

A BETTER VIEW OF THE WORLD

MEASUREMENT OF OPTICAL PARAMETERS OF MICROSCOPE OBJECTIVES

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EVROPSKÁ UNIE
Evropské strukturální a investiční fondy
Operační program Výzkum, vývoj a vzdělávání



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MEASUREMENT OF OPTICAL PARAMETERS OF MICROSCOPE OBJECTIVES

Content

- **WHAT IS A MICROSCOPE OBJECTIVE (MO)**
- **WHAT WE CAN KNOW ABOUT MO**
- **WHAT CAN BE MEASURED**
- **WHAT CAN BE CUSTOMISED**



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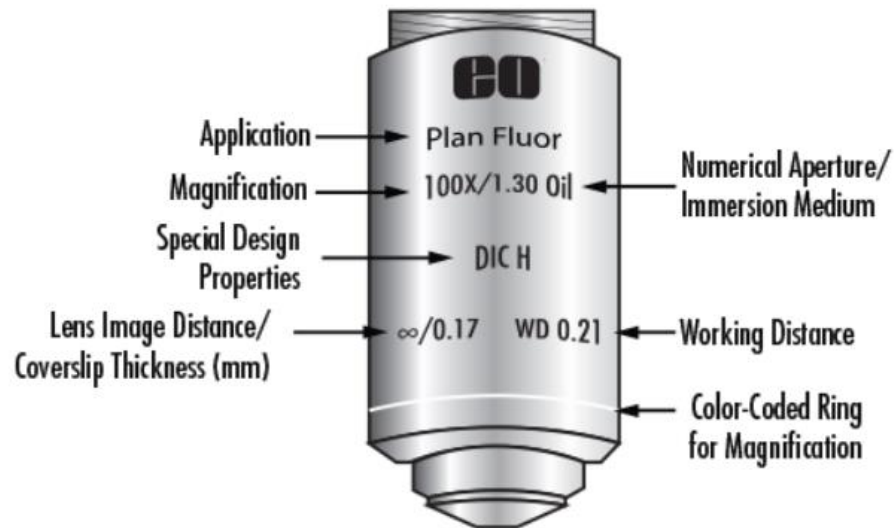
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MLÁDEŽE A TĚLOVÝCHOVY

Podpořeno z projektu OP VVV „Partnerská síť v oblasti výzkumu a vývoje zobrazovací a osvětlovací techniky a optoelektroniky pro optický a automobilový průmysl“, registrační číslo: CZ.02.1.01/0.0/0.0/17_049/0008422.

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What is a microscope objective?

At its simplest definition: mo is a very high-powered **magnifying lens**, with very short **focal length**.

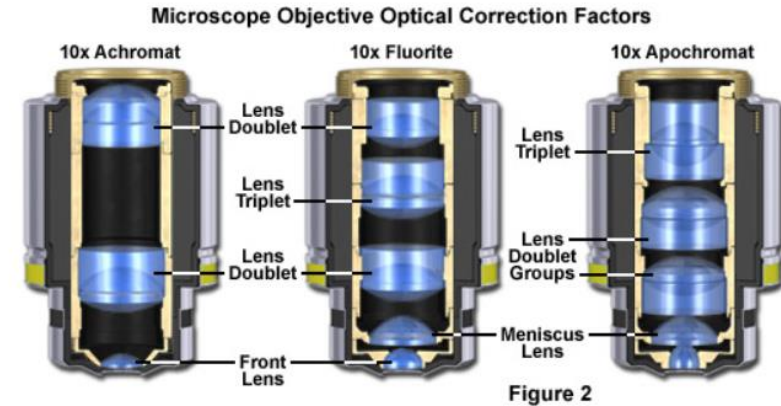


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How to sort the Microscope objectives?

MICROSCOPE OBJECTIVES CAN BE SORTED BY:

- Magnification (1x, 10x, 20x, 100x, ...)
- Numerical aperture (resolution) (0,2, 0,4, 0,7, 0,9, 1,2, ...)
- Manufacturer (nikon, zeiss, olympus, leica, mitutoyo, ...)
- Working distance (short WD, long WD, ...)
- Immersion or cover glass correction (yes / no)
- Application (aberration correction type)



Microscope Objective Correction for Optical Aberration

| Objective Specification | Spherical Aberration | Chromatic Aberration | Field Curvature |
|-------------------------|----------------------|----------------------|-----------------|
| Achromat | 1 Color | 2 Colors | No |
| Plan Achromat | 1 Color | 2 Colors | Yes |
| Fluorite | 2-3 Colors | 2-3 Colors | No |
| Plan Fluorite | 3-4 Colors | 2-4 Colors | Yes |
| Plan Apochromat | 3-4 Colors | 4-5 Colors | Yes |

