

Microdeflectometry for transparent objects

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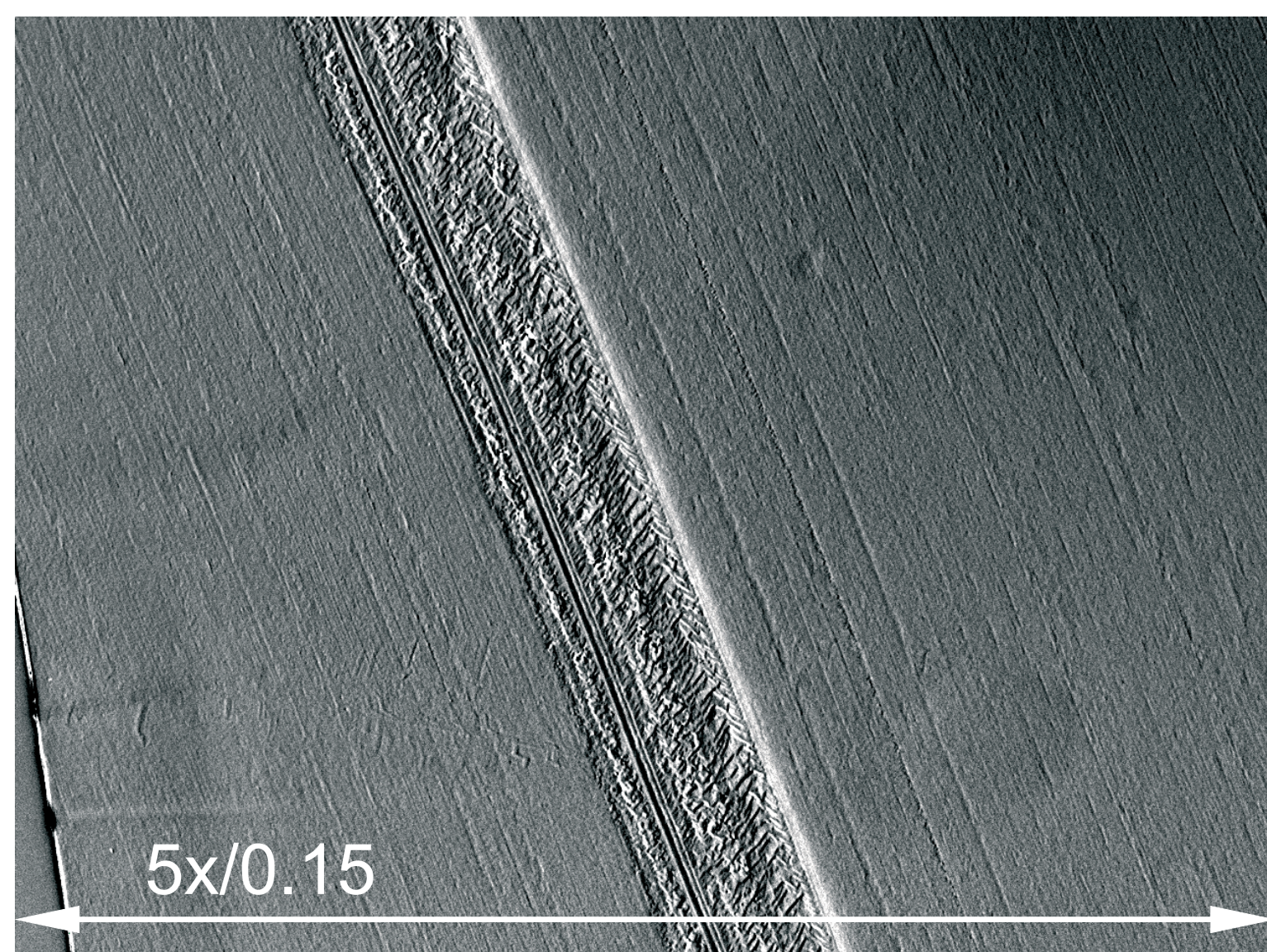


Fig. 1 Measurement of a defect on a plastic lens — intensity-encoded slope image (in x-direction).

