

# QUANTUM SUPER-RESOLVED IMAGING WITH SPAD ARRAYS

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Super-resolution microscopy techniques surpass Abbe's diffraction limit by relaxing one or more of the assumptions at its base. A less explored path involves utilizing quantum properties of light, as the limit is implicitly derived for classical light. The abundance of non-classical light sources in life-science imaging combined with advances in single photon avalanche diode (SPAD) array technology allows us to demonstrate an elegant and scalable realization of a quantum super-resolution technique, quantum image scanning microscopy (Q-ISM)<sup>1,2</sup>.

Fluorescent markers, extensively used in biological imaging, are typically single-photon emitters. In this work, we are able to harness this non-classical property for super-resolved microscopy by imaging the temporal photon correlation signal instead of the standard emission intensity contrast. However, measuring such photon correlations with conventional detectors poses stringent limits in either acquisition rate (CCD and CMOS technologies) or complexity and scalability (multiplexed single-pixel detectors). Here we alleviate these restrictions by utilizing a novel SPAD array detector - featuring an on-chip array of fast single-photon detectors<sup>3</sup>. This compact 23-pixel detector allows multiplexed detection and correlation of single photons at acquisition rates surpassing CCD or CMOS cameras by several orders of magnitude. The implementation of this technique is done in an image scanning microscopy (ISM) architecture, a classical super-resolution technique. The two independent sources of super-resolution combined allow us to demonstrate a factor of  $\sim 2.6$  resolution enhancement in a simple and cost-effective quantum imaging apparatus. The inherent scalability of this approach has the potential to enable widefield quantum imaging and to promote wider use of quantum technologies in life-science imaging.

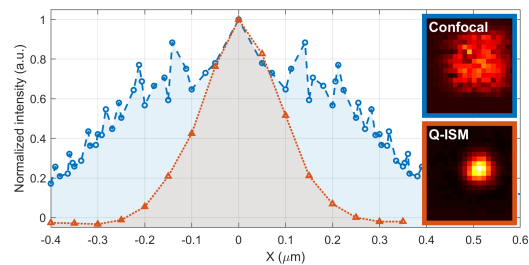


Fig 1. Q-ISM super-resolution demonstrated with a SPAD array microscope

## References

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- [2] G. Lubin et al. *Opt. Express*, **27**, 32863-32882, 2019
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