‘Imaging’ Imaging physics

Like many other physicists, I’ve always found light and its properties interesting. However, despite this, I never considered the potential applications of light to improve human well-being through imaging techniques until listening to the talk by Professor Bjorg Larson about the use of physics principles in biomedical imaging. As a brief background, I will discuss the traditional modes of medical imaging used in hospitals. One of the most common imaging techniques is MRI, or magnetic resonance imaging, which operates by using a strong magnetic field(This is an example of a quantum two-state system, and the hamiltonian can be solved analytically!) to cause protons to precess in the human body, and then spontaneously emitting photons which are detected using an RF detector. This process repeats several times, and the Fourier transform of the spatial components of the signal constructs an image of the specimen. Next, ultrasound imaging uses a transducer, a piezoelectric device that turns electrical energy into mechanical energy, creating a sound pulse. The pulse is sent through the body and returned to the transducer, which also works as a sensor. Then the amplitudes of the pulses received by the transducer are extracted to image the subject. Nuclear imaging operates on a similar principle but instead uses x-rays. Because x-rays so easily pass through human tissue, medical professionals insert an ionizing source called a radionuclide into the body. The signal is enhanced proportional to the strength of the radionuclide, making it valuable in analyzing the effectiveness of blood circulation, digestive tracts, or other complex systems in the body. Interventional imaging sends a camera into the body and uses conventional optical imaging. Finally, confocal microscopy uses laser light to illuminate a spot on a sample to reflect fluorescent light onto a sensor that corresponds directly to that spot. There is a small pinhole to block out of focus light, and the laser is translated in the xyz plane to generate a 3d image.

Professor Bjorg Larson’s talk focuses on advancements in confocal microscopy, particularly in diagnosing skin cancer. Traditional skin cancer diagnosis consists of a skin biopsy, where doctors remove the area of interest from the skin. In addition to being invasive skin, biopsies require around ten days to receive results for analysis. The delay in the analysis is due to the labor involved in preparing these samples; the tissue must be excised, preserved, and then stained before a traditional optical microscope finally analyzes it. However, confocal microscopy can image freshly excised tissue or, in some cases, tissue still on the patient due to the ability to produce high-resolution images instantly. Confocal microscopy works well for skin cancer, but the small (0.5 mm x 0.5 mm) field of view for confocal microscopy limits its application for cancers where a larger tissue sample is preferable, like breast cancer. In this case, mosaicking is an emerging technique that allows multiple confocal microscopy images to be stitched together when the sample size is too large. Going forward, I would be excited to see if there are any potential applications of confocal microscopy to image protein-protein interactions inside cells. Traditionally, I know imaging small biological samples with optical equipment suffers from poor resolution due to the speed at which biological samples move. Still, confocal microscopy has already demonstrated the ability to image somewhat larger living samples.

The future of confocal microscopy and its applications are exciting. Still, even beyond the fundamental physics, I was particularly intrigued by the communication between end-users, in this case, medical professionals, and the team of physicists and engineers who developed confocal microscopy, but imaging technology based on physical principles in general. I wonder what scientific communication looks like amongst an interdisciplinary team of experts, particularly from a physicist's perspective in multidisciplinary teams, and I would love to hear more from Professor Larson about this aspect of her research.