Coherent Control of Light Transmission and Absorption in Random Scattering Media

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Strongly scattering media usually look opaque, even though the material has little absorption. Due to the diffusion of light, the average transmission varies as one over the thickness of the medium. It poses a severe limitation for biomedical imaging and telecommunication. Recently it has been shown that shaping the wavefront of the incident light can focus light through a scattering medium or inside the scattering sample. Nevertheless, focusing through a sample mainly involves a rearrangement of the intensity distribution of the transmitted waves and does not significantly modify the total transmission.

We experimentally demonstrate that the total transmission through a multiple-scattering film can be varied by one order of magnitude with wavefront shaping. The experimental is designed to control the phase of both polarizations of light on a large number of pixels and with minimal phase fluctuations between the two polarizations. Using a sequential algorithm, we minimize and maximize the total transmission through highly scattering samples consisting of layers of nanoparticles of various thicknesses and of mean free path. We show that the mesoscopic correlations are essential to significantly modify the total transmission, by comparing the experimental results to the prediction of an uncorrelated model that ignores these correlations. The ability to modify the total transmission in disordered environments can help to improve imaging and telecommunication techniques, allowing to increase the penetration depth of the waves.

We have applied the same technique to coherent control of optical absorption in random scattering media. Absorption is commonly regarded as an intrinsic property of the medium. Recent theoretical studies predicted that the total amount of light absorbed in a weakly-absorbing scattering medium can be tuned significantly by controlling the interference effects of multiply scattered waves. We experimentally demonstrated this with a dye-sensitized solar cell, where the mesoporous nanocrystalline TiO$_2$ photoanode provides strong scattering, and a dye absorbs light and thereby injects electrons into the TiO$_2$ conduction band. By optimizing the input wavefront of a laser beam, we are able to increase or decrease the closed-circuit current. The ability to control globally or locally the absorption opens new ways to study photochemistry.