Designing sources for enhancement of early-time diffusion in short pulse propagation through random particulate media[+]

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It is known that imaging and communication with short pulses through random particulate media (such as atmospheric clouds, fog, etc.) is seriously ihhibited by scattering in the medium and resultant signal diffusion leading to spatial and temporal pulse spreading time. A phenomenon of early-time diffusion in the solutions of the radiative transfer equation (RTE), recently described in E. Bleszynski, M. Bleszynski, and T. Jaroszewicz, Optics Letters, vol. 39, pp. 5862-5865, 2014, offers a possibility of alleviating these adverse effects by isolating, in the time-resolved intensity of the received pulse, a rapidly rising component immediately following the ballistic (coherent) signal, but attenuated at a substantially lower rate. The early-time pulse component is present provided the medium particles are sufficiently large compared to the wavelength, and arises from strongly forward-peaked scattering, giving rise to a persistent random-walk process and a distinctive "early-time" diffusion (ETD) behavior.

In the present contribution we consider the possibility of enhancing the contribution of the early-time diffusion relative to that of the usual "late-time" diffusion (LTD).

We describe radiance of a propagating pulse as a superposition of eigenmodes of the RTE, i.e., radiance configurations which have plane-wave-type spatial dependence (including exponential attenuation) and whose angular distribution in the energy flux direction ($\hat{\boldsymbol{s}}$) remains unchanged throughout their temporal and spatial evolution. We find that, for propagation distances large compared to the mean free path, the pulse intensity is dominated by only a few families of eigenmodes, belonging either to the ETD or the LTD class. As the properties of the ETD and LTD eigenmodes – their distributions in the wave number and in the flux-direction – are very different, the field source (or the beam shape) may be designed to couple more strongly to the ETD than to the LTD modes, thus reinforcing early-time diffusion component of the radiance.

In this presentation we discuss several approaches to constructing ETD-enhancing sources, including spatial (transverse) and temporal, as well as angular ($\hat{\boldsymbol{s}}$), modulation of coherent and partially coherent sources. Special attention is paid to the role of the constraints due to the physically necessary positive semi-definiteness of the radiance. Enhancement of the ETD contributions is shown on a number of examples, especially those utilizing partially coherent sources.

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