Another Physicist wandering into Biology and Biomedicine

For three quarters of a century, physicists have been numerous contributions in the development of new tools and the application of these tools in biophysics, biology and biological and biomedical imaging. Contributions include protein x-ray crystallography, molecular structures from NMR, DNA sequencing, mass spectroscopy of biological molecules, optical tweezers, and super-resolution microscopy, single molecule/single molecular systems such as single molecule FRET (fluorescence resonance energy transfer). Contributions in medical imaging that include x-rays, MRI, CT imaging, electron microscopy including cryo-EM.

Since returning to Stanford after my time as Secretary of Energy in 2013, I have begun a new research program beyond optical tweezers, single molecule FRET and super resolution imaging. Since 2014, I have ventured into several new research areas that included biological and biomedical imaging, batteries, and novel applications in electrochemistry.

In this talk, I will focus on our recent work where we developed significantly improved, fully photostable rare earth nanoparticles[[1]](#footnote-1) and excellent surface functionalization methods. We have begun to use these particles in biology. In particular, I will discuss how these particles allow us to track the motion of specifically targeted membrane proteins (e.g. channel rhodopsin), and the transport of molecular cargos in live DRG (dorsal ganglia root) neurons with single molecular step resolution over millimeter distances. With this capability, we are able apply concepts in non-equilibrium thermodynamics to measure properties of molecular motors that were not previously accessible in live cell measurements.[[2]](#footnote-2)

I will also discuss a novel method of combining multiple frequencies[[3]](#footnote-3) and multiple angles in ultrasound imaging data that allow us to greatly reduced the speckle noise in ultrasound imaging. The method does not significantly increase the imaging time, so that the advantages of real-time medical ultrasound imaging with non-ionizing radiation are retained. In addition, we have developed elastic image registration methods to further enhance the image quality. The combined frequency and angle compounding of images plus elastic registration are allowing us to approach the theoretical diffraction limit defined by the wavelength and numerical aperture of the sound used in the imaging.[[4]](#footnote-4) The results of non-linear ultrasound imaging and its enhanced tissue contrast will also be presented.[[5]](#footnote-5)

1. Single upconversion nanoparticle imaging at sub-10 W cm-2 irradiance, Qian Liu, Yunxiang Zhang, Chunte Sam Peng, Tianshe Yang, Lydia-Marie Joubert,Steven Chu, Nature Photonics 12, ,548–553 (2018).
 [↑](#footnote-ref-1)
2. Sam Peng, Yunxiang Zhang, Qian Liu, Steven Chu, to be submitted.
 [↑](#footnote-ref-2)
3. Optimization of ultrasound speckle reduction by frequency compounding, Yilei Li, Yonatan Winetraub, Orly Liba, Adam de la Zerda, and Steven Chu, Transactions on Medical Imaging,DOI 10.1109/TMI.2018.2856857, IEEE Transactions on Medical Imaging (2018).
 [↑](#footnote-ref-3)
4. Ultrasound imaging with multiplicative frequency and angular speckle reduction, Yilei Li, Noah Toyonaga, James Jiang, Alex Cable, and Steven Chu, to be submitted.
 [↑](#footnote-ref-4)
5. Yilei Li and Steven Chu, to be submitted. [↑](#footnote-ref-5)