Single-Scattering Optical Tomography

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We address the problem of three-dimensional optical imaging of mesoscopic systems. These are systems of intermediate optical thickness, where the photon mean free path is of the order of the system size. In this case, light exhibits sufficiently strong scattering so that the image reconstruction methods of computed tomography are not applicable, yet the detected light is not diffuse and the diffuse tomography can not be employed either. On the mesoscopic length scale, applications to biological systems include imagining of engineered tissues, semitransparent organisms, or superficial tissues.

The light transport in the mesoscopic system is described by the first-order scattering approximation to the radiative transport equation, and a relationship between the scattering and absorption coefficients of the medium and the scattered light intensity is derived. This represents the basis for a novel three-dimensional optical imagining technique that we refer to as *single scattering optical tomography* (SSOT). SSOT uses angularly-selective measurements of scattered light intensity to reconstruct the optical properties of inhomogeneous media, assuming that the light is predominantly single-scattered.

The mathematical formalism of SSOT is similar to that of x-ray tomography, except that the ray integrals are evaluated not along straight lines but along broken rays. As a result, the method does not require rotating the imaging device around the sample to aquire data from multiple projections and, therefore, can be used in backscattering. The potential advantages of SSOT also include linearity and well posedness of the inverse problem (in contrast to the diffuse optical tomography). Further, SSOT does not require phase measurements, in contrast to the optical coherence tomography. It can exploit additional contrast mechanisms, compared to OCT and x-ray tomography. Finally, the inverse problem of SSOT is two dimensional and image reconstruction can be performed slice-by-slice.

An image reconstruction algorithm is proposed and numerically implemented. To this end, the forward data is simulated by solving the radiative transport equation numerically. We demonstrate that SSOT enables simultaneous reconstruction of scattering and absroption properties of an inhomogeneous system. The reconstructed image quality and level of detail are significantly above those obtained in diffuse optical tomography and comparable to those in x-ray computed tomography, even when the system size is of the order of several transport mean free paths.

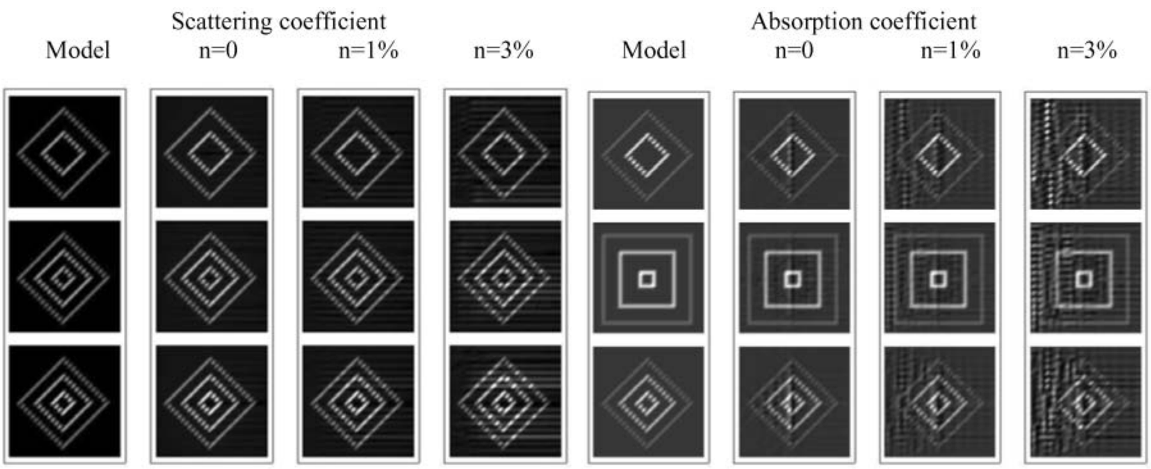

Fig. 1 Image reconstruction for the scattering and absorption coefficients for an inhomogeneously scattering and absorptive sample of optical depth 2 and for various noise levels n in the data. The rows show the slices where the inhomogeneities are placed. Three dimensional imaging is performed slice-by-slice.

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