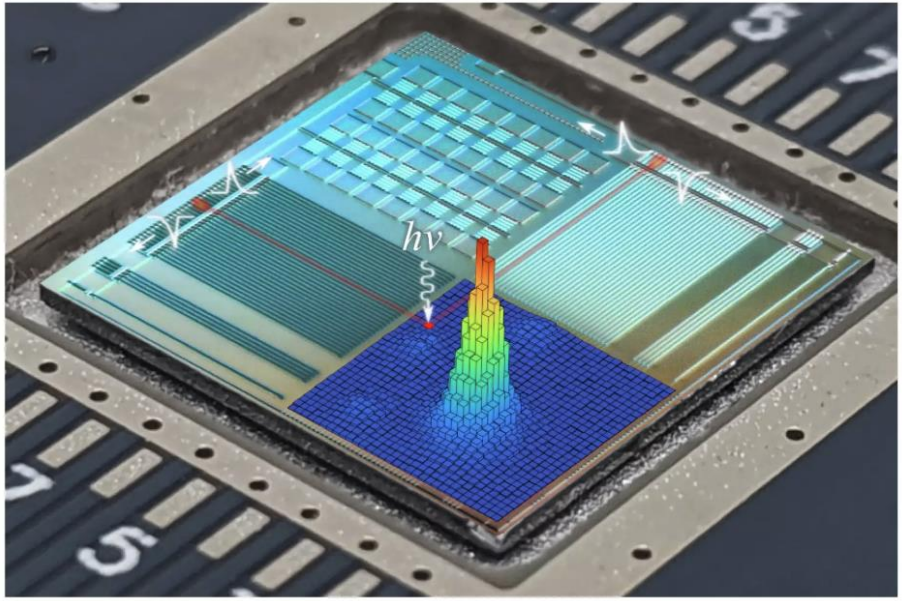
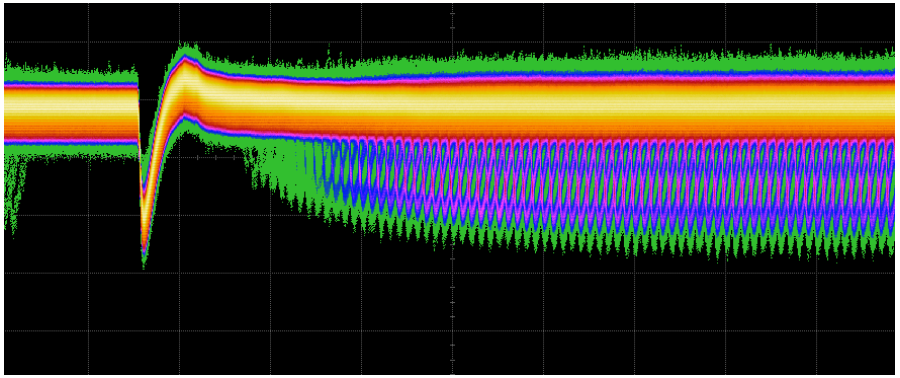




29th Oct 2025

Cryostat design considerations for SNSPD testbeam

Boris Korzh
University of Geneva, Switzerland

UNIVERSITÉ DE GENÈVE

boris.korzh@unige.ch

Career Background

2008

Imperial College London
MSci Physics

Masters thesis:
Max Planck Institute for the Science of Light
Erlangen

2012

University of Geneva
PhD Physics

- *Single-photon detection: SPADs & SNSPD*
- *Quantum communication*

Prof. Hugo Zbinden

2017

NASA Jet Propulsion Laboratory
Postdoctoral Scholar

Fundamental limits of single-photon detection with superconducting devices

Dr. Francesco Marsili
Dr. Matt Shaw

2019

Technical Group Lead
(permanent pos.)

- *Deep-space optical communication*
- *Detectors for astronomy*

2024

University of Geneva
Assistant Professor (Tenure track)
Dep. of Applied Physics

Single-photon detection for:
- *Quantum science*
- *High-energy physics*
- *Biomedical imaging*
- *Astronomy*

