Wavelens: a novel wavefront shaping digital microscopy lens

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ABSTRACT

Recent technologies have demonstrated that light propagation through scattering materials can, counterintuitively, significantly improve optical imaging and light control. The field of wavefront shaping uses the wave nature of light to control its propagation in complex media [1,2]. Using spatial light modulators in concert with scattering structures to provide wavefront control opens up a plethora of applications, with a disruptive effect when used to biological imaging methods in terms of enhancing the depth to resolution ratio [2]. The effects are particularly pronounced in optical microscopy, which suffers from multiple scattering when imaging deep into biological tissue, where diffusive light propagation due to random variations in the refractive index prohibits any realistic in vivo applicability in deep tissue.

In this work, we demonstrate an illumination system in the form of an opaque lens [3] configured as a microscope objective. The device, purposefully named Wavelens, exploits wavefront shaping and can provide improved illumination by incorporating a Spatial Light Modulator (SLM) that controls the light propagation through a custom made scattering photonic structure with symmetry along one dimension and a robust iterative optimization algorithm with optical feedback. Wavelens achieves super achromatic response in varied working distances and can create aberration free, near diffraction limit light sheets at user-controlled positions. We present preliminary characterization results and we compare its behavior with standard optics. We finally demonstrate its capability in imaging biological specimens (10μm-1mm) such as live cancer spheroids by utilizing our in house designed SPIM and we discuss the results.

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