |
|---|---|---|---|---|---|---|---|---|
| 100x / 2.0 | 1.25 water | quartz | 244.08 | 0.12 | 119 | 0.20 | 20 |  |
| | 1.25 water | CaF2 | 193.4 | 0.13 | 94 | 0.20 | 20 | |
| 100x / 2.0 | 0.95 | LiF | 121.6 | 0.52 | 78 | 0.20 | 20 |  |
| | | LiF | 106 | 0.40 | 68 | 0.20 | 20 |  |

Our opinion that the transition to a shorter wavelength is justified only for the extremal numerical apertures of objectives. For objectives without immersion, the theoretical values of the numerical aperture are 0.90-0.95, in practice the aperture of 0.90 is the most probable if takes in note the technological errors in the manufacture of lenses and assembly of objective. In this case, the optical system of the microscope containing the lighting system (collector, condenser, intermediate matching components) and the projection system (objective) should not only provide high transmission but also have a perfect aberration correction for the selected wavelength (spectral range). For example, the condenser should also provide a numerical aperture of 0.90-0.95, its aberration correction should correspond to the aberration correction of the objective. It is logical to use two identical objectives, one of which serves as a condenser. It is believed that the intermediate optics of the illuminating microscope, as well as the collector, can be substantially inferior to the quality of the aberration correction to the condenser and the objective.

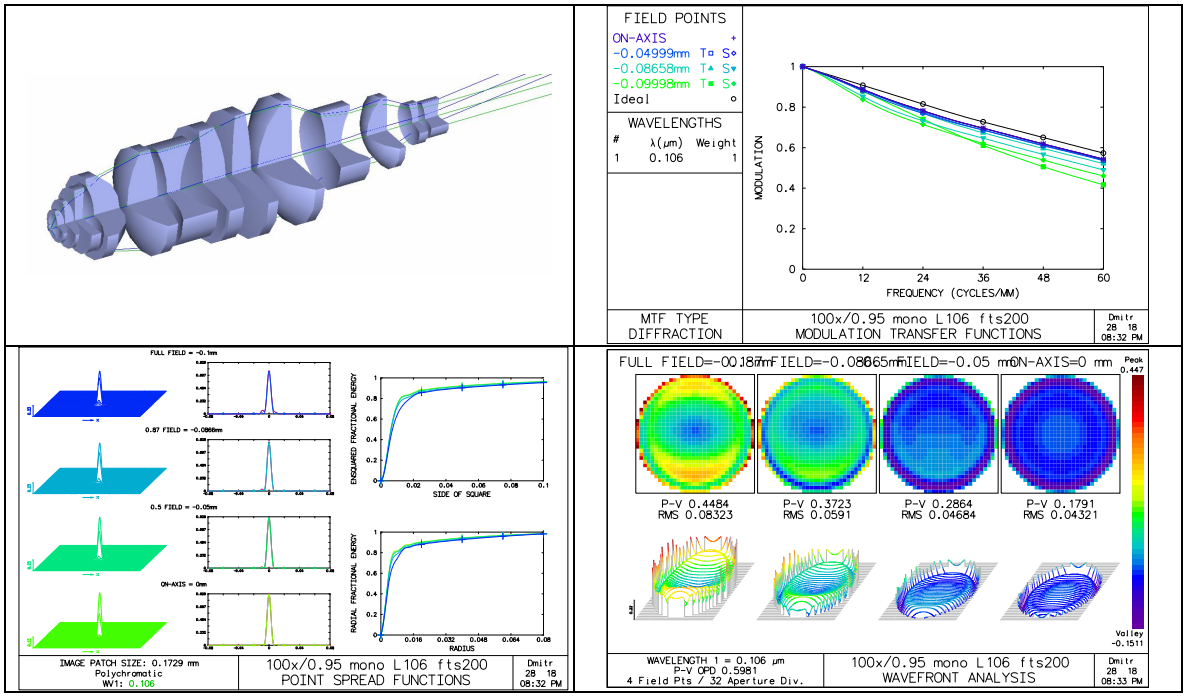



Figure 2. The design graphs of aberrations of the 100x objective NA=0.95 for λ=106 nm.

**2. Conclusion.** Some suggestions for building a NUV-DUV microscope are presented. The construction of a microscope in this area is a complex task that combines specific requirements for optics, mechanics and positioning devices. However, the main requirement is that the optical system provides advantages in terms of resolution and transmission. Optical design of the original objectives are presented. The principal possibility of creating dioptric systems for NUV-DUV microscopy with a high numerical aperture is shown. In the developed objectives, high numerical apertures of 0.95 for dry systems and 1.25 for water immersion systems are realized. The use of the proposed objectives, as well as some practical engineering solutions, can significantly improve the quality of research on a microscope.