Reply to "Comment on 'Polarization memory of multiply scattered light' "

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The breakdown of the diffusion approximation in describing temporal autocorrelation functions of multiply scattered light can be probed by collecting light from different polarization channels. Contrary to the claim of Freund and Kaveh, the diffusion approximation cannot be used to predict the value of γ, nor can it be used to make any statement about the universality of the value of γ.

Freund and Kaveh claim that the value of γ obtained from a fit of the unpolarized autocorrelation function to Eq. (2) in their Comment is in agreement with scalar-wave treatments and is universal. In discussing this claim, it is crucial to note that the diffusion approximation for the transport of light is implicit in the "scalar-wave theory" which they use. This is important because, within the diffusion approximation, it is impossible to make quantitative predictions about the value of γ, let alone its universality. As shown below, the claim of Freund and Kaveh is based on a circular argument.

The form of the autocorrelation function for the backscattering geometry and the value of γ depend sensitively on the transport of light near the boundary where the light enters the sample.[1] In particular, the value of γ depends on exactly how the nondiffusive light incident from outside the sample becomes diffusive inside the sample. This must occur within a distance of the order of a transport mean free path, ℓ^*, where the diffusion approximation simply cannot apply.[1] The reason for this is that the diffusion approximation is a continuum theory which cannot describe discrete scattering events on length scales comparable to or less than ℓ^*. The problem is further exacerbated by finite-sized particles which do not scatter light isotropically. Since the diffusion approximation does not give any prescription for how nondiffusive light is converted to diffusive light, one must either go beyond the diffusion approximation, which is very difficult, or make some *ad hoc* assumption about how this process occurs, which is usually done. In previous work, we have made the convenient, but clearly unphysical ansatz that all the incident light is converted to diffusing light at exactly one transport mean free path inside the sample.[1] Freund and Kaveh have made exactly the same assumption in their work.[2,3] This *ad hoc* choice ensures *a priori* that γ is simply a constant, independent of the system. Thus, basing the claim of universality on this "scalar-wave treatment of the optical field" amounts to circular reasoning. Furthermore, other physically reasonable models for how the incident light is converted to diffusive light give different, system-dependent results. For example, in Refs. 5 and 6, $\gamma \simeq 2.4$ for small isotropic scatterers while $\gamma \simeq 1.67$ is found for very large anisotropic scatterers.

In our work on polarization memory,[4] we investigated the conversion of the incident light to diffusive light by exploiting the fact that different polarization channels select different sets of nondiffusive paths. While this is certainly a first step in attempting to address the breakdown of the diffusion approximation, the complete solution to the problem of how to describe the nondiffusive propagation of light near sample boundaries has yet to be found. Experimentally we found that the value of γ was nearly system independent for weakly interacting spherical particles over a relatively narrow range of sizes and only for relatively dilute solutions. Given the very broad variety of media that exhibit diffusive-light propagation, this apparent system independence may be purely fortuitous, and it would seem premature to claim that the value of γ is universal. Moreover, given the tenuous state of current theoretical work on this point, any claims of strong universality are clearly premature and misleading.

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