Quantum communication

2017

National Institute of Science and Technology
Guest Researcher

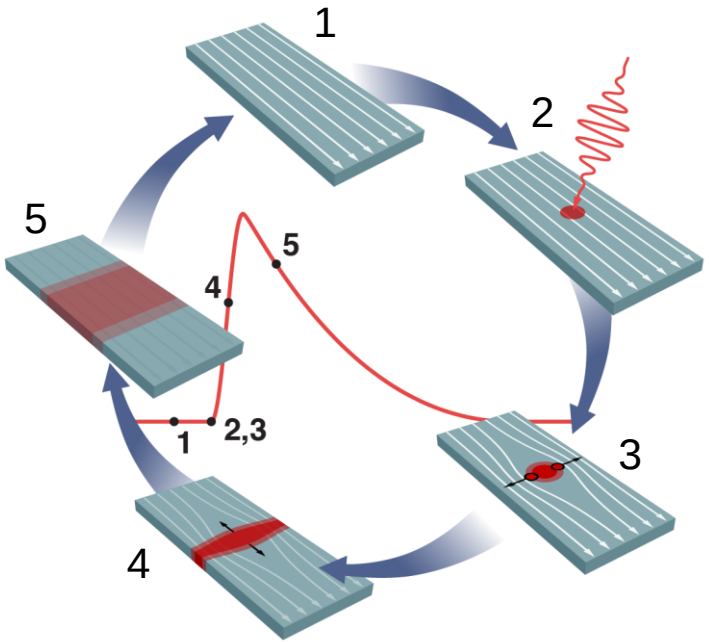
Dr. Sae Woo Nam

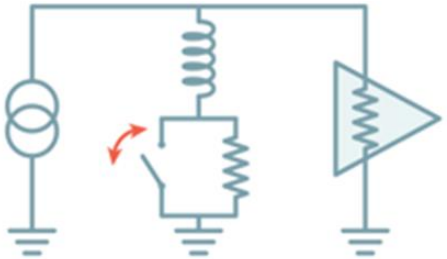
2018

California Institute of Technology
Visiting Scientist

- *Quantum communication*
- *Dark matter detection*
- *Detectors for fundamental physics*

Superconducting nanowire detector mechanism



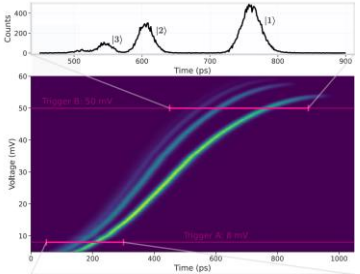


Typically operating at 0.3-5 kelvin

Established SNSPD Applications

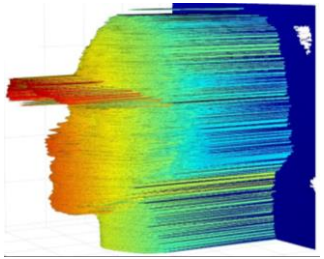
Quantum Information Science

- *Quantum comm*
- *Quantum optics*
- *Trapped ion and neutral atom quantum Computing*
- *Linear optical quantum computing*
- *Space-to-ground quantum comm*



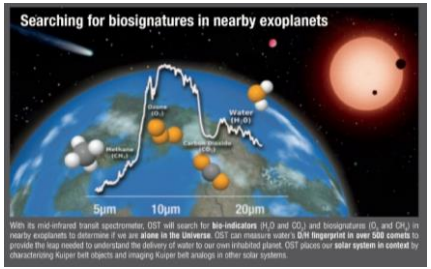
Laser Comm, Ranging, Remote sensing

- *Deep Space Optical Comm*



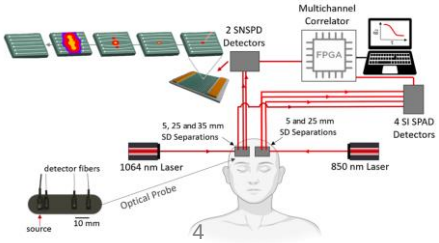
Physics, Astronomy

- *Stellar Inter… Interf.*
- *…rches*
- *…hes*
- *…ntum*
- ***Particle detection***



Biomedicine, Physical chemistry

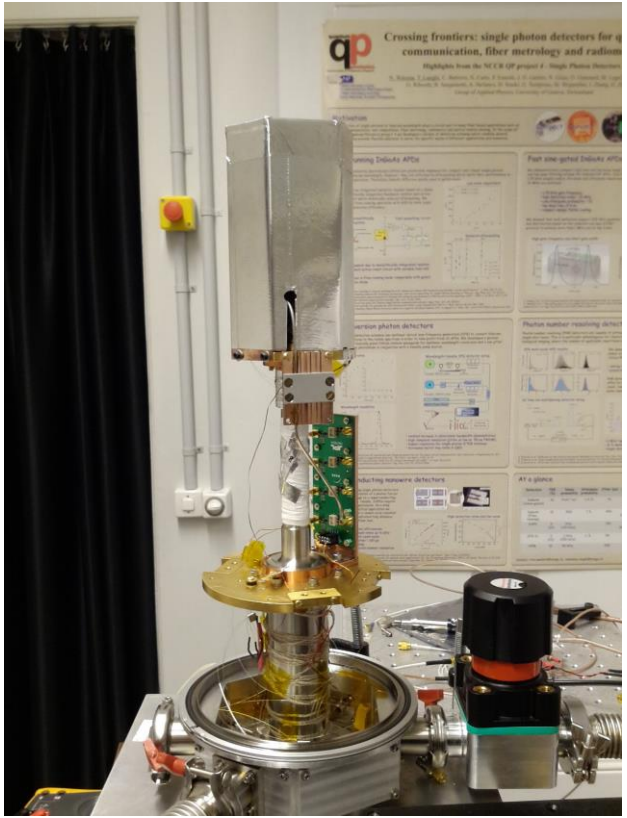
- *Ultrafast transients*
- *Fluorescence microscopy*
- *Dosimetry in cancer therapy*
- *blood-flow monitoring*
- *Deep tissue imaging*
- *MIR spectroscopy*



Many different cryogenic system considerations

First closed cycle cryostat for SNSPDs (2015)

First designed by
Rob Hadfield
at NIST,
<2010



Advances in superconducting nanowire detectors

Timing jitter	Intrinsic photon number resolution	Efficiency	Array size	Maximum count rate	Dark count rate	Active area	Cut-off wavelength
18 ps	None	93%	64	1 Gcps	4 /s/mm^2	0.001 cm^2	5 µm
2.6 ps [1]	3-5 photons	98% [2]	4x10^5 [3]	1.5 Gcps [4,5]	4x10^{-5} /s/mm^2 [6]	0.1 cm^2 [3]	29 µm [7]
1 ps	10	99 %	10^7	10 Gcps	1x10^{-6} /s/mm^2	1 cm^2	100 µm

