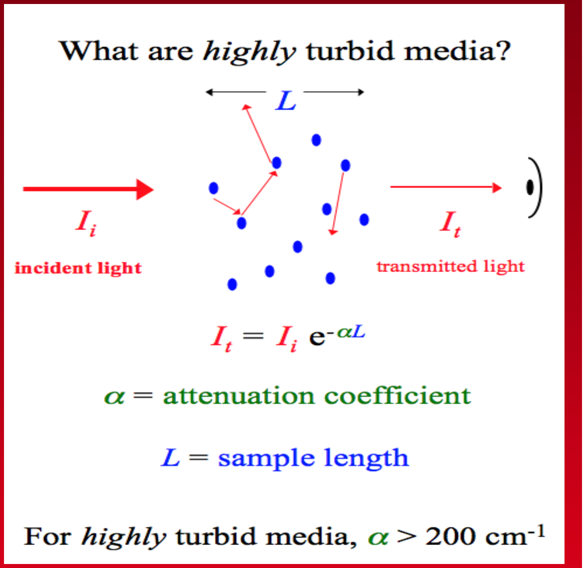
New Model for Total Internal Reflection from Turbid Media and Applications

Samir Bali, Department of Physics,
Miami University Oxford, OH 45056-1866

Turbid media refers to disordered media such as colloidal suspensions that generate extensive multiple scattering of the incident light. Turbidity is described by the attenuation coefficient α (see inset on right).

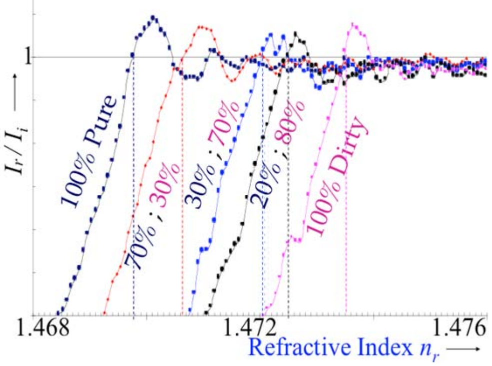
For example, the value of α for milk in the visible/near-IR frequency band varies between 40 cm^{-1} (skim milk) and 125 cm^{-1} (whole milk), while for highly turbid media such as biotissue and crude petroleum α lies between 800 and 1500 cm^{-1}

The attenuation coefficient α is directly related to the imaginary part of the refractive index, and is determined by a transmission measurement as indicated in the inset on right. The real part of the refractive index is the "usual refractive index" arising from the bending of light at the surface, and Is determined by measuring the critical angle for total internal reflection (TIR).



The problem is that for *highly* turbid media the critical angle does not exist and, further, almost no light transmits through samples as thin as ~ 0.1mm. We have developed a new theoretical model for TIR that enables us to make a first-ever accurate measurement of the refractive index and attenuation coefficient of a turbid medium.

Real-time measurement of refractive index of engine oil



Preliminary measurement of the reflectance ratio of reflected to incident light, I_r / I_i, from the surface of a sample of engine oil, showing clear change in refractive index (shifting point of intersection with 1) as degradation increases.

We have applied our new model toward a first real-time measurement of refractive index changes in auto-engine oil of slightly varying states of degradation. By contrast, in the auto industry, oil quality is "monitored" by mileage-based software without any actual sensing.

Our next goal is to apply our new understanding of TIR in turbid media toward detection of the onset of asphaltene precipitation in *undiluted* petroleum fluids and early detection of wax formation in fuels at low temperatures.