Phase measuring deflectometry (PMD) [1] has been used to measure specular reflective surfaces such as eye glasses or wafers [3]. And it has been used to measure the local refractive power of car windows in transmission [2]. We now present "**Microdeflectometry in transmission**". Microdeflectometry in transmission acquires the local gradient of the optical path length and needs very simple hardware. We can measure **local defects or structures** of a **few nanometers** in depth and local **variations of the index of refraction** in the range of 0.05.

Possible applications are histology or the measurement of index inhomogeneities, as well as the measurement of thickness variations.

Principle

For microdeflectometry we observe the **aerial image** of a **sinusoidal pattern** located at a defined distance remotely from the object under test. For measurements in transmission we have to use two micro objectives (for projection and for observation: Fig. 2, left).

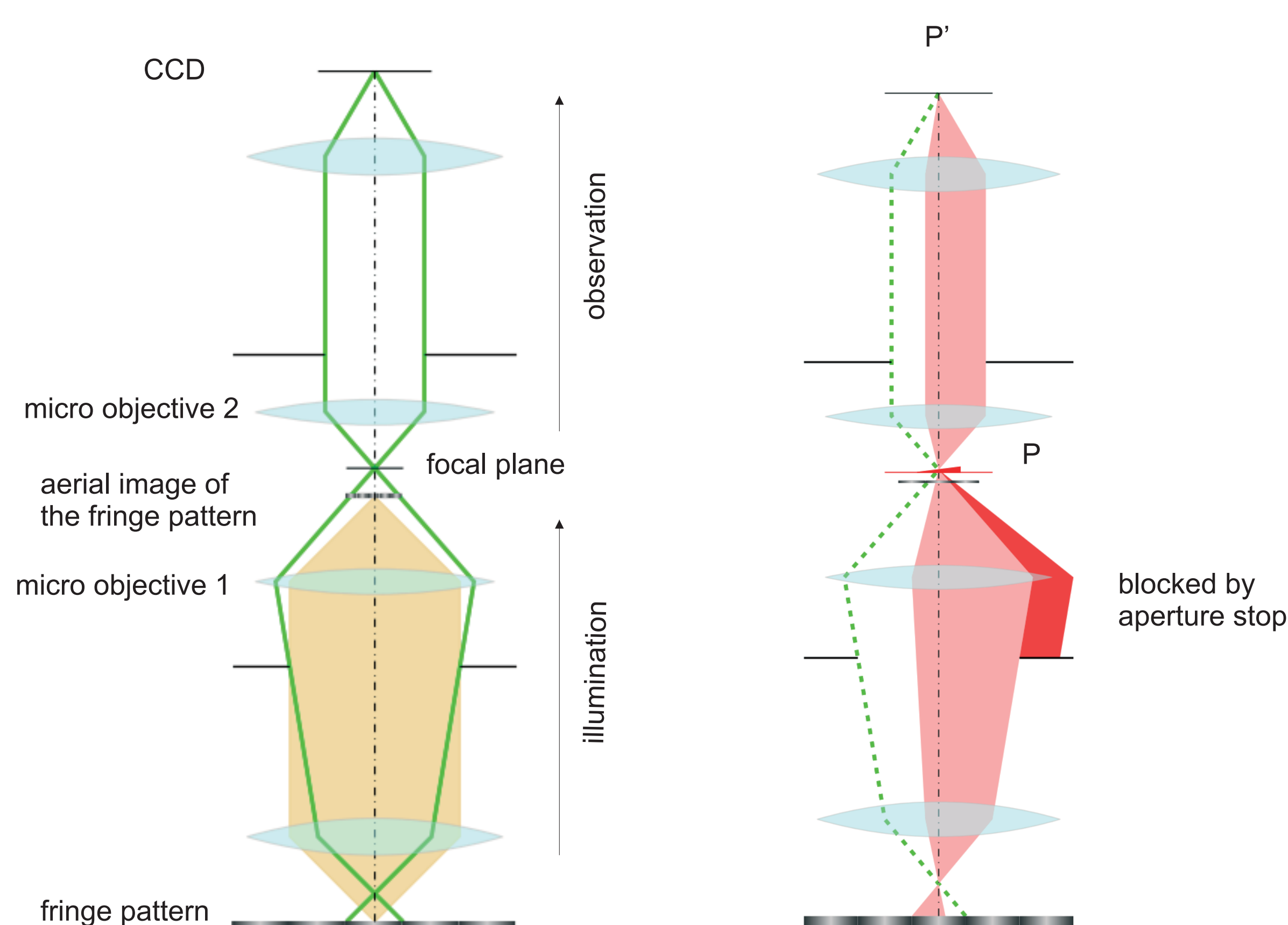


Fig. 2 Principle of microscopic PMD. Left: Observation and illumination through separate micro objectives. Right: Imaging rays with and without object.

The measured **signal** in the image point P' depends on the **local gradient** of the optical path of the object at the point P (Fig. 2, right). For objects without path gradient, the entire cone of imaging rays (green and light red) contributes to the signal. With a gradient, the cone will be tilted, shifted away from the optical axis, or changes its size. Hence, a fraction of the cone is blocked by the aperture stop.

The measured phase is shifted depending on the path gradient and the resulting signal is the **averaged phase** of the observed area of the fringe pattern (light red).

Results

Microdeflectometry provides DIC-like images, with high lateral resolution, **low noise** and the potential to acquire **quantitative data** of the slope of the surface and the gradient of the refractive index. In particular, the examination of histologic specimen is easier as staining is no longer necessary [4].

