Optical diffraction tomography using a digital micromirror device

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Optical diffraction tomography (ODT) allows measurements of quantitative imaging of three-dimensional (3-D) refractive index (RI) distribution of biological samples, which provides structure and chemical information about the samples. 3-D RI distribution is reconstructed from the measured multiple 2-D optical fields diffracted by the sample from various illumination angles via the Fourier diffraction theorem [1-3]. Conventionally, galvanometers have been utilized to control illumination angles of illumination beams, however, due to the electric noise and nonlinearity in the galvanometer response at high voltage values, jittering and positioning errors are occurred.

Here, we present an ODT technique using a digital micromirror device (DMD) for measuring 3-D RI distribution with high speed and high stability [4]. Plane waves with various illumination angles are produced by displaying binary patterns on a DMD with proper spatial filtering. Optical fields diffracted by a sample corresponding to various incident angles are recorded via Mach-Zehnder interferometry. The presented method is cost-effective and highly stable. We demonstrate measurements of 3-D RI distribution of various biological cells and 3-D Brownian motion of colloidal particles at the frame rate of 100 Hz.

Figure 1: Cross-sectional slices of a reconstructed tomogram in the x-y, x-z, and y-z planes of (a) a lipid droplet inside a Huh-7 cell, (b) a PMMA bead with the diameter of 3 μm, (c) 3D trajectory of a bead, (c) MSD of a bead in (b) with respect to the lag time in double-logarithmic scale. Dashed line indicates the fitted slope.