National Aeronautics and Space Administration

FY23 Lew Allen Award

New applications for superconducting nanowire single-photon detectors

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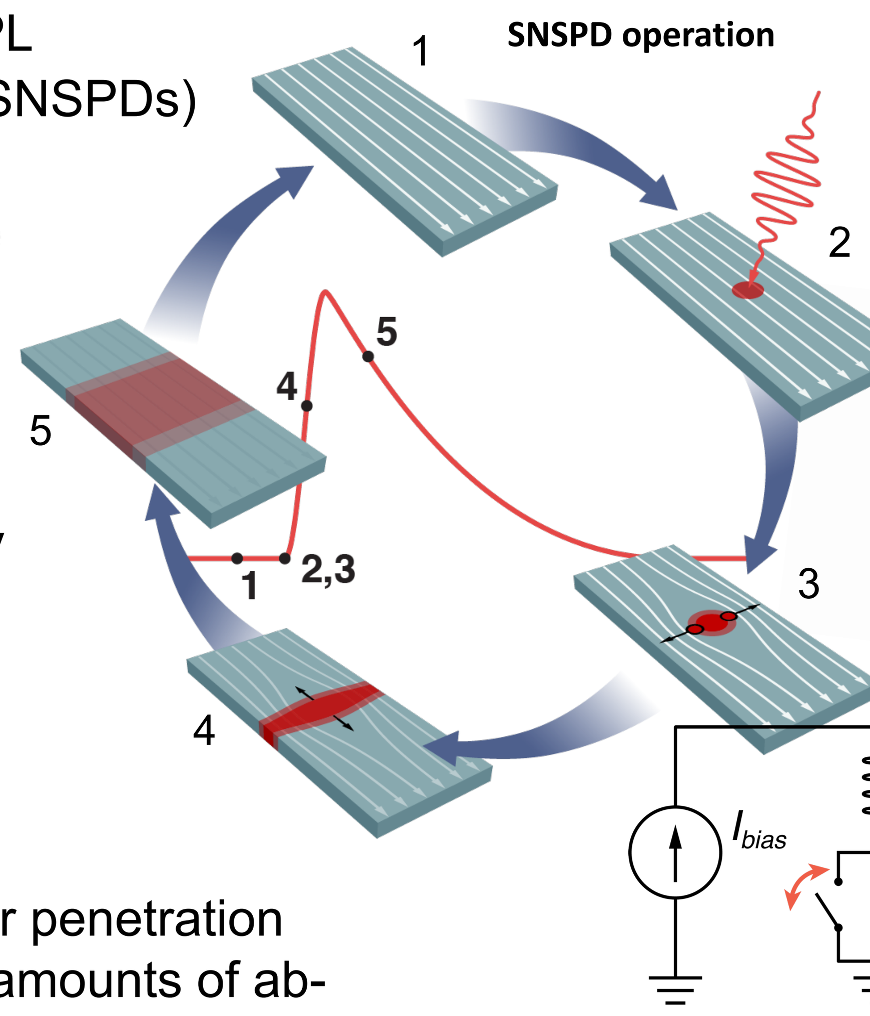
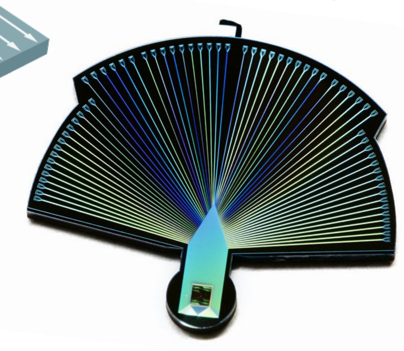
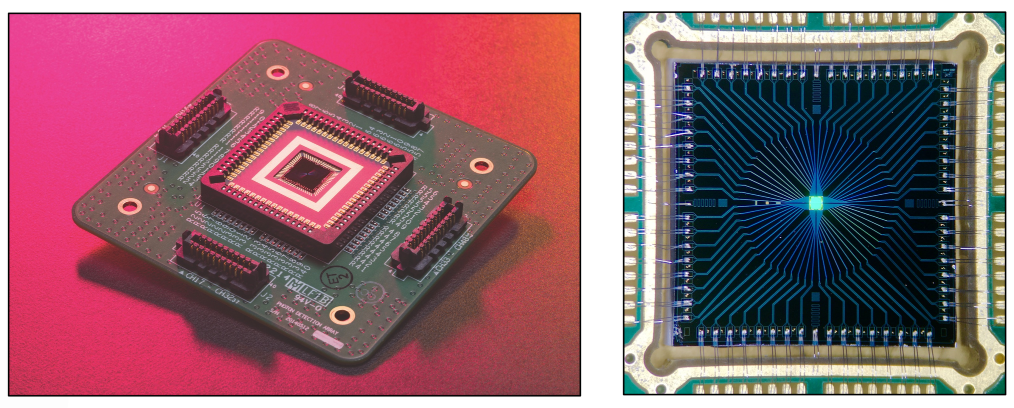
Objective:
To investigate new applications for JPL superconducting nanowire single-photon detectors (SNSPDs)