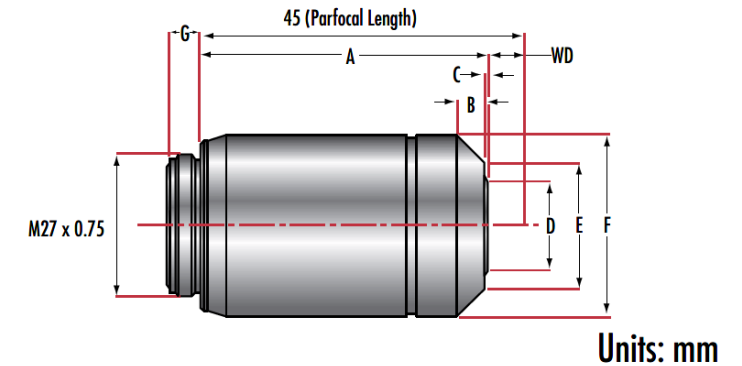
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What are the parameters published by supplier?

SPECIFICATION – Typical published objectives parameters

| Specifications Learn More Accessories Technical Information Related Products | | | |
|--|------------------------|--|--|
| Magnification: | 40X | Numerical Aperture NA: | 0.6 |
| Compatible Tube Lens Focal Length (mm): | Focal Length: 164.50mm | Compatible Cover Glass Thickness (mm): | N/A |
| Depth of Field (µm): | 0.76 | Field Number (mm): | 23 |
| Focal Length FL (mm): | 4.10 | Length excluding Threads (mm): | 42.8 |
| Manufacturer: | ZEISS | Maximum Diameter (mm): | 30 |
| Model Number: | 422060-9901-000 | Mounting Threads: | M27 x 0.75 |
| Parfocal Length (mm): | 45 | Resolving Power (µm): | 0.46 |
| Style: | Infinity Corrected | Type: | Microscope Objective |
| Weight (g): | 180 | Working Distance (mm): | 2.2 |
| Wavelength Range (nm): | 480 - 650 | Immersion Liquid: | N/A |
| Operating Temperature (°C): | +10 to +40 | Typical Applications: | Fluorescence, BrightField, Differential Interference Contrast, Reflected Light DIC, DIC with circular polarized light, total interference contrast |

Built-in (instalation) parameters



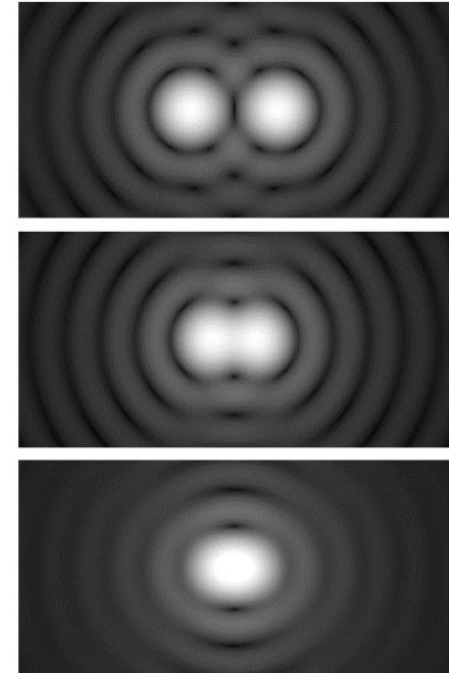
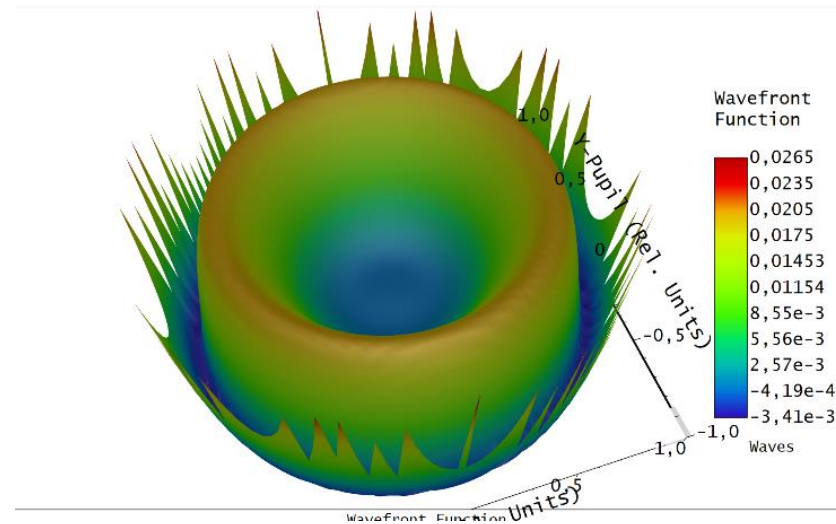
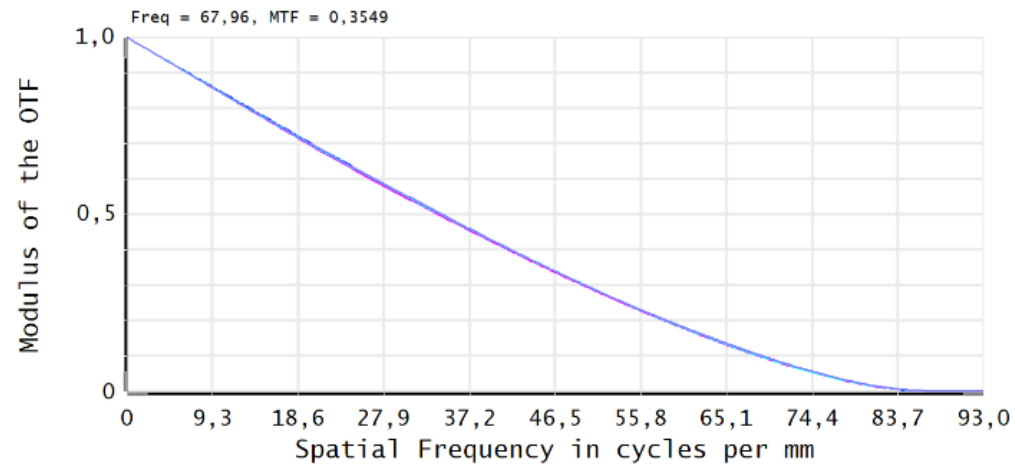
Technical Information