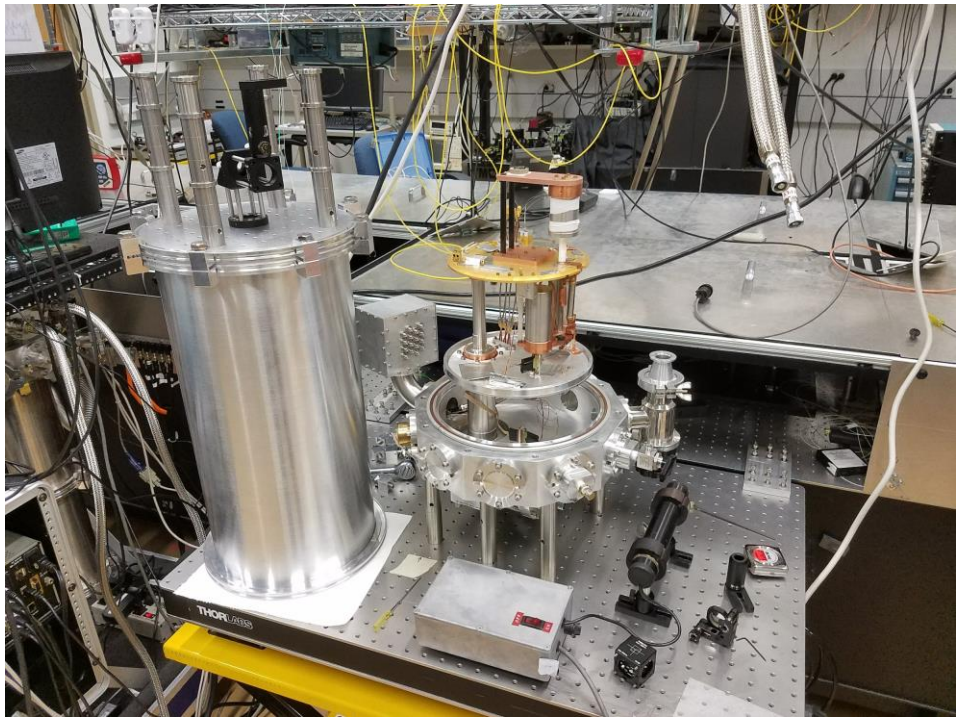
Records in 2016

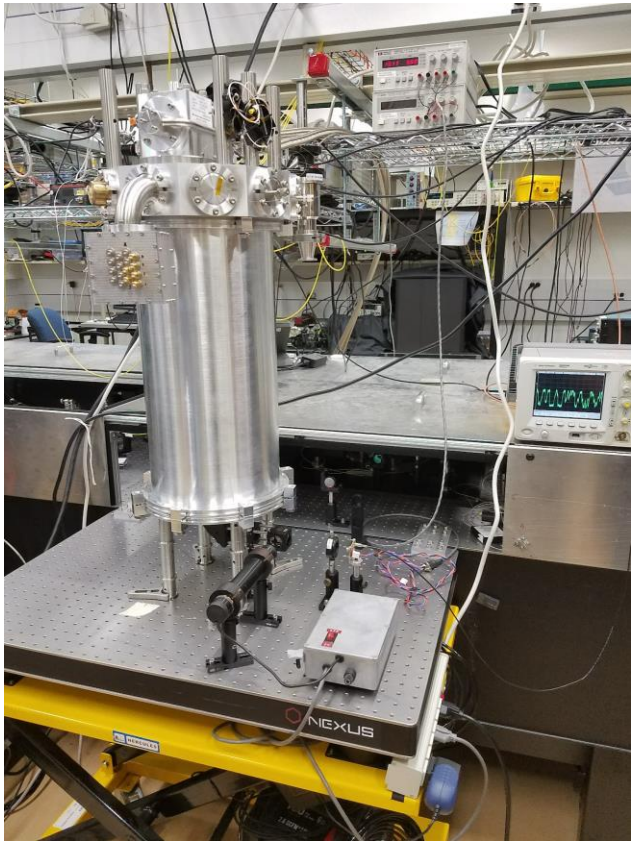
Current records for isolated devices

Expected performance by 2030

[1] Korzh, Zhao et al, ***Nature Photonics*** *14*, 250 (2020)
[2] Reddy et al, ***Optica*** 7, 1649 (2020)
[3] Oripov, Rampini, Allmaras, Shaw, Nam, Korzh, and McCaughan, ***Nature*** 622, 730 (2023)
[4] Craiciu, Korzh et al, ***Optica*** 10, 183 (2023)
[5] Resta et al, ***Nano Letters*** (2023)
[6] Chiles, ***PRL*** 128, 231802 (2022)
[7] Taylor, Walter, Korzh et al, ***Optica***, (2023)

