Binary phase modulation in focusing through multiple scattering media using a DMD

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Abstract

Since I.M.Vellekoop and A.P.Mosk's monumental work [1], a variety of techniques to enhance targeted light delivery through multiple scattering media by wavefront shaping have been implemented. Wavefront shaping techniques (WFS) can be largely categorized into transmission matrix approaches, phase conjugation approaches and iterative feedback-based approaches. Liquid crystal based spatial light modulators (SLMs) have been one of the most popular devices to employ wavefront shaping. However, because of their slow refresh rate, they are hard to use for practical applications in dynamic scattering media, especially living biological samples.

To decrease optimization time, various iterative algorithms [2] and hardware configuration upgrades such as FPGA-based DOPC [3] and micro-electro-mechanical system (MEMS) based wavefront shaping [4] have been proposed. Since the optimized focus intensity through scattering media is linearly proportional to the number of controlled modes, increasing the modulation, detection speed has been at the center of many previous works. In contrast, we present a novel scheme to increase the maximum achievable wavefront shaping efficiency using a binary amplitude modulator. The significance of our work is that WFS is achieved with the efficiency of a binary phase modulator with the speed of DMDs. The concept demonstrated in this work is applicable for any WFS methods in principle.

References :

[1] I. M. Vellekoop and A. P. Mosk, "Focusing coherent light through opaque strongly scattering media," *Opt. Lett.* 32, 2309-2311 (2007)

[2] Ivo M. Vellekoop, "Feedback-based wavefront shaping," *Opt. Express* 23, 12189-12206 (2015)

[3] Daifa Wang, Edward Haojiang Zhou, Joshua Brake, Haowen Ruan, Mooseok Jang, and Changhuei Yang, "Focusing through dynamic tissue with millisecond digital optical phase conjugation," *Optica* 2, 728-735 (2015)

[4] Tzang, O., Niv, E., Singh, S. et al. Wavefront shaping in complex media with a 350 kHz modulator via a 1D-to-2D transform. *Nat. Photonics* 13, 788–793 (2019) doi:10.1038/s41566-019-0503-6