| Stock No. | EC Epiplan | Dimensions (mm) | | | | | | | | W.D. | PFL | Mounting Threads |
|-----------|------------|-----------------|------|------|------|------|------|-----|-------|-------|----------|------------------|
| | | A | B | C | D | E | F | G | | | | |
| #13-822 | 5X | 33.20 | 2.10 | 6.00 | 11.6 | 22.5 | 30.0 | 3.9 | 11.80 | 45.00 | M27x0.75 | |
| #13-823 | 10X | 34.00 | 2.10 | 6.80 | 11.6 | 22.5 | 30.0 | 3.9 | 11.00 | 45.00 | M27x0.75 | |
| #13-824 | 20X | 41.80 | 7.40 | 3.80 | 12.6 | 22.5 | 30.0 | 3.9 | 3.20 | 45.00 | M27x0.75 | |
| #13-825 | 40X | 42.80 | 9.40 | 2.80 | 9.1 | 14.5 | 30.0 | 3.9 | 2.20 | 45.00 | M27x0.75 | |
| #13-826 | 50X | 44.05 | 8.10 | 5.35 | 9.0 | 22.5 | 30.0 | 3.9 | 1.00 | 45.00 | M27x0.75 | |
| #13-827 | 100X | 44.15 | 8.10 | 5.45 | 9.0 | 22.5 | 30.0 | 3.9 | 0.87 | 45.00 | M27x0.75 | |

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What about quality?

There does not exist any information about quality in any of manufacturer (MTF, WFE, resolution)? Why?

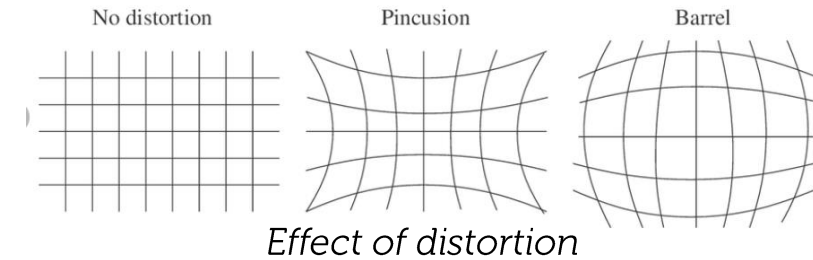


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What would we really like to know about the microscope objective?

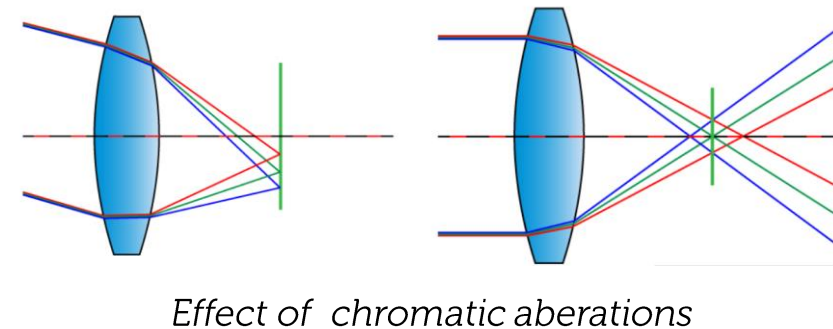
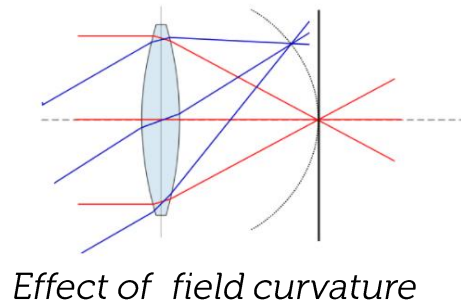
GEOMETRICAL OPTICAL PARAMETERS:

- Distortion
- Field curvature
- Lateral & longitudinal chromatic aberration



QUALITATIVE OPTICAL PARAMETERS:

- WFE / MTF / resolution



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How to determine microscope objective quality?

WHAT OPTIONS WE HAVE?

- Ask supplier *
- Hope for good results / condition
- **Measure**



* The only information which is (sometimes) possible to ask from supplier can be a blackbox design (zemax, codev)

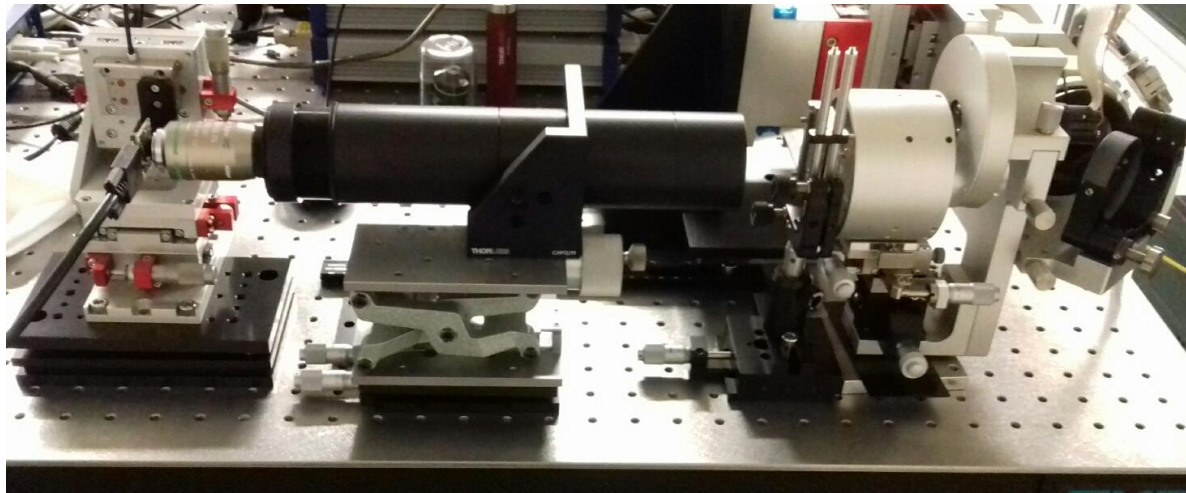
- > BUT even if so, this shows just the nominal design
 - > no real system behaviour (after tolerancing)
 - > no volume statistics

MEASUREMENT OF OPTICAL PARAMETERS OF MICROSCOPE OBJECTIVES

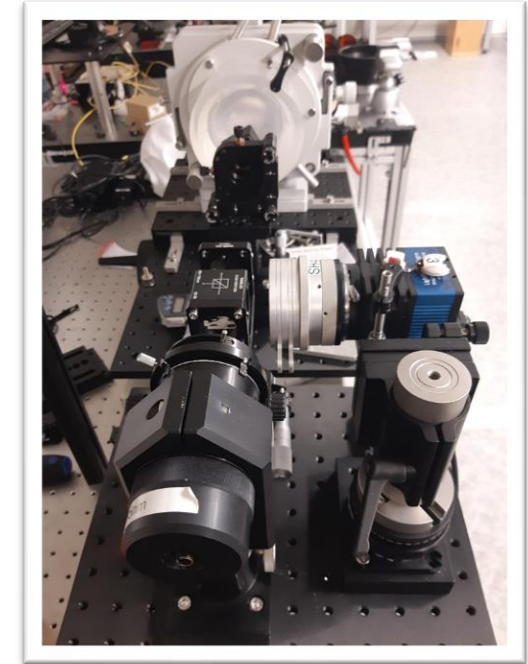
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How to measure microscope objectives?