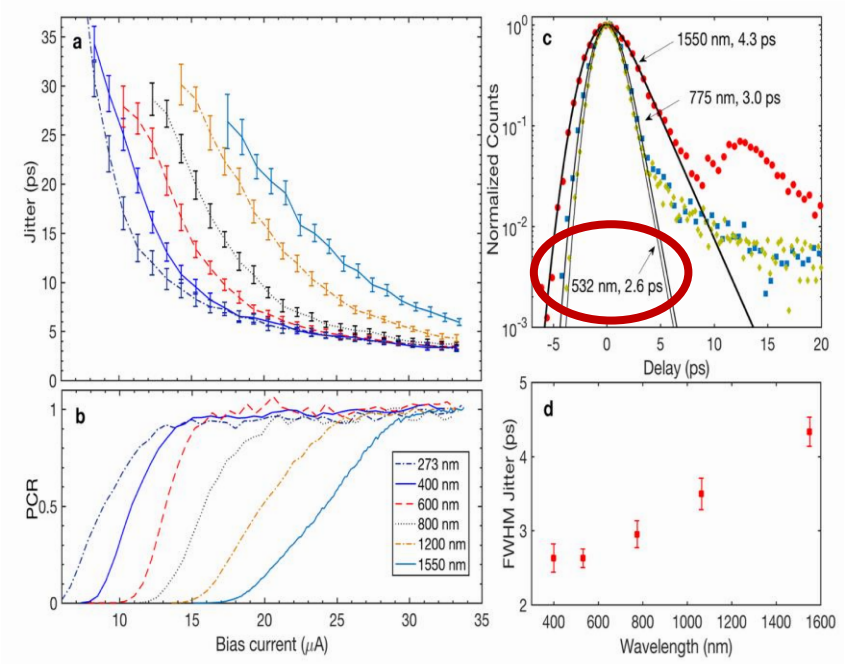
Custom cryostat at NIST (2017)

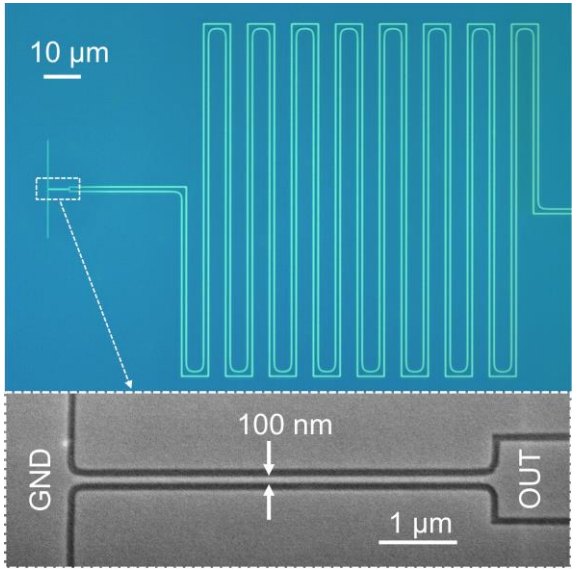




Wanted fast results, so we stuck with what we know + a hole in the bottom…

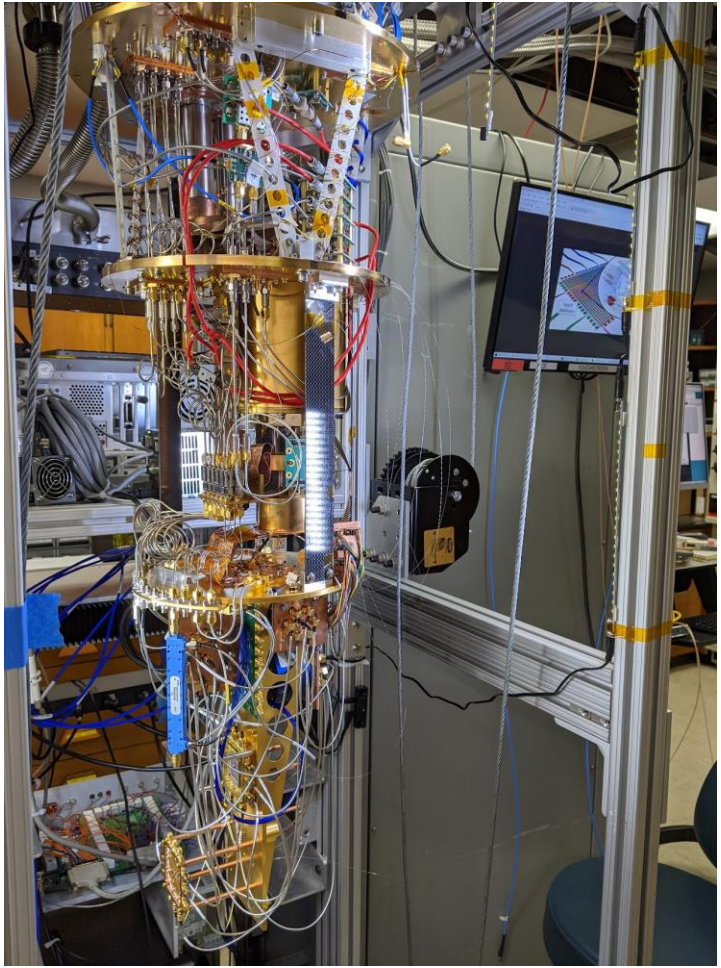
Record timing accuracy



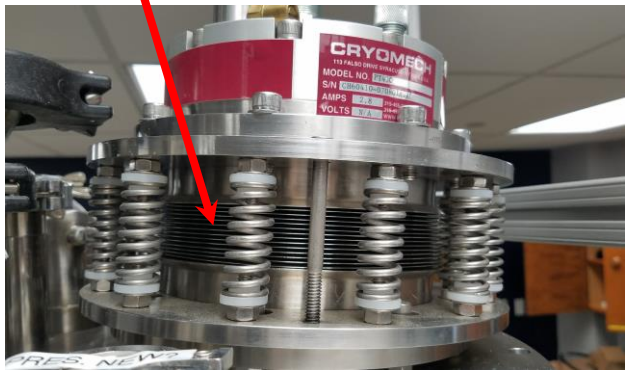


Korzh, Zhao, Allmaras, Frasca *et al* ***Nature Photonics* 14,** 250-255 (2020)

