FY23 Strategic Initiatives Research and Technology Development (SRTD)

Next-Generation Deep Space Optical Communication Ground Systems

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Strategic Focus Area: Optimizing Deep Space Optical Communication Ground Systems | **Strategic Initiative Leader:** Dimitrios Antsos

Background and scientific goals

Single-photon imager for a future IR/O/UV (0.2…2 μm) space telescope with:

- near-unity efficiency
- megapixel resolution
- $< 10\ \mu m$ spatial resolution
- $< 10^{-2}$ dark counts/hr/px
- > 10 kHz count rate/px
- few 10s of ps timing jitter
- radiation tolerance

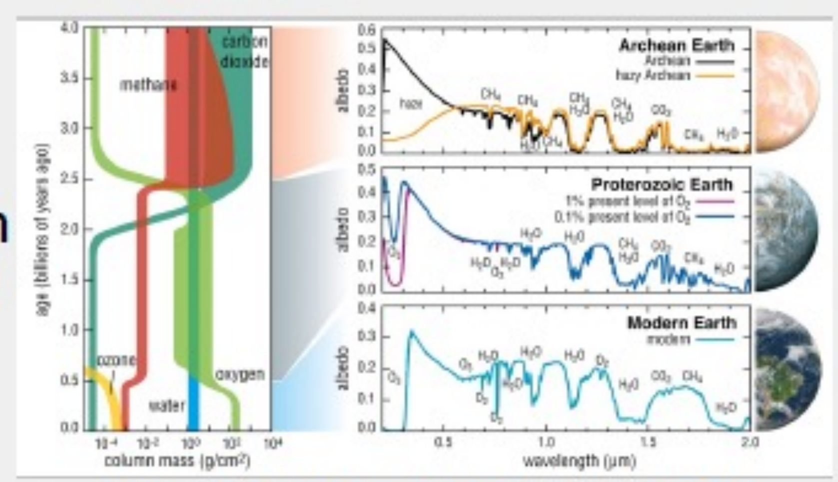


Fig. 1.1, Astro2020 report [1]

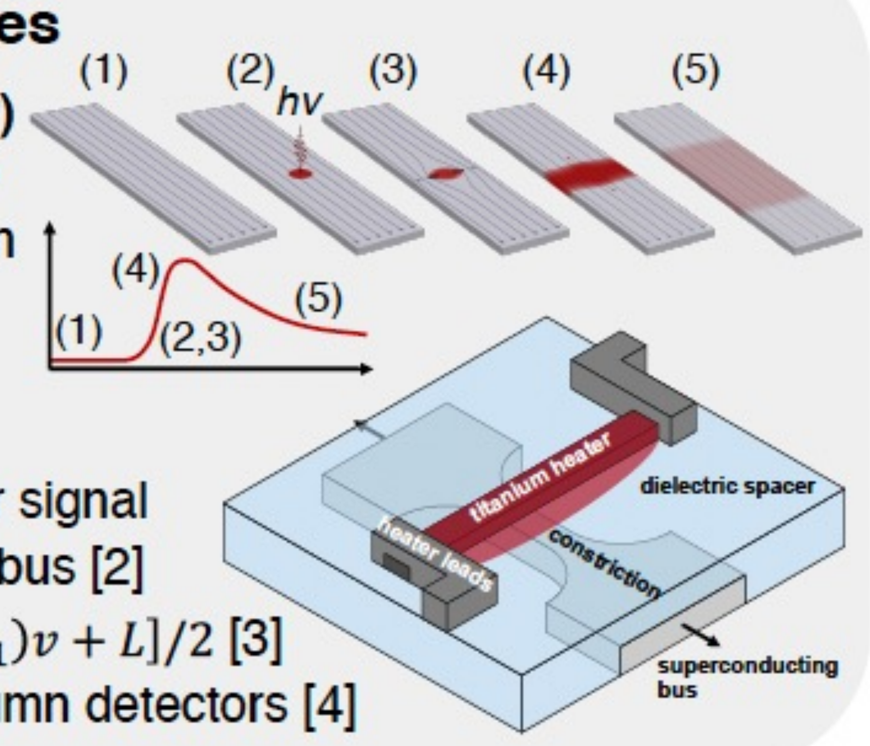
SNSPD and multiplexing principles

SNSPD (nanowire single-photon detector)

- current-biased superconducting nanowire
- photon absorption induces resistive region
- bias current is shunted to readout