Meopta R&D labs has dedicated experimental setups to measure geometrical & qualitative parameters



Experimental setup for geometrical parameters measurement



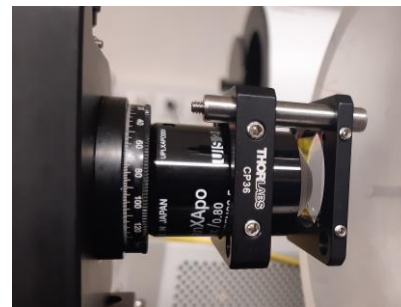
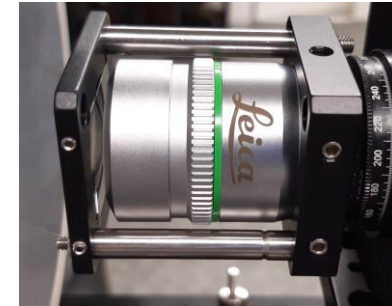
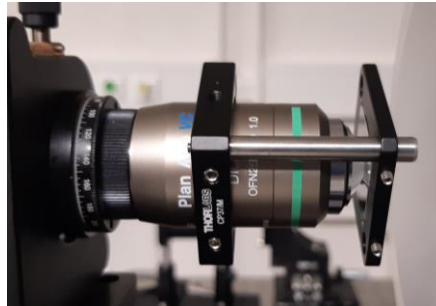
Experimental setup for qualitative parameters measurement

MEASUREMENT OF OPTICAL PARAMETERS OF MICROSCOPE OBJECTIVES

Example of MO measurement / selection

Target: to select the optimal option of MO for specific design / application

| MO selection parameters | |
|-------------------------|-------------|
| NA | 0,7-0,8 |
| Magnification | 20x |
| Spectrum | 350 – 650nm |
| WD | 0,5 – 1,5mm |



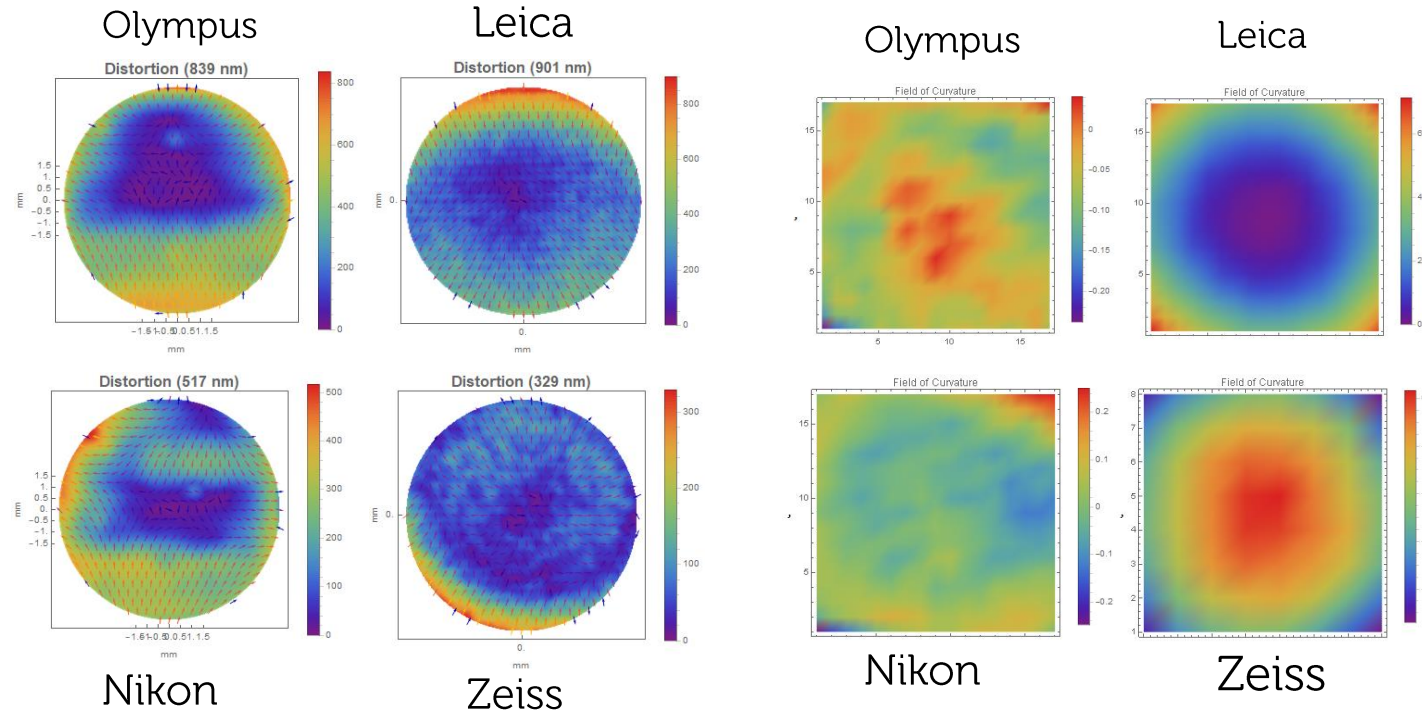
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How to measure microscope objectives?