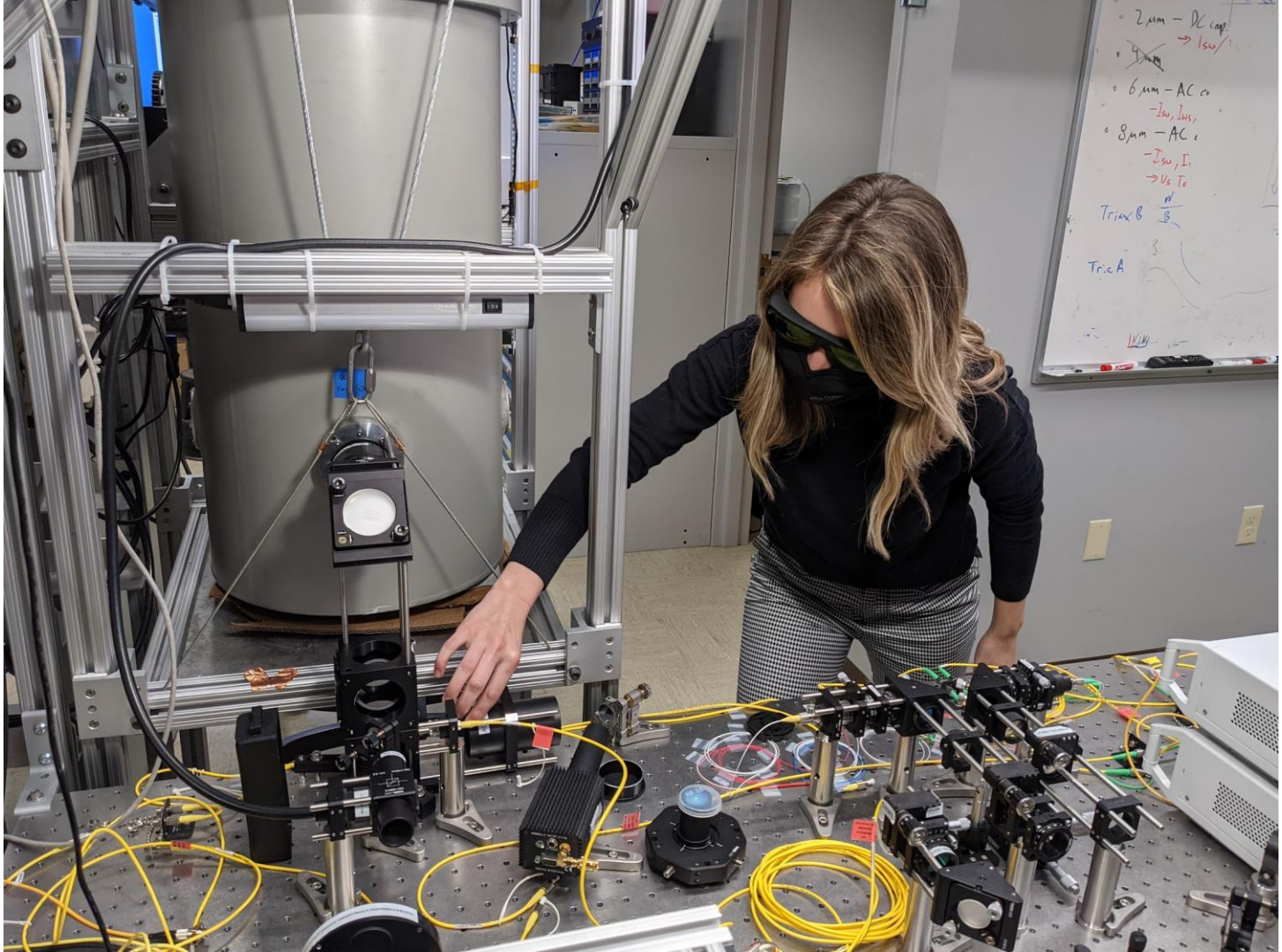
Larger R&D cryostat at JPL



Vibration isolation



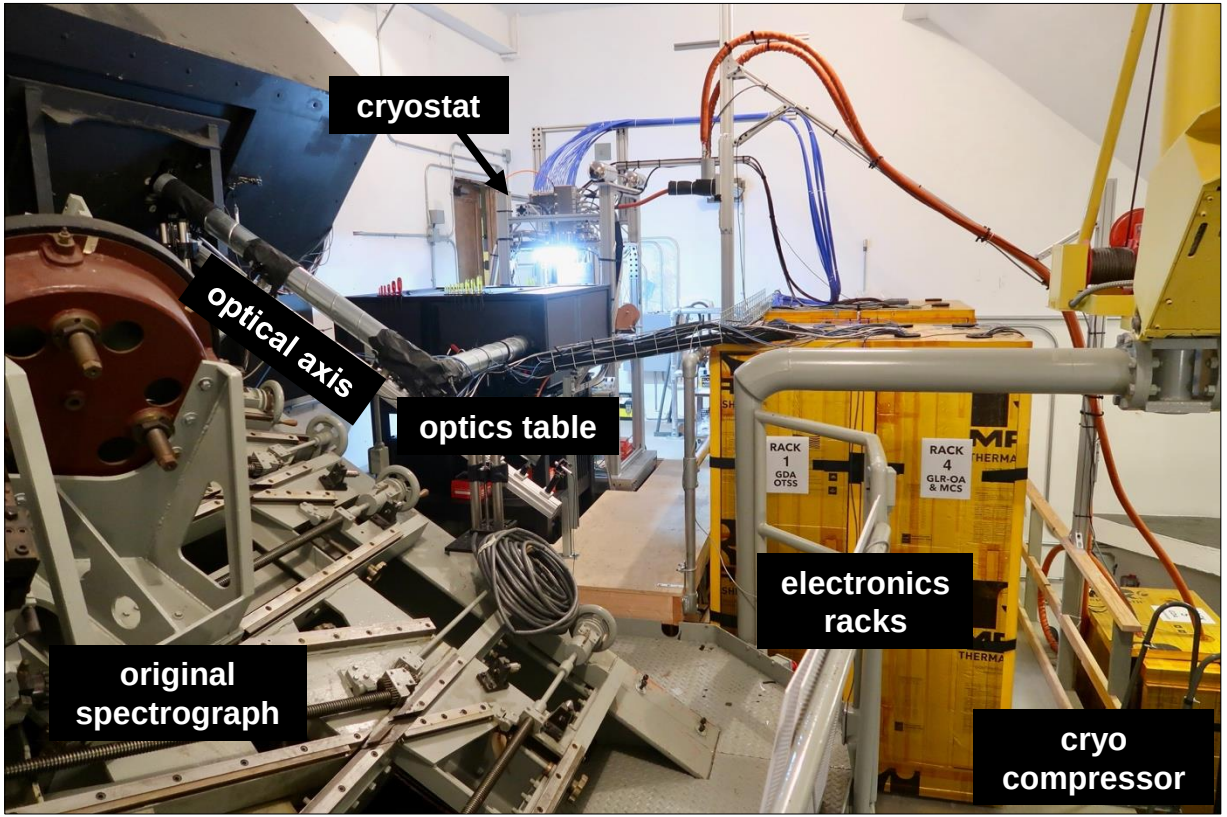
Had to use what was there already and adapt
… revamped a dilution fridge that never worked….


2 μm – DC
6 μm – AC
8 μm – AC
Trio A

Lifting vacuum cans

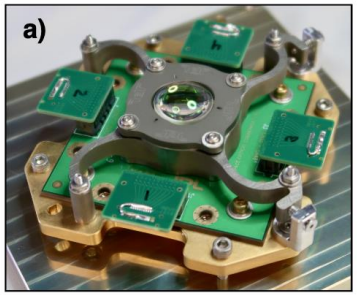
Why ?