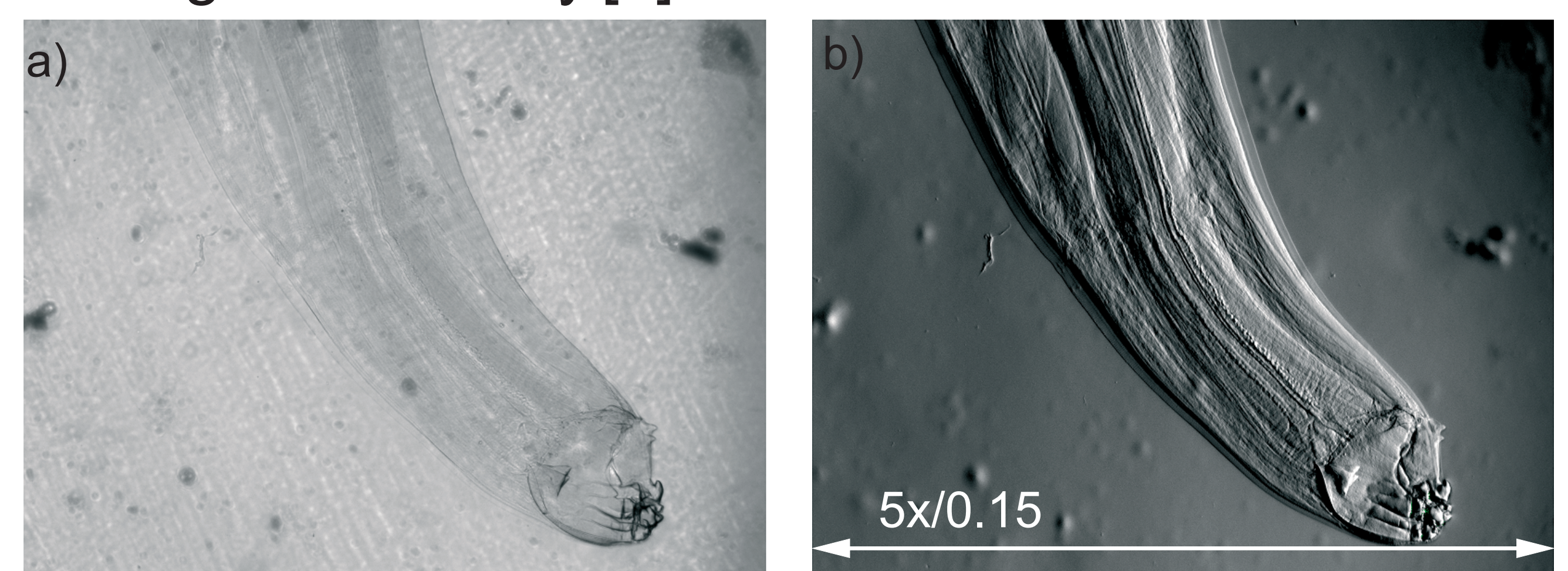


Fig. 3 Measurement of a hookworm. a) light microscope image (stained) b) intensity-encoded gradient (x-direction)