Multiplexing

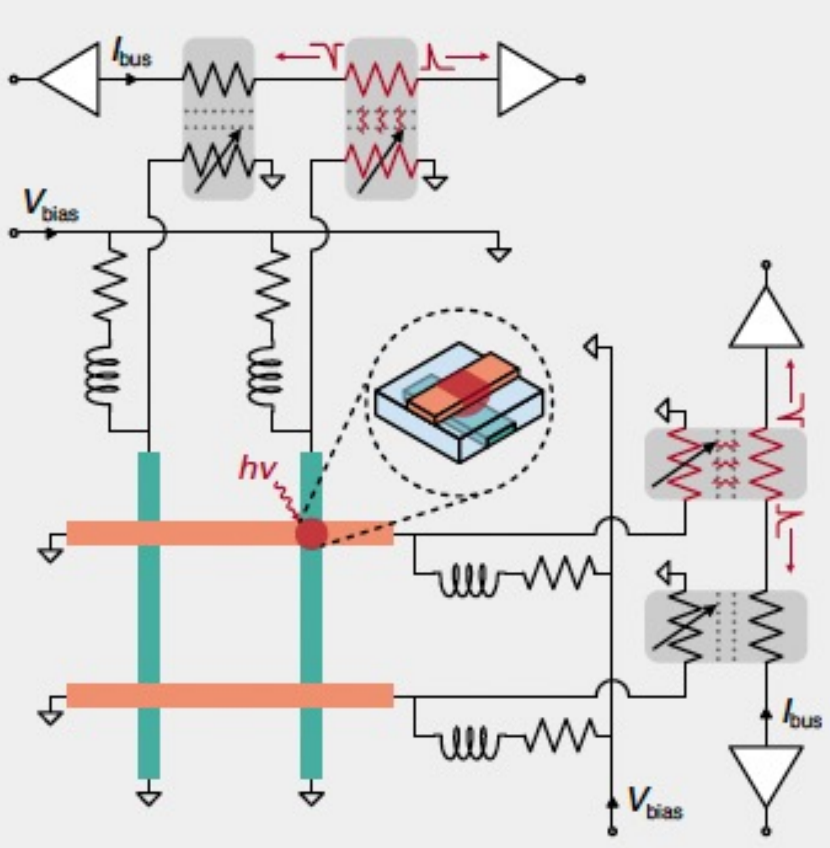
- unidirectional thermal coupling of detector signal via heater to a common superconducting bus [2]
- time-of-flight measurement: $x_p = [(\tau_2 - \tau_1)v + L]/2$ [3]
- pulse coincidences between row and column detectors [4]



Detector architectures

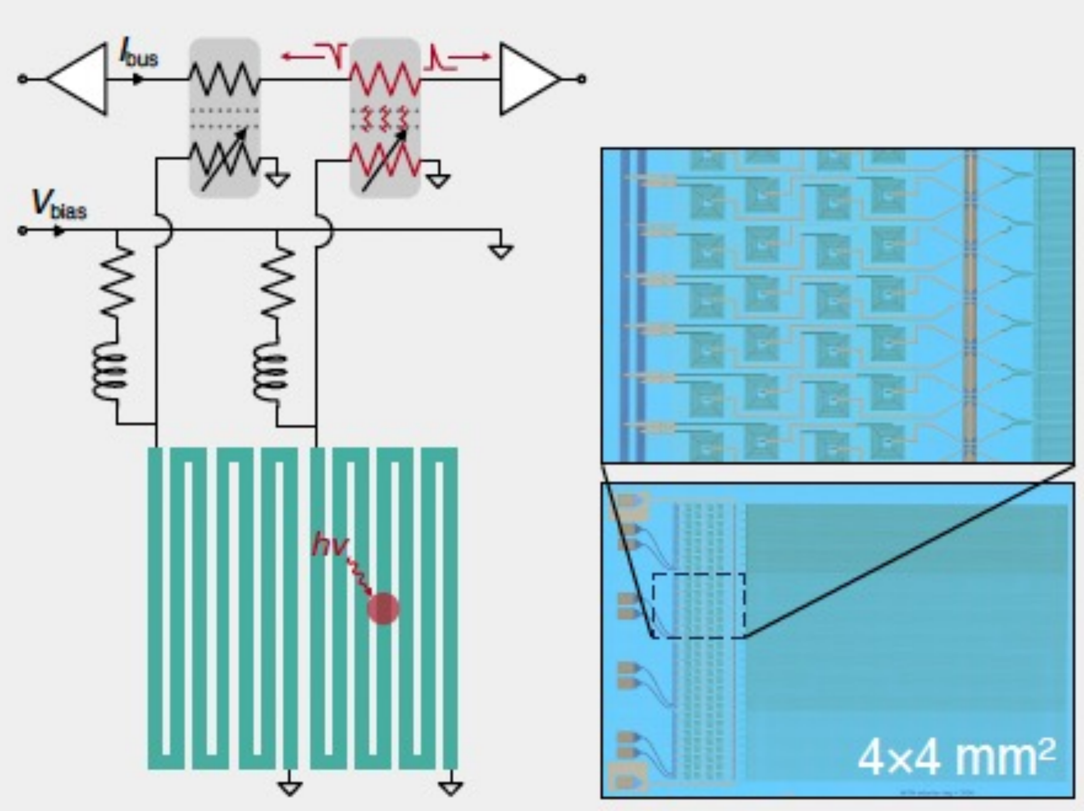
Megapixel array

- scale to megapixel array with high fill factor
- thermal coupling between stacked nanowires
- only 4 microwave lines for array readout



