Application Note

Photon Detection for Deep Brain Imaging

Brain imaging is the use of various techniques to image the structure, function, or pharmacology of the nervous system. It is an emerging discipline crossing the boundary of medicine, neuroscience, and psychology.

Traditionally, models for neural dynamics in the brain have been formed through research conducted on slices, with electrodes, or by lesions to functional areas. Recent developments in functional dyes and optogenetics have made brain research more accessible through the use of light. However, this improved accessibility does not necessarily apply to deep regions of the brain which are surrounded by scattering tissues.

There are multiple optical windows in NIR where water has low absorption and brain tissue has low scattering, both of which are important preconditions for deep brain imaging. By far near-infrared (NIR) radiation has been employed using fluorescence imaging at wavelengths 650–950 nm (optical window I) for deep brain imaging. However, it has been shown by recent scientific studies that the third (III, 1,600–1,870 nm) optical tissue window is the best for deep brain imaging while windows II (1,100–1,350 nm) and IV (centered at 2,200 nm) offer better deep-tissue-imaging quality than window I.

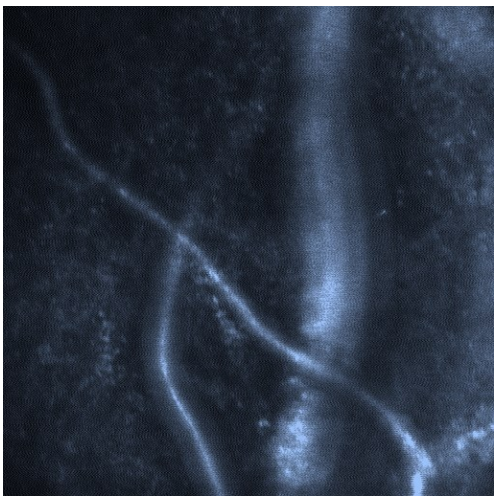
Longer wavelengths in NIR, i.e. windows II, III, and IV have long been avoided due to a lack of suitable photon detectors. Single Quantum's SNSPD (superconducting nanowire single photon detector) offers superior performance in these wavelength ranges and above all in window III. The experiment below proves that it is a powerful tool for deep brain imaging.

Experimental setup

Fluorophores are injected into a mouse brain. A 1550 nm pulsed femtosecond laser is employed to excite the fluorophores. A confocal microscope is used to collect the emission and the photons are coupled to a single mode fiber. A fiber splitter is used to channel the photons to two of Single Quantum's detectors. The analog output is fed into a comparator to generate a TTL pulse. This step is crucial for low noise imaging since the analog output of our SNSPD system has a large spectral noise contributing below 10 MHz due to electrical interferences. Next, they use a low pass filter with 1.9 MHz cut-off frequency. Both channels are further summed in a summation amplifier with gain of 10. The signal is sampled with a 5 MHz analog to digital converter (ADC).

Imaging results

In-vivo imaging of blood vessels inside the brain of a mouse is demonstrated. The image was acquired at 1800 nm excitation and collection. The field of view is 500 x 500 microns, the resolution is ~ 1.3 microns, and the image took 1s to acquire. It demonstrates high contrast and fast acquisition. A video is acquired, which shows the dynamics of the blood flow. Acquiring image at this wavelength was not possible using conventional photon detectors.



This experiment is the first of its kind in applying SNSPD in deep brain imaging. It will open up a plethora of applications of SNSPD where confocal fluorescence microscopy is used for deep tissue imaging.

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