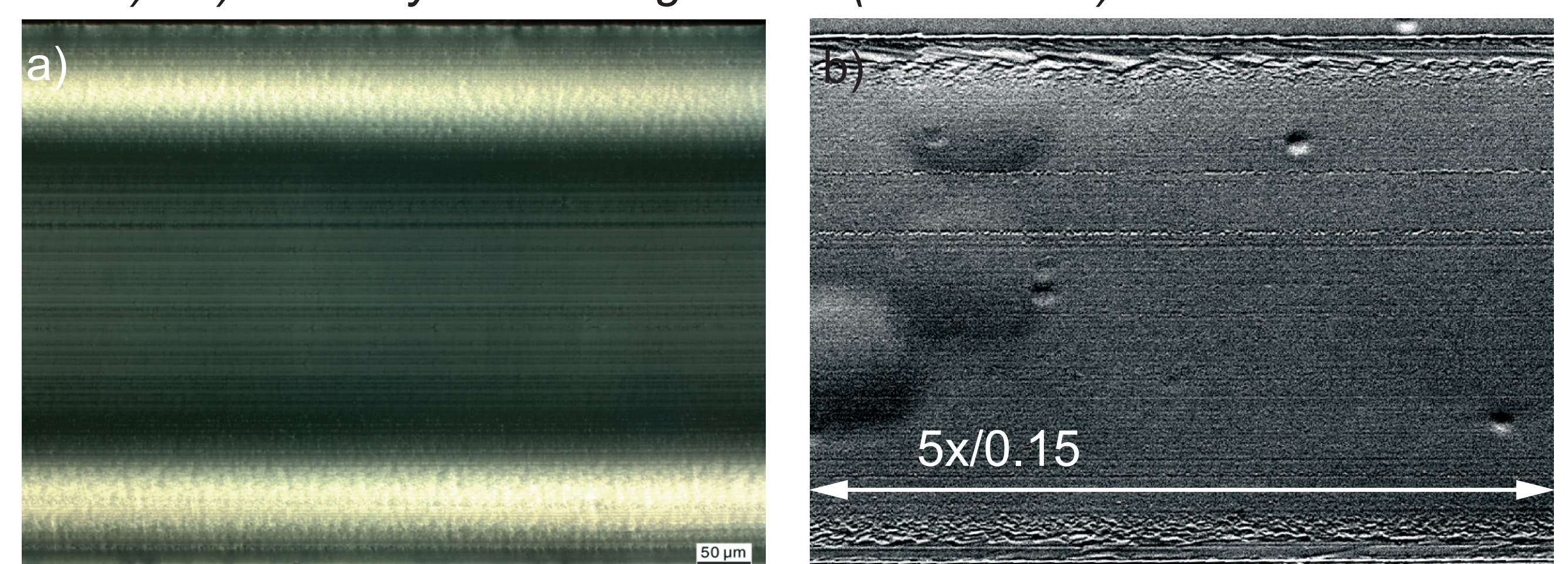


Fig. 4 Measurement of a tension rod. a) image obtained with a polarizing microscope b) intensity-encoded gradient image (y-direction)