GEOMETRICAL PARAMETERS

Distortion & field curvature results – displacement in lateral & longitudinal axis

| Distortion | |
|------------|-----|
| PV [nm] | |
| Leica | 901 |
| Zeiss | 326 |
| Nikon | 517 |
| Olympus | 329 |



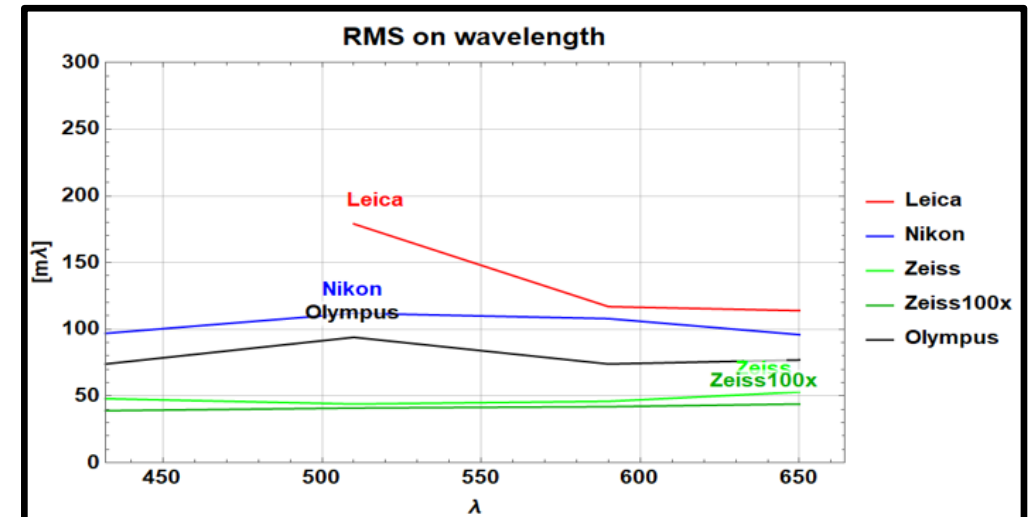
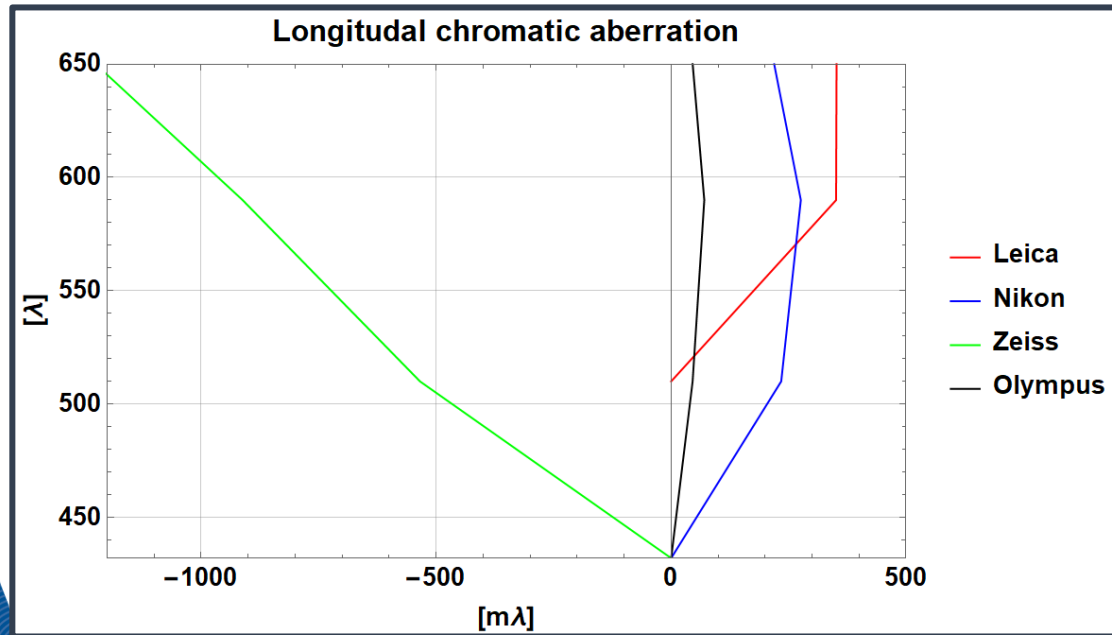
| Field curvature | |
|-----------------|-----|
| PV [nm] | |
| Leica | 750 |
| Zeiss | 430 |
| Nikon | 80 |
| Olympus | 280 |

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How to measure microscope objectives?

