Wavefront shaping techniques for biomedical applications

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We demonstrate that multiple scattering can be controlled via wavefront shaping in order to obtain a sub-sub-wavelength focusing and imaging, as well as one-wave optical phase conjugation for biomedical applications.

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We demonstrate that multiple scattering can be controlled via wavefront shaping in order to obtain a sub-diffraction limited focus at an arbitrary position and the full-field dynamic sub-wavelength imaging. Due to the random structure of the highly scattering media there are no restrictions on the physical position of the focus giving the system a high degree of freedom. We also present that the full-field dynamic sub-wavelength imaging can be obtained by transferring the optical near-field into propagating far-field components by multiple light scattering from disordered nanoparticles, which was previously demonstrated in microwave regime.

In many fields of research, the diffraction-limited optical resolution with visible light is a limiting factor, which cannot be easily surpassed simply by using shorter wavelengths to lower the diffraction limit. Besides the technological difficulties in fabricating optical components for shorter wavelengths at the UV or X-ray range, photons at these energy levels are usually either harmful or have negligible light-matter interaction which discourages their use as optical probes. This is especially pronounced in the field of bio-imaging where probing at the sub-cellular regime is critical for the understanding of cellular mechanism.

In this work, we demonstrate that we multiple light scattering can be utilized to obtain a sub-diffraction limited focus at an arbitrary position. Through multiple scattering, impinged far-fields are transformed into random near-fields after transmitting turbid media. Using a spatial light modulator which can control the phase of the impinging far-fields, we demonstrate that the phase of the near-fields can be controlled as well. Due to the random structure of the highly scattering media, there are no restrictions on the physical position of the focus giving the system a high degree of freedom.

We also demonstrate the realization of a one-wave optical phase conjugation mirror. We propose and experimentally demonstrate a novel but extremely simple method and achieve a time-reversal mirror exploiting the simply physical concept that single-mode channels can only carry a single phase, so the light that propagates in the opposite direction through the channel will naturally be its phase conjugated counterpart.

References

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YongKeun Park received his BS degree (Mechanical Eng.) from Seoul National University, and his MS degree (Mechanical Eng.) from MIT, and PhD degree (Medical Engineering and Medical Physics) from Harvar-MIT in 2004, 2007, and 2010, respectively. Prof. Park 's research interest has been in the area of quantitative phase imaging and wavefront shaping. His has co-authored +80 peer-review papers, and currently he is an Editorial Board Member in Scientific Reports, Optics Express, Experimental Biology and Medicine, and Journal of Optical Society of Korea. To learn more about Paul's research projects, visit his website: http://bmol.kaist.ac.kr