Background:
SNSPDs are able to detect single photons with record-breaking timing accuracy, high efficiency, large dynamic range, and low noise. They have become the detector of choice for quantum optics and deep-space optical communication applications. Recent advances in SNSPD technology at JPL may enable infusion into new fields.

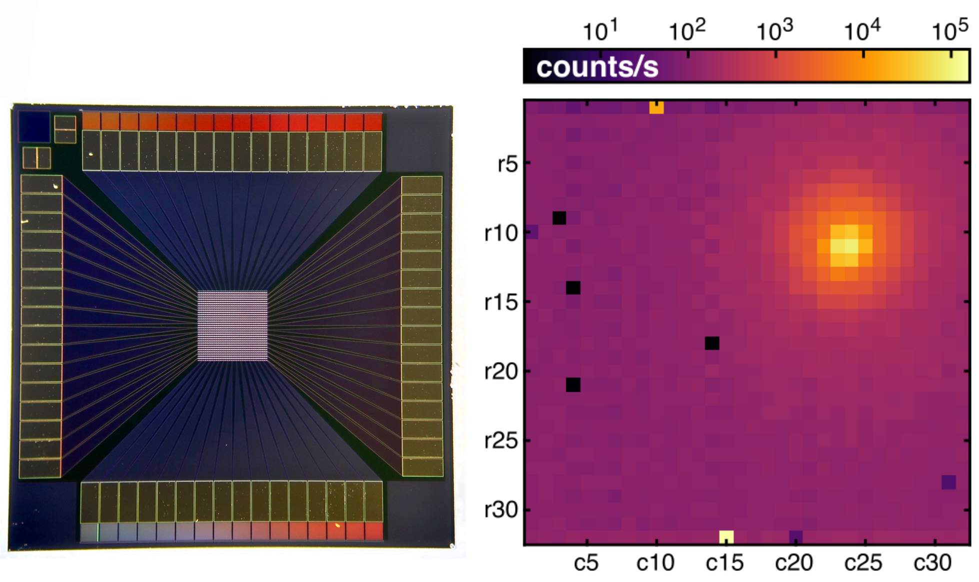




32-channel PEACOQ array



64-channel Deep Space Optical Communication array

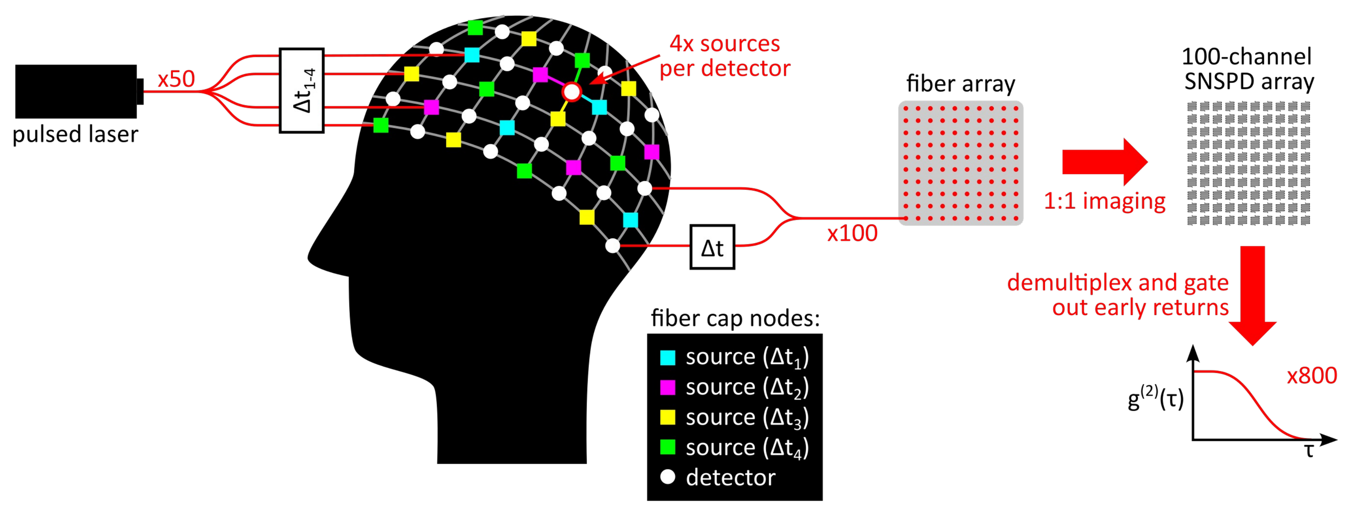


Kilopixel-scale SNSPD array (collaboration w/ NIST)

