

Controlling the propagation of light in disordered scattering media

I. M. Vellekoop. ISBN 978-90-365-2663-0

This thesis describes experimental work on the use of wavefront shaping to steer light through strongly scattering materials. We find that scattering does not irreversibly scramble the incident wave. By shaping the incident wavefront, we make opaque objects focus light as sharply as aberration free lenses. We use feedback from a target behind, or in, an opaque object to shape the incident wave. This way, light is focused through, or inside, opaque objects for the first time ever.

The novel term ‘opaque lens’ is introduced to describe a non-transparent object that focuses light with a properly shaped incident wavefront. In our experiments, we find that opaque lenses focus light to a sharp, high contrast focus. Analytical theory is developed to quantitatively explain the experimental results.

For a different experiment, a transport theory for optimized wavefronts is developed. We show both theoretically and experimentally that wavefront shaping significantly increases the total transmission through opaque objects. Thereby, we give direct experimental evidence of open transport channels for light. This is an example of how wavefront shaping can be used to study fundamental properties of scattered waves.

Our results lay both an experimental and a theoretical basis for wavefront shaping experiments. The concepts that are developed are generally applicable to any linear complex system. Therefore, our methods can be translated directly to other disordered systems such as scattering of microwaves, sound, seismic waves, electrons or neutrons.

We expect wavefront shaping to have applications in imaging, spectroscopy and light delivery in scattering media. Additionally, our method could be used to focus light inside non-random complex systems. This way, one could focus light on a quantum dot in a three-dimensional photonic crystal cavity, or excite a desired mode in a complex photonic metamaterial or plasmonic device. All in all, wavefront shaping can be used to guide light (or any other wave) to any desired position in an arbitrary complex environment.