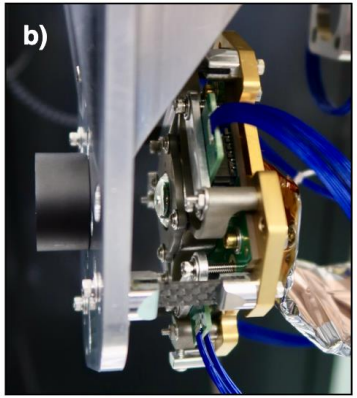
DSOC Deployment at 5 m Palomar telescope

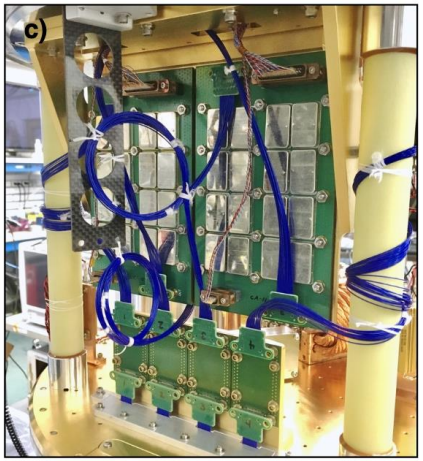


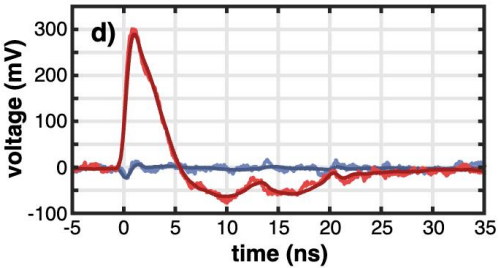
Wollman, Allmaras, Beyer, Korzh, Runyan, Narváez, Farr, et al. 2024. “SNSPD-Based Detector System for NASA’s Deep Space Optical Communications Project.” *Optics Express* 32 (27): 48185.