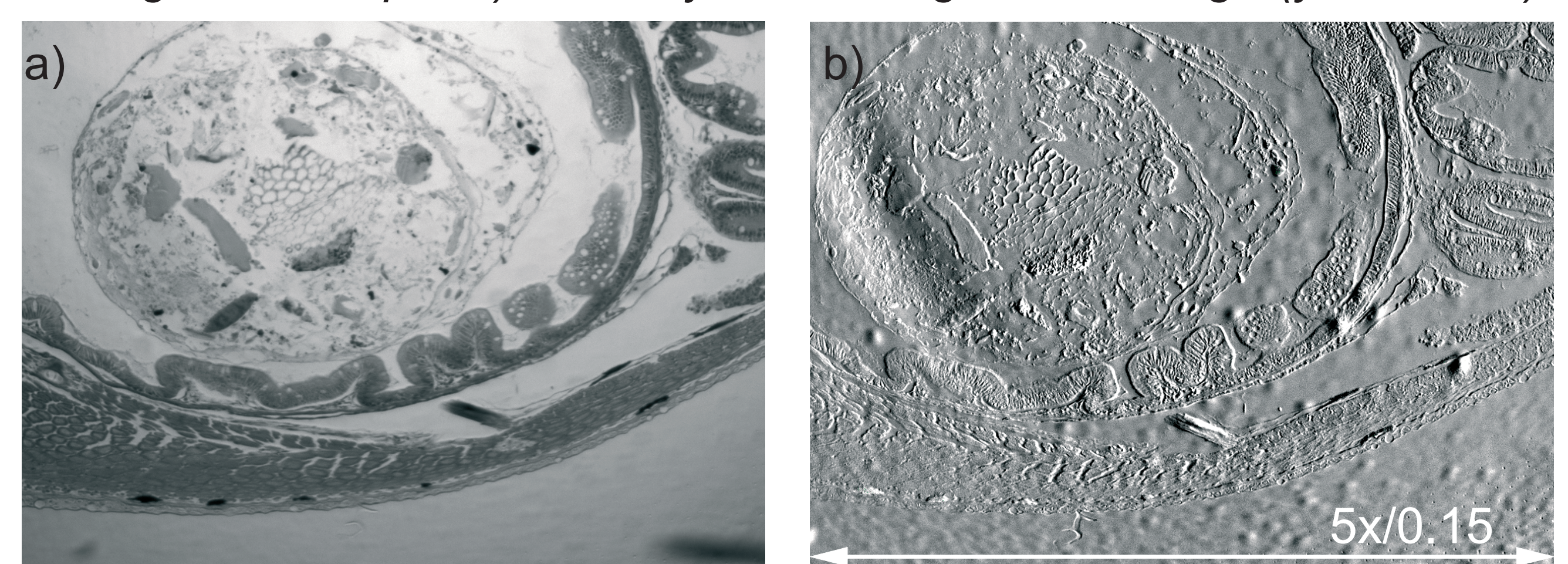


Fig. 4 Measurement of a young trout. a) light microscope image (stained) b) intensity-encoded gradient (x-direction)

[1] M.C. Knauer, J. Kaminski, G. Häusler: "Phase Measuring Deflectometry: a new approach to measure specular free-form surfaces", Proc. SPIE 5457, pp. 366-376 (2004)

[2] M.C. Knauer, C. Richter, G. Häusler: "Measuring the refractive power with deflectometry in transmission" Proc. DGaO A24 '08

[3] G. Häusler, C. Richter, K.-H. Leitz, M.C. Knauer: "Microdeflectometry — a novel tool to acquire 3D microtopology with nanometer height resolution", Opt. Lett. Vol. 33, pp.396-398 (2008)

[4] G. Häusler, M. C. Knauer, C. Faber, C. Richter, S. Peterhänsel, C. Kranitzky K. Veit: "Deflectometry Challenges Interferometry: 3-D-Metrology from Nanometer to Meter", in Digital Holography and Three-Dimensional Imaging, OSA Technical Digest (CD) (Optical Society of America, 2009)