New Applications:

Biological Imaging:

The NIR-II window, from 1 - 2.3 µm, allows for deeper penetration depths in imaging biological tissue. Due to the large amounts of absorption and scattering in the tissue, single-photon detectors are needed to detect fluorescence. SNSPDs have recently been used for imaging techniques such as diffuse correlation spectroscopy (DCS) [1-3] and confocal fluorescence imaging [4-5].



Concept for multi-channel DCS where a 100-pixel SNSPD array is used to measure cerebral blood flow across the whole head.

Atmospheric Lidar:

The upper atmosphere is very difficult to study, because the low densities mean that emission or absorption occurs on the single-photon level. In the past year, two groups have used SNSPDs for atmospheric lidar: one studied aerosols in the stratosphere [6], and one observed fluorescence from metastable helium in the upper thermosphere [7]. The helium lidar measurements were limited by the active area of their commercially-available SNSPD. We recently submitted a ROSES proposal with this group to use a large active-area SNSPD array to increase the SNR of their measurements by a factor of >30.

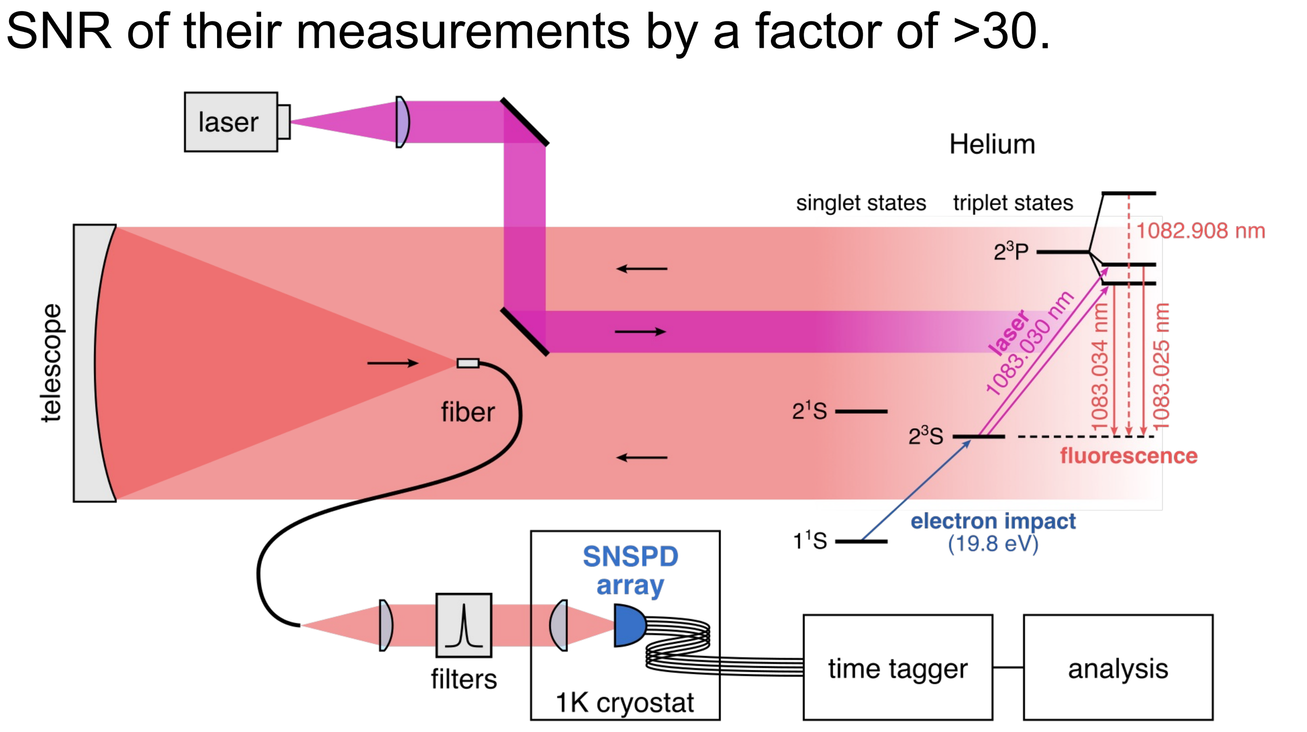
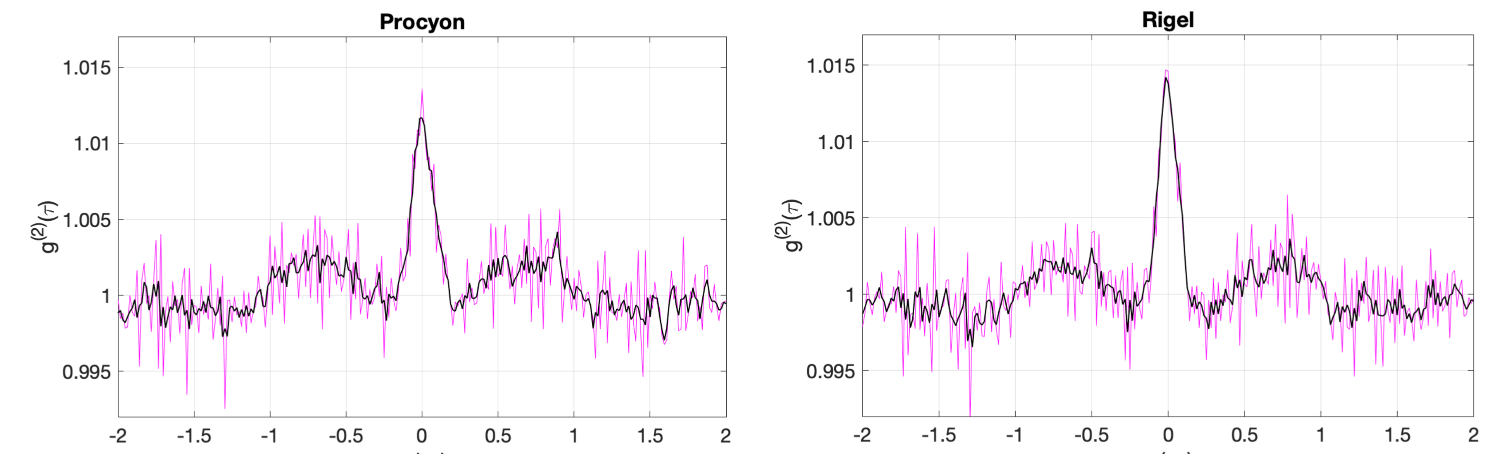