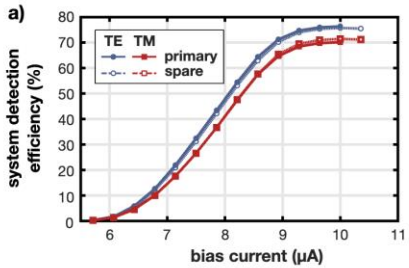
System technical details

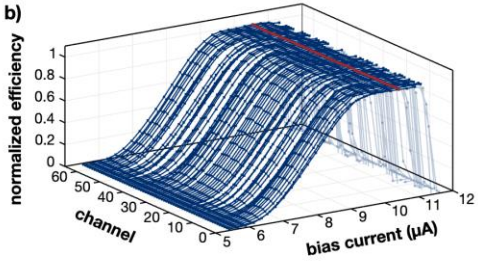


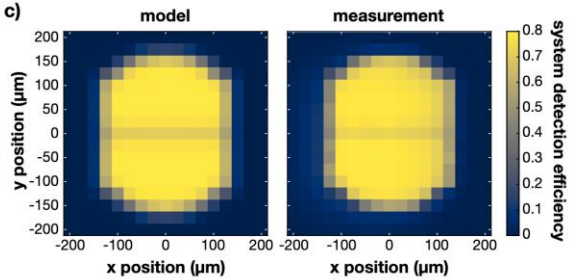


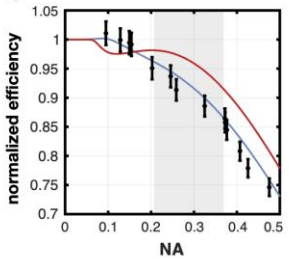






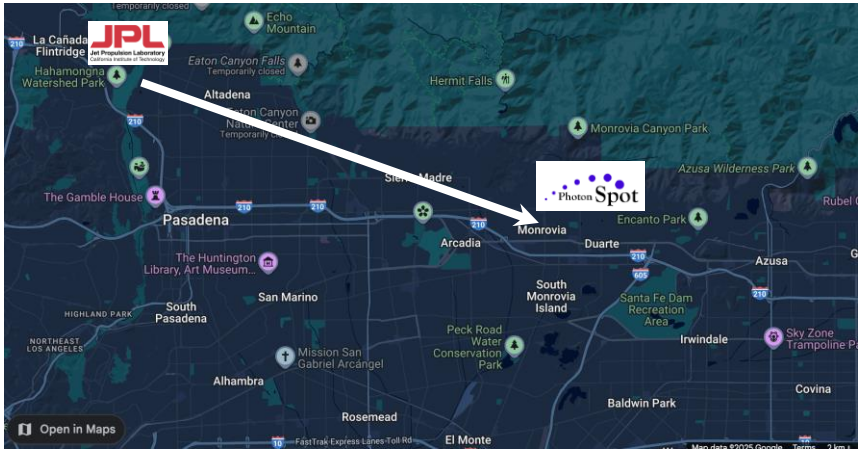




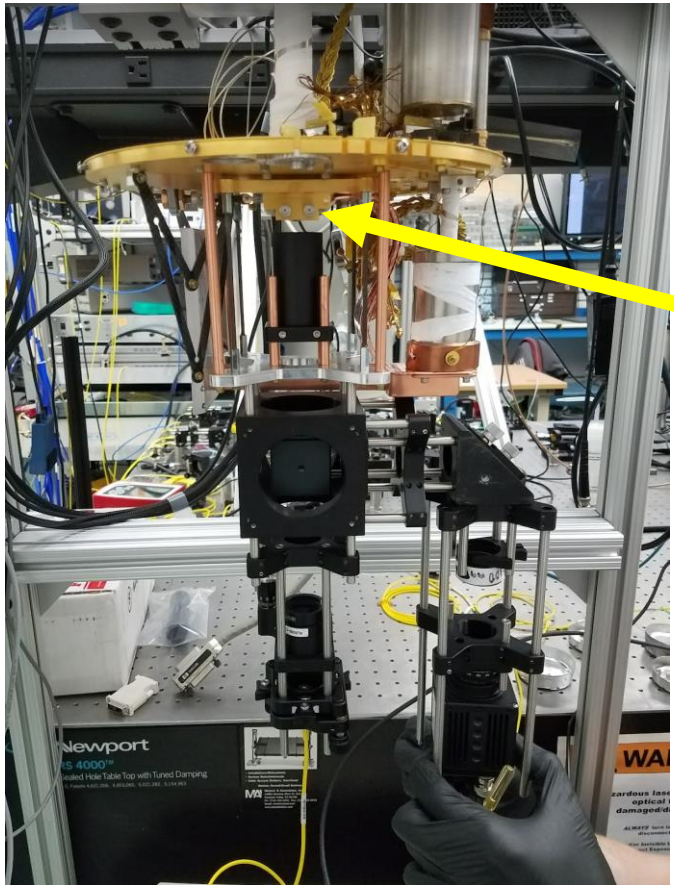


Wollman, Allmaras, Beyer, Korzh, Runyan, Narváez, Farr, et al. 2024. “SNSPD-Based Detector System for NASA’s Deep Space Optical Communications Project.” *Optics Express* 32 (27): 48185.

