High-resolution 3D refractive-index microscopy of multiple-scattering samples from intensity-only measurements

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Abstract:
We describe a new computational technique for 3D refractive-index (RI) tomography of biological samples that incur multiple scattering. Reconstruction of such samples typically fails when using standard tomographic techniques that assume weak-scattering (Born and Rytov approximations) [1], since multiple-scattering effects are not accounted for. Here, we develop a nonlinear optimization framework, based on the multi-slice beam propagation model, to recover the sample's 3D RI distribution at high resolutions and with multiple-scattering effects included. Furthermore, we do not collect phase at each projection angle, but rather use only intensity measurements as our input data. Our framework is similar to 3D Fourier Ptychography [2], but uses a more rigorous inversion model to account for layer-to-layer multiple-scattering, enabling greater 3D reconstruction accuracy for axially-dense samples. Additionally, we introduce a new hardware design that is key to obtaining higher-resolution RI reconstructions with 1.2 numerical aperture.

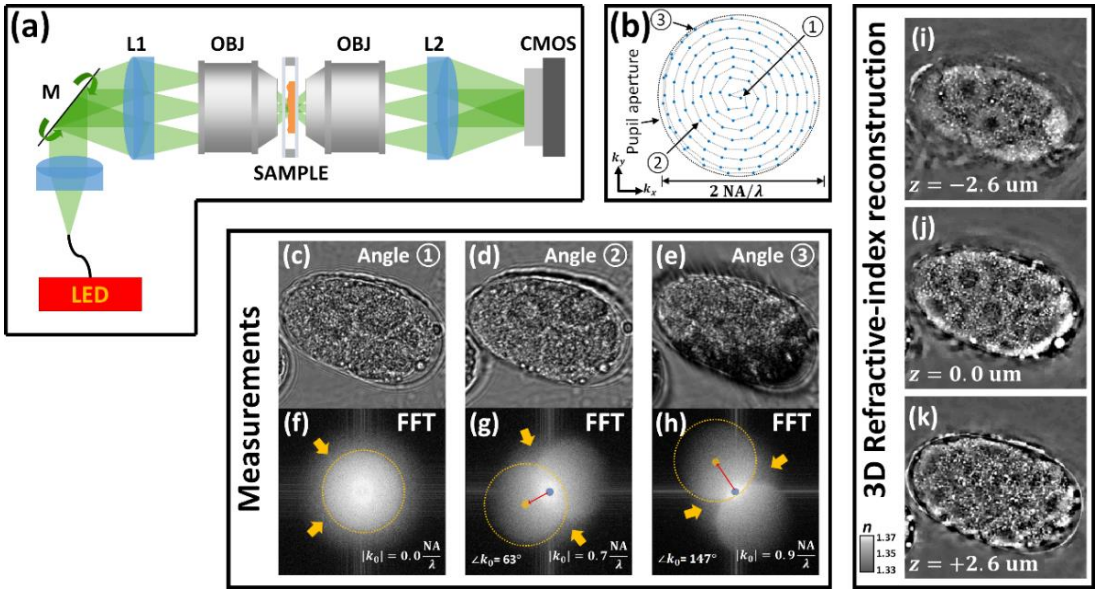

Figure 1: (a) Experimental setup for high-NA angular illumination scanning. (b) Illumination angle scanning trajectory is a spiral which fills the objective's pupil. (c,d,e) Raw intensity measurements for a *C. elegans* embryo sample and (f,g,h) the associated Fourier transforms, for illumination angles ①, ②, and ③. (i,j,k) Lateral cross-sections of the reconstructed 3D refractive index volume at depth planes (i) z = -2.6 um, (j) z = 0.0 um, and (k) z = +2.6 um.

References

1. Y. Sung, W. Choi, C. Fang-Yen, K. Badizadegan, R. R. Dasari, and M. S. Feld, Optics Express 17, 266-277 (2009).
2. L. Tian and L. Waller, Optica 2, 104-111 (2015).