Biophotonics and Light in Scattering Media

I work in the field of biophotonics, and I am interested in the general problem of light in scattering media. My work has theoretical, modeling (including imaging) and experimental aspects. One sphere of my activities in this area is directed towards biomedical imaging, where the use of light is bringing about a revolution in the detection, monitoring and treatment of disease. I have worked in, and helped define, the area of optical diffusion tomography, where centimeter-scale tissue domains can be imaged, and spectroscopy can be exploited. The image becomes the spatially-dependent diffusion and absorption coefficients in a diffusion equation model, where the photons are treated as particles. My current work extends the basic contributions I've made in fluorescence imaging and the imaging of kinetic parameters to the imaging of fluorescence resonance energy transfer (FRET) parameters. Surprisingly, we have shown that it is possible to image the nanometer FRET distance within a diffusion model, and we have studied targeted anti-cancer drug delivery in a mouse model. As an example application, protein misfolding has been implicated as a cause of Alzheimer's disease, and we have made a case that it will be possible to image FRET parameters to understand and monitor such brain developments *in vivo*. We are also working on efficient ways to solve the inverse problem (forming the image from measurements, a nonlinear optimization problem), as this will improve resolution and reduce computation time. Jointly, this work will pave the way for fundamental biochemistry and clinical applications (with current and future collaborators), directions I find exciting. *The other (related) dimension of my work in this area is in the field of statistical optics, where scattered coherent light forms speckle. Whether the problem be imaging through tissue, the atmosphere, or some emulsion, or the understanding of how random lasers work, the basic problem boils down to the interaction of light with scattering elements and the use of various measures (spectral and spatial correlations, for example).* We showed that third-order correlations of speckle intensity patterns over frequency yield the temporal impulse response, which is a key measure for imaging. We were able to measure the scattered field directly and hence show for the first time that the scattered fields were circular Gaussian, an assumption that underpins all of statistical optics. We discovered a new type of interferometer, where coupling is facilitated by a scattering medium, and this is important in optical time/distance measurement and imaging, and may also relate to information capacity for communication with scatter. Rather amazingly, we have recently shown that incident wave vector information remains under heavy scatter and can be extracted from a spatial correlation over source position, and this will lead to new imaging opportunities. *I am interested in basic information issues, various (strong and weak) scattering regimes (with related models), active media, and random scattering with entangled photons.*