Optical Tomography of Arbitrarily Shaped Object with Randomly Rough Boundaries

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This paper presents the results of research designed to fulfill two main objectives including development of laser reflectance modeling of complex convex or concave objects with randomly rough boundaries and investigation of tomographic reconstruction of these objects.

This paper addresses the utility of physics based modeling of the laser backscattering of complex rough targets. The physics based model, we present in this paper, is designed to provide accurate results but to also include all of the electromagnetic interaction mechanisms. To model the laser interaction with the randomly rough surface, we use the second order Small-slope Approximation method. Because the problem, we consider in this paper, is three-dimensional, all the scattering coefficients (coherent and incoherent component of the electromagnetic field) are functions of the azimuth angles, and the cross-polarized terms do not vanish. We define, in this case, the Mueller matrix, which gives all the combinations of the polarization states of the scattered electromagnetic waves. The randomly rough surfaces of the complex object are characterized by electromagnetic parameters (permittivity...) and roughness parameters (standard deviation of rough surface height and autocorrelation function). One of the great advantages of this physics based model is its extensibility. Electromagnetic interactions of higher levels of complexity can be added to the model. Illustrative examples are presented for laser scattering from large convex objects. Our model addresses also transparent structures. With this model, we can obtain high temporal resolved laser backscattering from complex objects.

In the second part of the paper, we investigate algorithms for tomographic reconstruction of complex objects. The reconstruction is based on compilations of time-resolved optical backscattering obtained at various angles. The laser backscattered energy at various angles is calculated by our reflectance modeling of complex objects. We use our model to generate sets of data, with which we can compare the different models of reconstruction. We compare direct back-projection method, filtered back-projection method, Fourier-Radon method and stochastic method. We analyze the stability of the different methods when we add noise to the laser backscattering.