GEOMETRICAL PARAMETERS

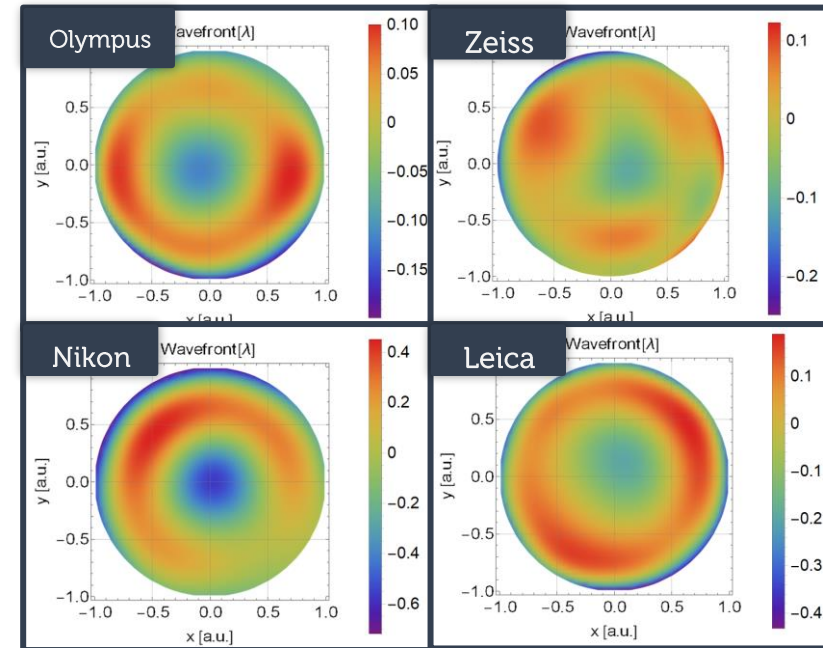
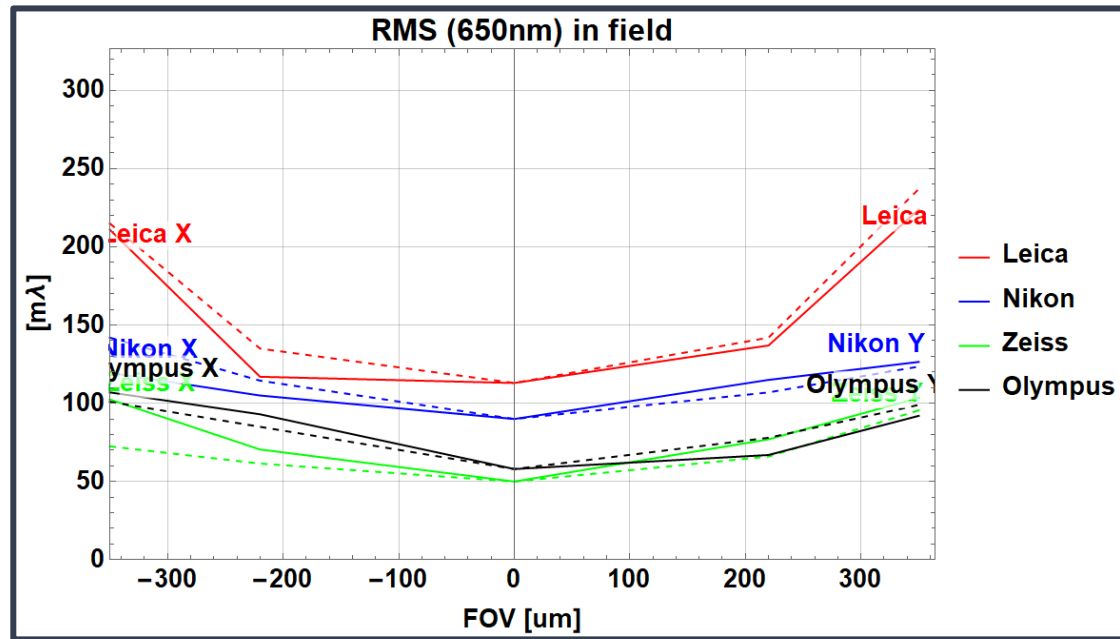
Longitudinal and transversal chromatic aberrations



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How to measure microscope objectives?

QUALITATIVE PARAMETERS - WFE



| Objektiv | průměr 440um [mλ] | průměr 700um [mλ] |
|----------|-------------------|-------------------|
| Leica | 132.75 | 221.75 |
| Nikon | 110.37 | 127.88 |
| Zeiss | 68.75 | 93.5 |
| Olympus | 80.75 | 99.75 |

MEASUREMENT OF OPTICAL PARAMETERS OF MICROSCOPE OBJECTIVES

How to measure microscope objectives?

