Enhancing the performance of the light field microscope using wavefront coding

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Light field microscopy is a high-speed volumetric computational imaging method that enables reconstruction of 3-D volumes from captured projections of the 4-D light field [1,2]. Recently, a detailed physical optics model of the light field microscope has been derived, which led to the development of a deconvolution algorithm that reconstructs 3-D volumes with high spatial resolution [3]. However, the spatial resolution of the reconstructions has been shown to be non-uniform across depth, with some z planes showing high resolution and others, particularly at the center of the imaged volume, showing very low resolution. In this paper, we enhance the performance of the light field microscope using wavefront coding techniques. By including phase masks in the optical path of the microscope we are able to address this non-uniform resolution limitation. We have also found that superior control over the performance of the light field microscope can be achieved by using two phase masks rather than one, placed at the objective’s back focal plane and at the microscope’s native image plane. We present an extended optical model for our wavefront coded light field microscope and develop a performance metric based on Fisher information, which we use to choose adequate phase masks parameters. We validate our approach using both simulated data and experimental resolution measurements of a USAF 1951 resolution target, and demonstrate the utility for biological applications with in vivo volumetric calcium imaging of the zebrafish brain.

References