Imaging in Absorptive and Scattering Media

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Abstract: In a media such as breast tissue, light at 800nm attenuates approximately 1 order of magnitude per centimeter due to absorption and scattering. We will discuss the possibility and some preliminary results of using optical pulses shaped as the mediums impulse response (Green's function) to reduce both absorption and scattering.

This work is related to optical precursors. Sommerfeld and Brillouin,[1] and Oughstun and Sherman [2] has shown that propagation of broadband pulses in *linear* dielectrics can give rise to precursors. The Brillouin precursor is of particular practical interest since it attenuates as $\frac{1}{\sqrt{z}}$ rather than $\exp(-\alpha\, z)$, [2].

As part of an ongoing investigation of optical precursors we found that the intensity of a broadband pulse exhibit reduced attenuation, as compared to Beer's law, after propagating several meters in distilled water.

Based on simulations, we argue that the reduced attenuation is due to the formation of precursors that dominate the behaviour of the light energy at longer distances. These, so called precursors, occur when the a pulse's spectrum is sufficiently broad to cover all the saddle points associated with the phase function $\Phi(\omega, \theta) = i\omega[n(\omega) - \theta]$ where $\theta = \frac{ct}{z}$ [2], for the whole propagation distance z.

Furthermore, we hypothesize that these so called precursors —that are special outcomes of the light interacting with the medium— should also give rise to reduced scattering, due to the dependence of the dielectric function for both the absorptive and scattering cross sections, equations (1) and, (2).

$$\sigma_a = \frac{\int_V k\epsilon_r''(r')|\mathbf{E}(r')|^2\,\mathrm{d}V'}{|\mathbf{E}_i|^2} \tag{1}$$

$$\sigma_s = \int_{4\pi} \left| \frac{k^2}{4\pi} \int_V \mathbf{E}_{\perp\mathbf{o}}[\epsilon_r(r') - 1] \exp(jk\mathbf{r}' \cdot \mathbf{o})\,\mathrm{d}V' \right|^2 \mathrm{d}\Omega \tag{2}$$

References

1. L.Brillouin, *Wave propagation and group-velocity*, (Academic Press, 1960).
2. K.E. Oughstun and G.C. Sherman *Electromagnetic pulse propagation in causal dielectrics*, (Springer Verlag, 1997).