Imaging single carbon nanotubes with the FirstLight C-RED2 InGaAs camera at high frame rates

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In recent years, single-walled carbon nanotubes (SWCNT) have been established as remarkable fluorophores for probing the nanoscale organization of biological tissues[1,2]. They are stiff, quasi-one-dimensional nanostructures, with a small diameter (~1nm) which enables excellent penetration into complex environments, and a large length (100nm to 1µm) which slows down their diffusion and thus allows the tracking of single fluorescent particles. Finally, their bright and stable near-infrared (NIR) fluorescence allows long-term tracking deep in biological tissues without suffering from biological autofluorescence. For example, SWCNTs could be detected in distant regions of the brain extracellular space (ECS) following their injection into the lateral ventricles of young rat brains, and the tracking of their diffusion yielded novel and quantitative insights about the local morphology and variations in viscosity in the brain ECS[1,2].

A central instrument required to perform such studies is a camera capable of tracking single SWCNTs at high speed. Indeed, one limiting factor for the spatial resolution of such diffusion analyses is the ability to observe displacements of SWCNTs over short time lags. So far, we have performed studies at frame rates up to 50 frames per second (20ms per frame).

Here, we show that the FirstLight C-RED2 InGaAs camera cooled to -40°C and mounted on a fluorescence microscope is capable of detecting single (6,5) SWCNTs immobilized on a glass slide at 25 frames per second, 125 frames per second and up to 250 frames per second (4ms exposure per frame).

Results

Nanotubes were easily detected on raw datasets acquired at 25 and 125 frames per second (Figures 1 and 2). Although they were less clearly visible on datasets acquired at 250 frames per second, they could still be detected.

The median signal-to-noise ratio (SNR) for detecting single nanotubes was around 4.2 at 25 frames per second, 2.7 at 125 frames per second, and 2.2 at 250 frames per second. The cumulative distributions of SNRs in each condition is shown on Figure 3.

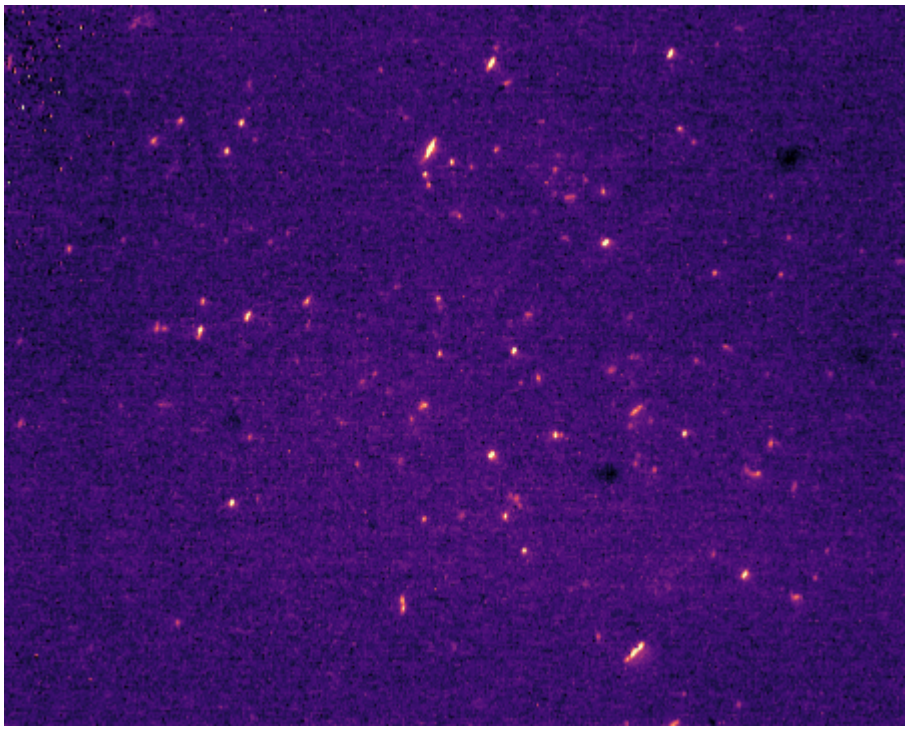

Figure 1: SWCNTs imaged at 25 frames per second, 40ms per frame.

