Digital Holographic Microscopy for 3-D Optical Metrology with Real-Time, Full-Field Nanometer Resolution

Digital Holographic Microscopy

Purpose: The Imaging, Signals and Machine Learning Group conducts applied computer vision research and development addressing important issues in industrial and economic competitiveness, biomedical measurement science, and national security.

Sponsors: Government agencies such as the Department of Energy, nongovernmental agencies, private companies, universities, and various consortia.

Features:
- High-speed imaging and throughput.
- Full-field imaging.
- Nanometer precision axial resolution.
- Noninvasive imaging.

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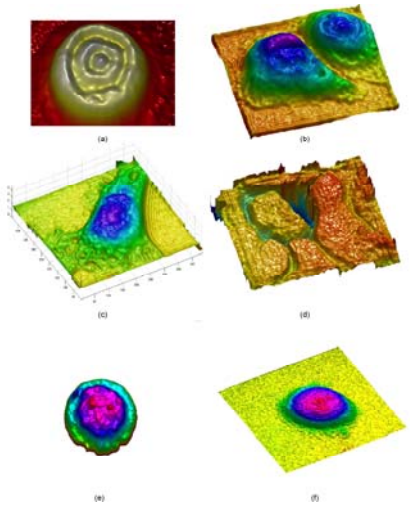
High-Resolution Surface Imaging Using Optical Phase Information

Measurement Science and Systems Engineering researchers at Oak Ridge National Laboratory have developed and patented a number of prototype microscopic imaging systems based on the technology of *Digital Holographic Microscopy*. These systems provide three-dimensional (3-D) quantitative information on the surface height topology of, for example, biological cells, with nanometer precision. The method involves recording the complex wavefront from a sample directly onto the surface of a charge-coupled-device camera in a single image.



Quantitative height profiles of biological cells.

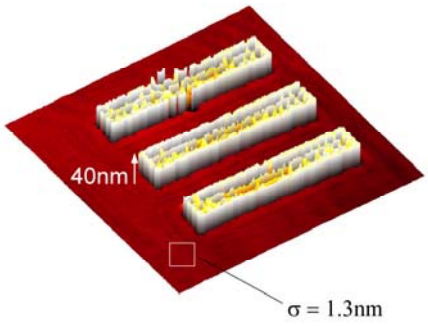
Unlike phase-shifting profilometry methods, the phase and amplitude of the imaged surface can be determined rapidly from just a single recorded digital image with high throughput using Fourier analysis. The phase information recorded is directly related to both the surface height of the object and the refractive index. A number of other unique capabilities make digital holography very appealing for application in a diverse range of areas, including industrial inspection and biological microscopy.

Base Technology

Prototype digital holographic instruments have been developed in both reflection and transmission modes. The axial resolution along the vertical (z) axis is on the order of a nanometer. The transverse resolution (in the x-y plane) is determined as in classical microscopy by the numerical aperture of the microscope objective. Video rate acquisition and fast digital reconstruction (30 fps) allow for real-time imaging

Specifications and Features

- High-speed imaging and throughput (30 fps rate).
- Full-field imaging (no scanning requirements).
- Nanometer precision axial resolution (roughly 1nm).



The current system resolves 1nm axial resolution in the axial direction. Shown is an element from a USAF resolution test target.

- Extended depth of focus (3-D volume information).
- Digital image focusing control.
- Complete digital aberration and sample tilt correction.
- Noninvasive imaging.

Contact Information

For more information on digital holographic microscopy capabilities and applications, please contact Christopher J. Mann (manncj@ornl.gov) at 865-576-5089.