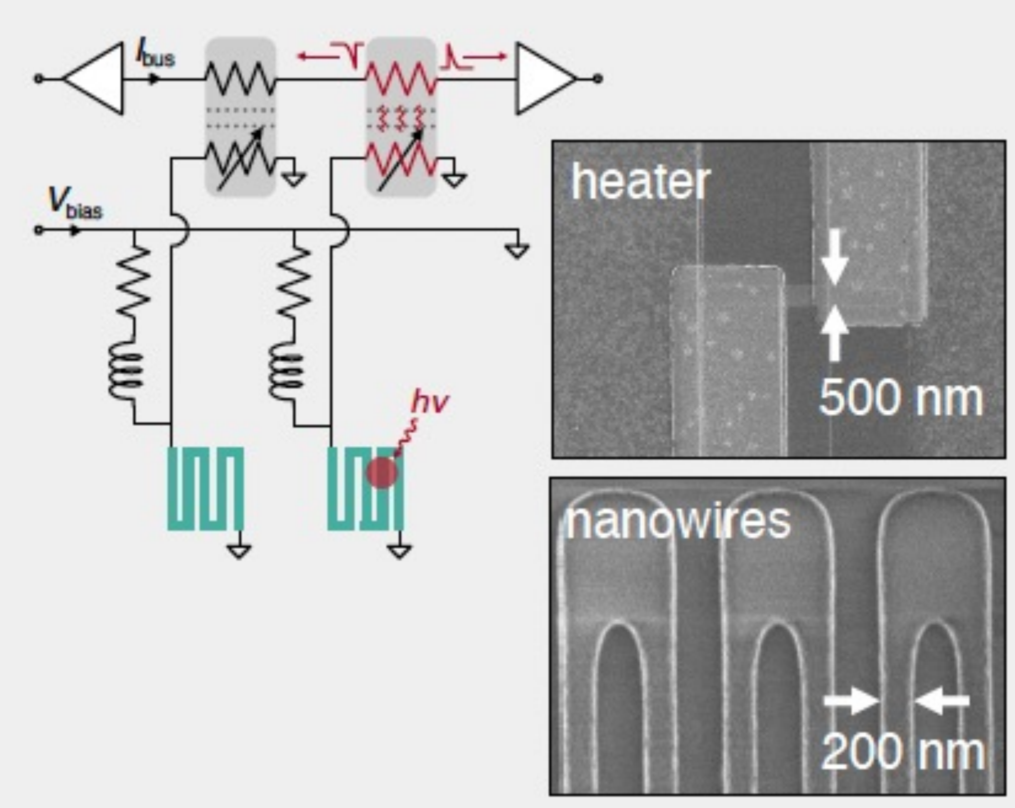
Superconducting photomultiplier

- large active area up to 10×10 mm²
- no imaging, fast bus integrates pulses, height proportional to photon number across array



