Complex Refractive-Index Imaging by Iterative Optical Diffraction Tomography

Key Points

• Iterative Optical Diffraction Tomography (iODT) approach for optically imaging phase objects with high index contrasts or large optical path differences
• iODT algorithm provides better accuracy, faster convergence, and better reliability by suppressing artifacts
• Enables the reconstruction of fiber refractive index profiles accurately and robustly with sub-wavelength resolution

Abstract

Researchers at the University of Central Florida have invented a technique for capturing and reconstructing images of phase objects with greater accuracy and quality than conventional optical diffraction tomography (ODT) inversion methods. Example objects include transparent samples such as biological cells, tissues and optical fibers with high contrast, complicated structure, or sizeable optical path difference (OPD).

With such targets, most non-iterative tomographic reconstruction methods adopt the weakly-scattering assumption, which degrades the imaging quality. In contrast, the UCF Iterative Optical Diffraction Tomography (iODT) method, with its algorithmic process, reconstructs such objects and those with complex permittivity with better accuracy, fast convergence, and sub-wavelength resolution.

Technical Details

The UCF iODT approach improves the reconstruction quality of multiply scattering two-dimensional and three-dimensional phase objects by iteratively reducing the error between the fields diffracted by the reconstructed object and the true fields measured experimentally or obtained through simulations of phantoms for all illumination angles.

In one example application, the first iteration of iODT provides an estimate of the unknown refractive index (RI) profile using the standard linearized ODT inversion algorithm. Subsequent iterations improve the estimate by applying a perturbative correction based on differences between the fields diffracted by the imperfectly reconstructed object and the measured fields diffracted by the true object. The process includes translating this error into an error in the associated complex phase and then computing a correction to the reconstructed object function. The method uses the Rytov approximation in every iteration as it is more applicable to the perturbative function, as opposed to the original function. Since the magnitude (distribution) of the perturbative function becomes smaller (smoother) at higher iterations, the Rytov approximation improves. Further, as expected, the number of phase vortices in the perturbative complex phase is gradually reduced in a self-healing process as the iterations converge.

In essence, the embodied iterative algorithm is a nonlinear reconstruction based on perturbative expansion, much like a higher-order Born or Rytov expansion for forward propagation.

Partnering Opportunity

The research team is looking for partners to develop the technology further for commercialization.

Stage of Development

Prototype available.

Benefit

• Heuristic iterative algorithm provides better accuracy and fast convergence, as well as sub-wavelength resolution
• Can suppress errors resulting from phase-unwrapping failures, which typically occur in field-based inverse

For more information, contact:
UCF Office of Technology Transfer | 12201 Research Parkway, Suite 501, Orlando, FL 32826
Market Application

• Quantitative refractive-index imaging of a highly scattering media
• Index and gain/loss imaging of optical fibers with high-index contrasts or large optical path differences
• Biological and biomedical imaging

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• US Patent Pending

Inventors
Guifang Li, Ph.D. • Bahaa Saleh, Ph.D. • Shengli Fan • Seth Smith-Dryden

For more information, contact:
UCF Office of Technology Transfer | 12201 Research Parkway, Suite 501, Orlando, FL 32826