Exploiting DMD as a binary phase modulator in focusing through scattering media

Kibum Nam[1], Jung-Hoon Park[1]

[1]Department of Biomedical Engineering, Ulsan National Institute of Science and Technology. UNIST-gil 50, Ulsan 689-798, Republic of Korea.

kbnam@unist.ac.kr

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Abstract

Light scattering by multicellular specimen itself (the subject of interest) ruins image quality in optical microscopy. In case of deep tissue imaging, such as mouse brain, imaging depth is mainly limited by scattering. To overcome scattering, a variety of wavefront shaping techniques (WFS) have been developed since Vellekoop and Mosk have generated a focus through scattering media [1]. The maximum achievable enhancement factor $\eta(\equiv I_{focus}/\langle I_{speckle}\rangle)$ for the optimized focus is determined by $\eta = \alpha(N-1)+1$, where N is the number of controlled input wavelets, $\langle I_{speckle}\rangle$ is ensemble average of intensity of desired area to make a focus with unoptimized fields and α is determined by type of wavefront modulator [2]. Liquid crystal based spatial light modulators (SLMs, $\alpha = \pi/4$) have been one of the most popular devices to employ WFS.

However, because of their slow refresh rate, they are hard to use for practical applications on dynamic scattering media, especially in living biological samples. Although its modulation efficiency is low, DMDs ($\alpha = 1/2\pi$) are most widely used for fast WFS because of its high N value and refresh rate. Since I_{focus} is linearly proportional to N, increasing the modulation and detection speed have been at the center of many previous works. In contrast to the traditional approach, we have increased the wavefront modulation efficiency of DMDs rather than focusing on its speed. Here, we show that a DMD, without losing its modulation speed, can be used as a binary phase modulator ($\alpha = 1/\pi$) by simply adding a liquid crystal retarder and beam splitter. In our novel scheme, with the increased efficiency, the same number of modes can be controlled to obtain higher focus intensity. The concept demonstrated in this work is applicable for any feedback based WFS method in principle.

References:

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