Reducing the effects of backscatter in reflection imaging through a particulate random medium

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Imaging through obscuring media continues to be a highly challenging problem in both remote and laboratory-scale imaging. We are developing a short-optical-pulse imaging technique (E. Bleszynski, M. Bleszynski, and T. Jaroszewicz, Optics Letters, 43, 3762-3765, 2018) taking advantage of enhancement of the propagating radiance due to multiple small-angle scattering on large (compared to the wavelength) medium constituents. This mechanism gives rise to the "early-time diffusion" phenomenon, observed in the radiative transfer equation (RTE) solutions as a sharply rising structure in the measured time-resolved intensity, immediately following the ballistic signal but attenuated at a lower rate.

In application to reflection imaging through an obscuring medium (Figure 1) the signal reflected from the target (and arriving at the detector after the time $2\,(H_\mathrm{d} + L + H_\mathrm{t})/c$) has to compete with the background caused by backscatter from the medium slab. That backscatter signal starts to arrive at the detector at the time $2\,H_\mathrm{d}/c$ and its long temporal tail (after the delay $2\,(L + H_\mathrm{t})/c$) overlaps the image-bearing signal.

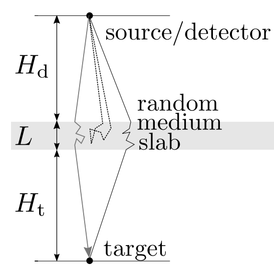

Figure 1: A schematic representation of a reflection imaging scenario in the context of imaging through a layer of atmospheric clouds.

The subject of this contribution is a reliable evaluation of the backscatter background and assessment of methods for its mitigation.

We compute the backscattered radiance from a rigorous solution of the time-dependent RTE for a slab, based on an eigenmode decomposition method. We find that, for many choices of parameters (and, in particular, for strongly collimated scattering in the medium) there is a significant discrepancy between this solution and the solution of the *diffusion equation* (DE), which is commonly used as an approximation to the late-time behavior of the radiance. Those discrepancies can be attributed to the failure of the DE in describing the *early-time* evolution of radiation, which strongly affects its late-time asymptotics.

Among the backscatter mitigation methods we will discuss temporal modulation of the illuminating beam combined with an appropriate matched filtering of the received signal; this procedure is expected to strongly reduce backscattering contributions due to time-dependent medium configurations.