Final selection done as a result of technical (quality & geometrical) parameters as well as non-technical parameters (application, space, etc.)

| Result | | | | |
|----------------|---------------|-----------------|---------------|----------------|
| | Score - tech. | Score - non-tec | Complex score | Complex rating |
| Zeiss | 15 | 6 | 21 | 1 |
| Olympus | 11 | 3 | 14 | 3 |
| Nikon | 10 | 5 | 15 | 2 |
| Leica | 1 | 1 | 2 | 4 |

| Technical parameters | | | Non-technical parameters | | |
|----------------------------|--------|--------|--|--------------|--------|
| Wavefront | | | Focal length / Working distance | | |
| | Rating | Points | | Rating | Points |
| Zeiss | 1 | 9 | Zeiss | 8,25 (WD1,3) | 2 |
| Olympus | 2 | 6 | Olympus | 9 (WD0,6) | 0 |
| Nikon | 3 | 3 | Nikon | 10 (WD1) | 1 |
| Leica | 4 | 0 | Leica | 10 (WD0,6) | 0 |
| Geometrical | | | Cover glass | | |
| Distorsion | | | | Rating | Points |
| Zeiss | 1 | 3 | Zeiss | No | 2 |
| Olympus | 3 | 1 | Olympus | Yes | 0 |
| Nikon | 2 | 2 | Nikon | Yes | 0 |
| Leica | 4 | 0 | Leica | Yes | 0 |
| Field curvature | | | Vacuum compatibility | | |
| | | | | Rating | Points |
| Zeiss | 2 | 2 | Zeiss | Yes | 2 |
| Olympus | 3 | 1 | Olympus | Maybe | 1 |
| Nikon | 1 | 3 | Nikon | Maybe | 1 |
| Leica | 4 | 0 | Leica | No | 0 |
| Chromatic aberation | | | Price | | |
| | Nedef | | | Rating | Points |
| Zeiss | | 1 | Zeiss | | 0 |
| Olympus | 1 | 3 | Olympus | | 2 |
| Nikon | 2 | 2 | Nikon | | 3 |
| Leica | 3 | 1 | Leica | | 1 |

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What is the other option?

Meopta designs a customised microscope objectives and microscope systems for customers from semiconductor, FPD, fluorescence microscopy, medical, etc.



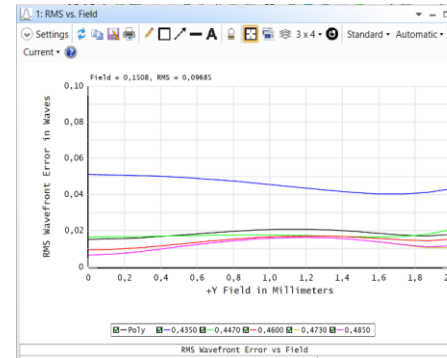
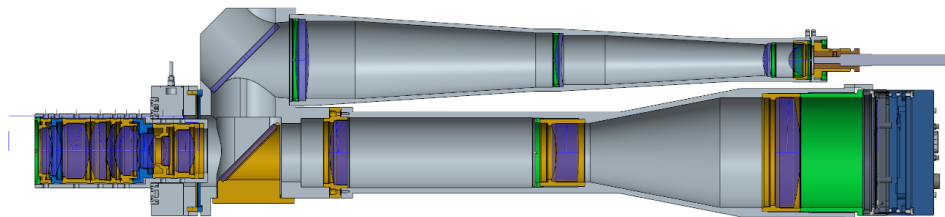
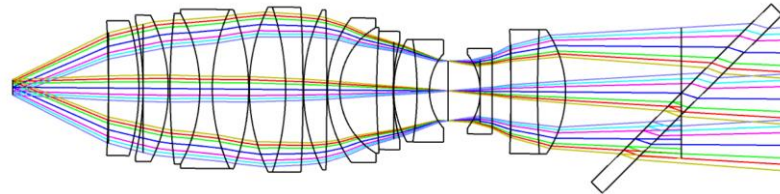
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Example of meopta design?

| | nominal design | units |
|------------------------|----------------|--------|
| Wavelength range | 435 - 485 | |
| Object NA | 0,4 | - |
| Image NA | 0,022 | - |
| Object FOV (semi-diam) | 4 | mm |
| Image FOV (semi-diam) | 80 | mm |
| Paraxial magnification | 20 | - |
| WFE | 0,008 | mλ RMS |
| Strehl ratio | 0,997 | - |

Example of customized microscope systems specs



MEASUREMENT OF OPTICAL PARAMETERS OF MICROSCOPE OBJECTIVES

Summary

- MICROSCOPE OBJECTIVES (MO) GENERALLY
- WHAT THE MANUFACTURERS PUBLISH ABOUT MICROSCOPE OBJECTIVES (WHY THERE IS NO INFO ABOUT QUALITY)
- WHAT CAN BE MEASURED + EXAMPLE OF MO SELECTION
- EXAMPLE OF CUSTOMISED MO



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