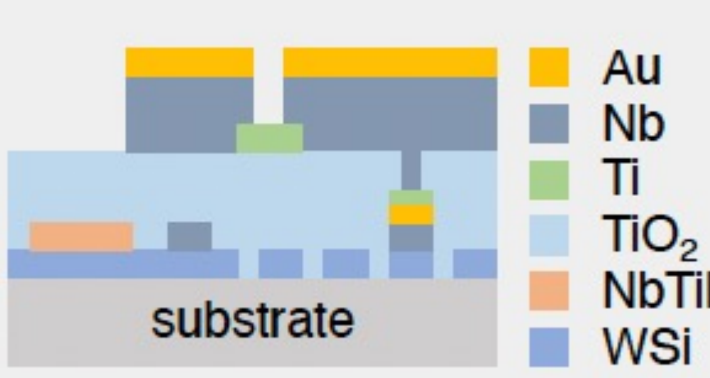
High-speed array

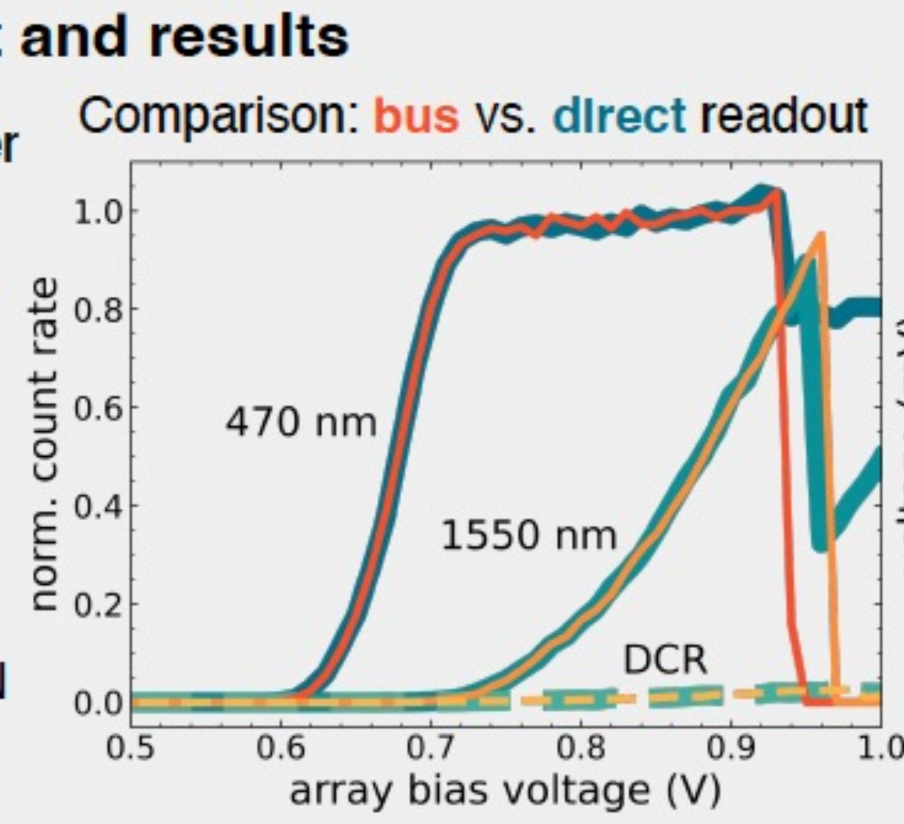
- 64 differential buses with 64 short nanowires each, for 4096 pixel array over ~5×5 mm²
- several GHz count rate across array

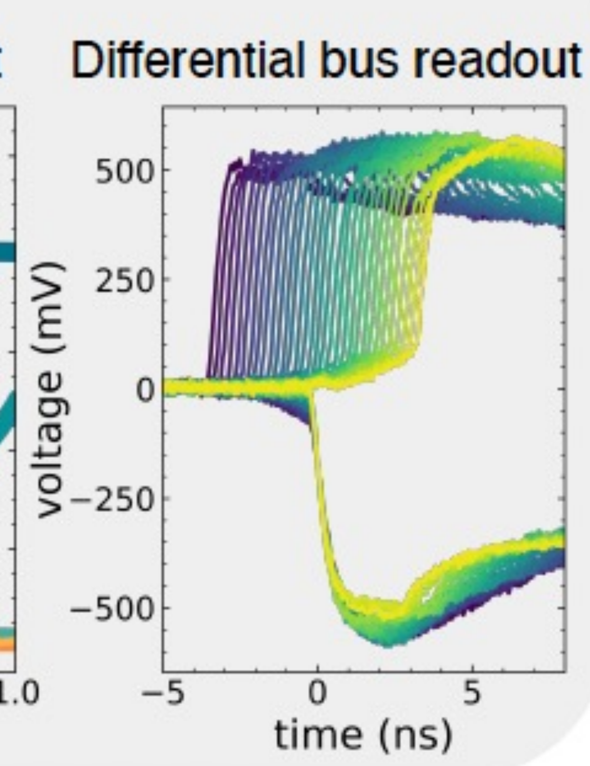


Technology development and results

- dielectric spacer for heat transfer
- resistive thermal coupler
- superconducting vias and wires
- high-yield nanowire patterning







Outlook

- ✔ reliable fabrication process
- ✔ thermal coupling to superconducting bus
- ✔ proof-of-principle readout of detector array
- ••• minimum energy to trigger the bus
- ••• timing characteristics of thermal coupling
- ••• planarization process for stacked nanowires
- ••• scaling to megapixel single-photon imager

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Publications:

[1] Oripov, B.G., Rampini, D.S., Allmaras, J., Shaw, M.D., Nam, S.W., Korzh, B. and McCaughan, A.N., 2023. A superconducting-nanowire single-photon camera with 400,000 pixels. arXiv preprint arXiv:2306.09473. In press with *Nature* (Publication date 26 October 2023).

[2] Luskin, J.S., Schmidt, E., Korzh, B., Beyer, A.D., Bumble, B., Allmaras, J.P., Walter, A.B., Wollman, E.E., Narváez, L., Verma, V.B. and Nam, S.W., 2023. Large active-area superconducting microwire detector array with single-photon sensitivity in the near-infrared. Applied Physics Letters, 122(24)

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