Light Science & Applications

Common-path grating-based digital holographic microscopy and optical diffraction tomography for biomedical imaging

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Digital holographic microscopy (DHM) has become essential for label-free quantitative phase imaging, enabling non-invasive characterization of transparent biological samples. However, conventional DHM setups utilizing separate reference beams are highly sensitive to environmental disturbances such as vibrations and require highly coherent illumination, introducing speckle noise and limits their practical biomedical applications.

To overcome these issues, we developed common-path grating-based digital holographic microscopy (CPDHM), employing diffraction gratings as integrated interferometric elements. This approach inherently provides robustness against environmental perturbations by using self-referenced interference, allowing low-coherence, quasi-achromatic illumination sources. The CPDHM setup significantly simplifies the optical design, enhances system stability compared to traditional reference-beam DHM with substantially reduced coherence requirements. Moreover, CPDHM can be easily integrated into standard microscopes by simply inserting a diffraction grating between the tube lens and camera.

Our system is also compatible with optical diffraction tomography (ODT), achieved through oblique illumination and multi-angle projection collection, enabling precise three-dimensional refractive index mapping. We recently demonstrated this capability in lipid droplet content assay. While common-path systems typically risk overlapping phase and conjugate-phase images in dense samples due to self-interference, we mitigate this by adjusting shear between interfering beams. Acquiring multiple frames with variable shear we numerically separate phase information from its conjugate, overcoming the problem of overlapping objects and also effectively extending the field of view of the system.

Short Bio:

Piotr Zdańkowski is a research assistant professor at the Institute of Micromechanics and Photonics, Faculty of Mechatronics, Warsaw University of Technology. He specializes in advanced optical imaging techniques, with a primary focus on super-resolution microscopy, adaptive optics, quantitative phase imaging (QPI), and optical diffraction tomography (ODT). Piotr earned his PhD from the University of Dundee in 2018, where he was developing a system integrating adaptive optics into stimulated emission depletion (STED) microscopy, for 3D imaging of biological samples.

Currently, Piotr co-leads the Quantitative Computational Imaging Lab (QCI Lab), developing cutting-edge imaging methodologies including common-path QPI and ODT, Fourier Ptychographic Microscopy (FPM), lensless microscopy and super-resolution fluorescence microscopy.