Sensing the position of a single scatterer in an opaque medium by mutual scattering

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Tracking the position of a single particle within opaque samples is a major challenge in optics. It is usually done by sending a single beam of waves to a target and studying the scattered waves, as in typical X-ray experiments for weakly interacting samples. The recent development of multiple-beam techniques such as optical wavefront shaping, where light scattering with multiple properly phased incident beams, has opened new potential for research of strongly interacting opaque samples. In this work, we show that mutual scattering is a powerful method to detect the displacement of a single scatterer in an optically dense sample of many (up to N=1000) similar scatterers. We illustrate that our multiple-beam technique provides speckle patterns with an angular sensitivity at least 10 times higher than the traditional one-beam techniques and can be a powerful tool in imaging and metrology applications.

Figure 1: Schematic of the numerical samples: (a) A cube with $N_{\text{dipole}} = 1000$ dipoles, and (b) a cube with $N_{\text{dipole}} = 250$ dipoles, whose polarizability is shown by the extent of the blue spheres. The target dipole (red sphere) at position $r_0$ is moved along a chosen direction, for example, the blue line shows the movement of the red scatterer in the $x$-direction, while the positions of all other ($N_{\text{dipole}} - 1$) scatterers are preserved.

Figure 2: Comparison in a semi-log scale between (top) the maximum mutual scattering of from two beams (bottom) the differential cross-section from one beam. Two-beam mutual scattering provides speckle patterns with an angular sensitivity at least 10 times higher than the traditional one-beam technique.

References

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