Illustration of metastable helium lidar using a large active-area SNSPD array. A pulsed laser causes fluorescence at 1083 nm, which is collected by a telescope, spectrally and temporally filtered, and detected by an SNSPD bucket array. The timing of the detection events provides altitude information.

Astronomical Interferometry:

Interferometry allows for high-resolution astrometry, because the angular resolution depends on the baseline between telescopes rather than the telescope diameter. At optical wavelengths, it becomes difficult to directly interfere signals for longer baselines. Intensity interferometry allows for counts from two single-photon detectors to be correlated without directly interfering optical signals. The technique was first demonstrated by Hanbury Brown and Twiss, but had fallen out of favor due to low SNR. Recently, there has been renewed interest in intensity interferometry, and several collaborations have measured the temporal and spatial correlations of different stars [8-12]. The detectors used were semiconductor-based SPADs, APDs, or PMTs, but SNSPDs could enable higher SNR with their higher count rates and better timing precision. Another recent paper proposes performing amplitude interferometry using two-photon interference [13] to correlate optical signals from two telescopes. SNSPDs were used for a laboratory proof-of-principle measurement [14].



Temporal correlations measured for two bright stars with the DSOC SNSPD array at the 200-inch telescope at Palomar Observatory. The magenta curves show the raw 0-baseline g(2) signal, and the black curves show the filtered signal. The integration times were 40 seconds for Procyon and 2 minutes for Rigel. Previously-published demonstrations required > 12 hour observations to produce similar SNR.

Benefits to JPL/NASA:
Technologies develop more rapidly when there are more applications (and therefore funding pathways) available to them. Just as the advances in SNSPD technology that were made possible by optical communication investment can now benefit biology, astronomy, or Earth science, the adoption of SNSPDs by these fields could lead to technology development that will improve future optical communication capabilities or other science goals.

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Clearance Number: CL#23-5920
Poster Number: RPC-213

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