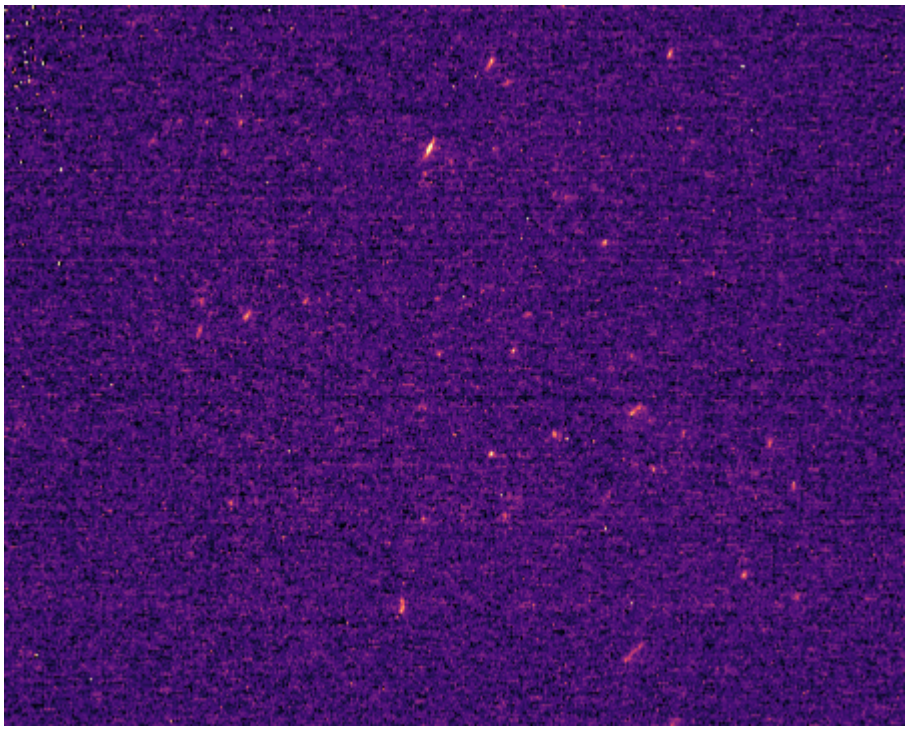

Figure 2: SWCNTs imaged at 125 frames per second, 8ms per frame.

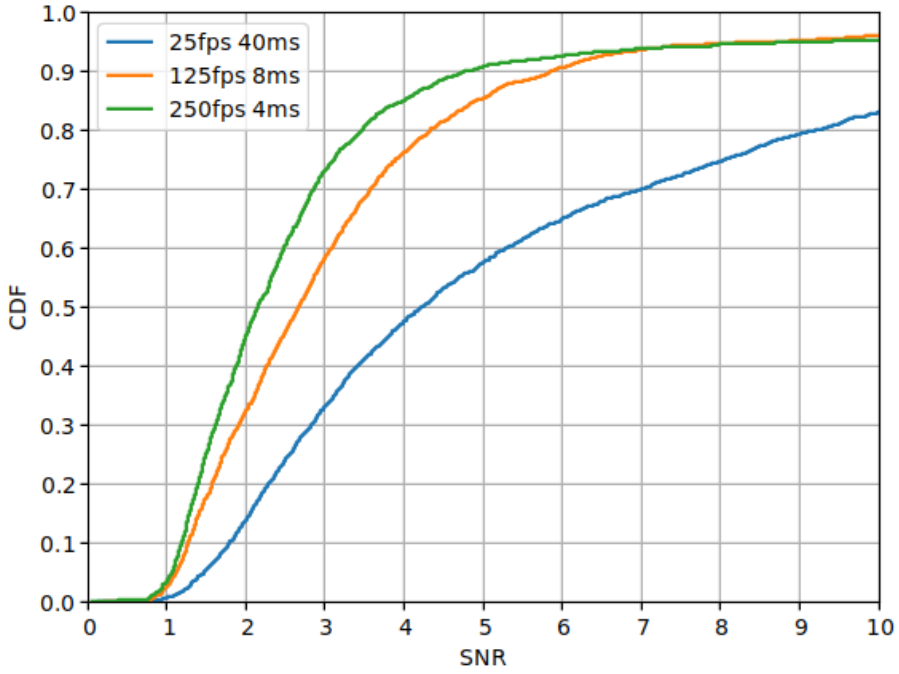

Figure 3: Cumulative distributions of SNRs of localization fits for individual SWCNTs imaged at various frame rates.

Conclusion

The FirstLight C-RED2 InGaAs camera is suitable for detection of single (6,5) SWCNTs at up to 250 frames per second.

Bibliography

1. Godin, A. G. *et al.* Single-nanotube tracking reveals the nanoscale organization of the extracellular space in the live brain. *Nature Nanotechnology* **12**, 238–243 (2017).

2. Paviolo, C. *et al.* Nanoscale exploration of the extracellular space in the live brain by combining single carbon nanotube tracking and super-resolution imaging analysis. *Methods* (2019).