White-light Mach-Zehnder interference microscopy in transmission

Task

Measurements of the refractive index can provide a variety of important information about the structure and material properties of microscopic objects. In materials research, micro-optical or crystal-optical components can be qualified using measurements of the refractive index and dispersion. One of the main difficulties encountered when examining thin, transparent objects under a light microscope is that of generating image contrast. When observing living cells in a dye-free medium, optical techniques alone are capable of quantifying cells on the basis of their refractive index and translating this into contrast. This measurement permits the dry mass of the cells to be determined, thereby opening the door to new applications in biology and medical diagnostics.

Method

The Horn design of the Mach-Zehnder interference microscope offers the best phase resolution for measurements of the refractive index coupled with maximum enlargement of the light microscope images. This is achieved by integrating two complete microscope optics with identical wavelength characteristics in the interferometer arms. Modern optomechanical concepts derived from laser technology can be used to automate the highly sensitive system and make it more user-friendly.

Results and Applications

Various experimental approaches were piloted in partnership with collaborating cell biologists, pathologists, environmental scientists and crystallographers. The cell movement of living cells and the associated mass transport processes were observed and recorded over several hours. Measurements of the dry mass of cells were successfully employed to identify tumor cells as distinct from healthy cells in streak cultures and microscopic sections. This method will serve as the basis for new applications in tumor diagnostics, where real physical measurements will help to provide a more reliable diagnosis. Measurements of the dry mass of cells were also employed to determine the carbon content of various types of algae, for subsequent use in environmental model calculations. The results showed a significant deviation from the tabulated values currently in use.

The aim of the project is to develop a commercial version of an interference microscope offering not only a unique means of performing high-precision measurements but also featuring exceptional user-friendliness.

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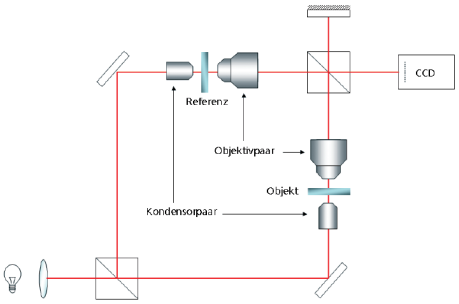

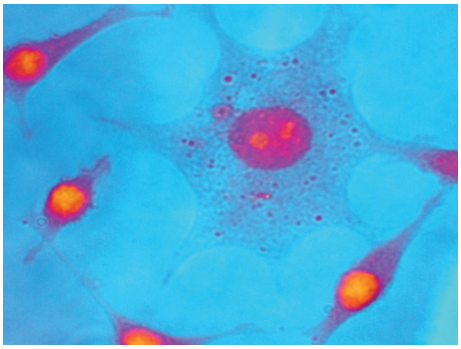

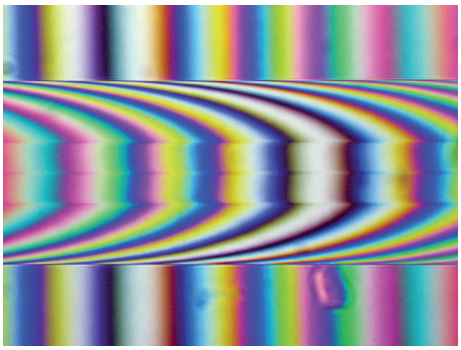

Above: Combined arrangement of Mach-Zehnder interferometer and matching microscope optics.
Middle: Interference contrast image of neurons. Unstained cells can be observed in detailed contrast and quantified.
Below: Interference fringe pattern of an optical waveguide. The refractive index profile can be measured to sub-nanometer accuracy as a function of the curvature of the interference fringes.

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