NIST/JPL design influences commercial system (2019)



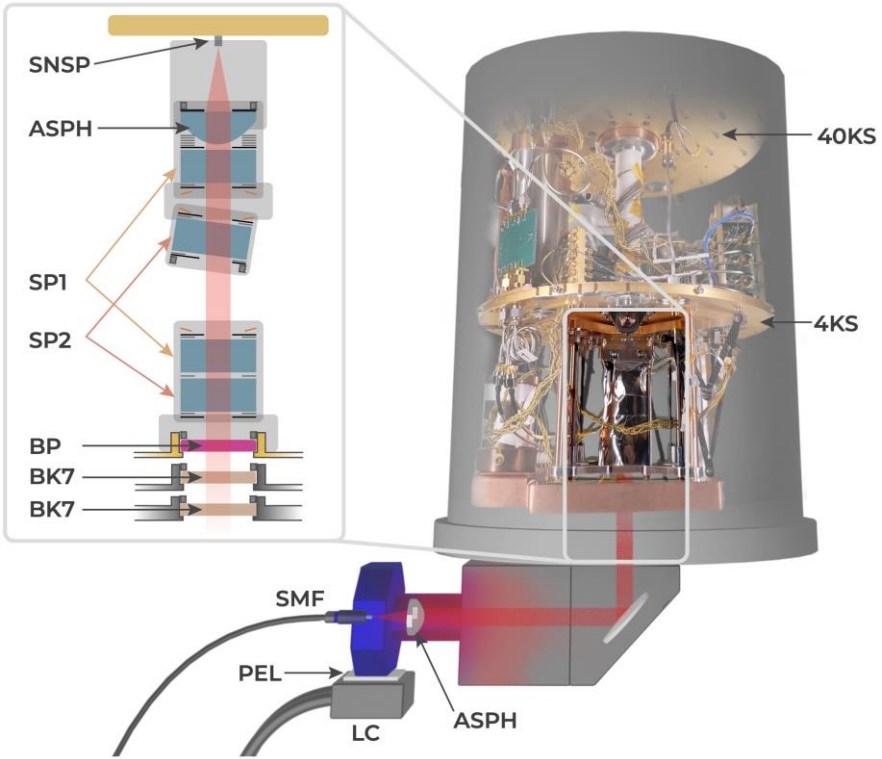
Novel free-space coupling

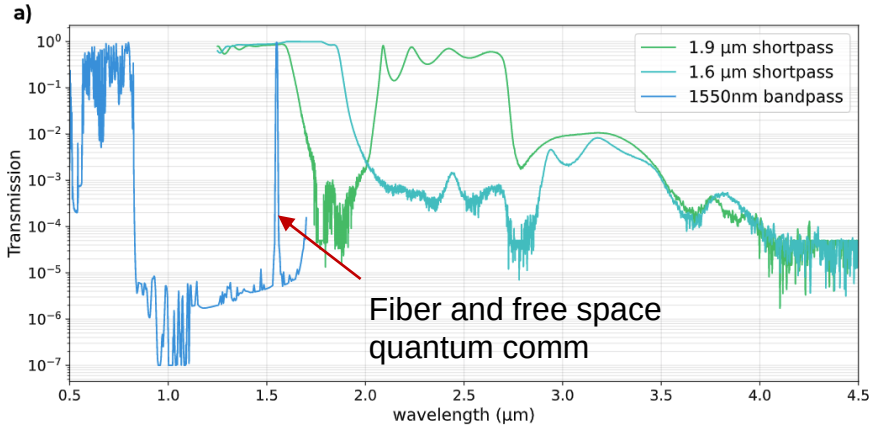


Vibrations on the order of 10 um
…rigid coupling to the coldhead

Internal JPL design

Low-background, free-space coupled SNSPD





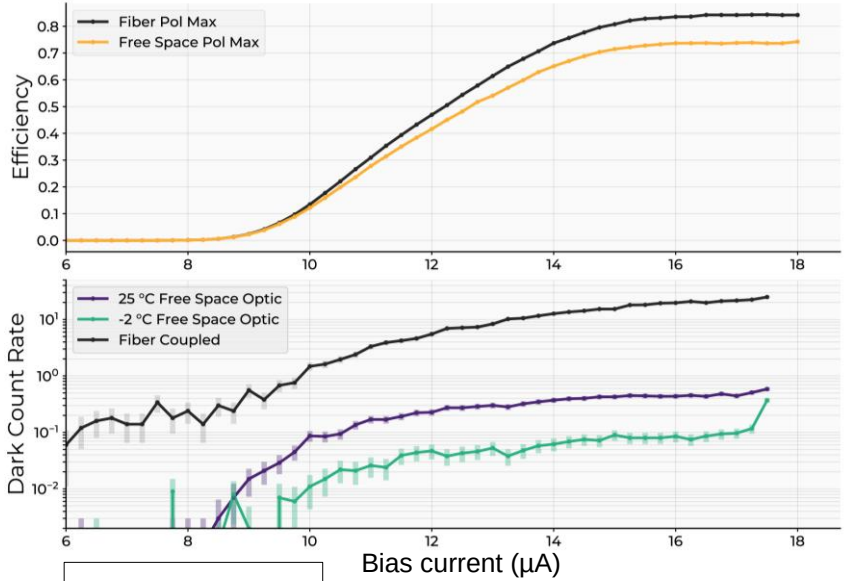
Remaining black body photons

- **Vibrations solved**
  - **Cryogenic lens coupled to the detector**

Mueller, Korzh, Runyan *et al,* ***Optica*** **8,** 1586 (2021)

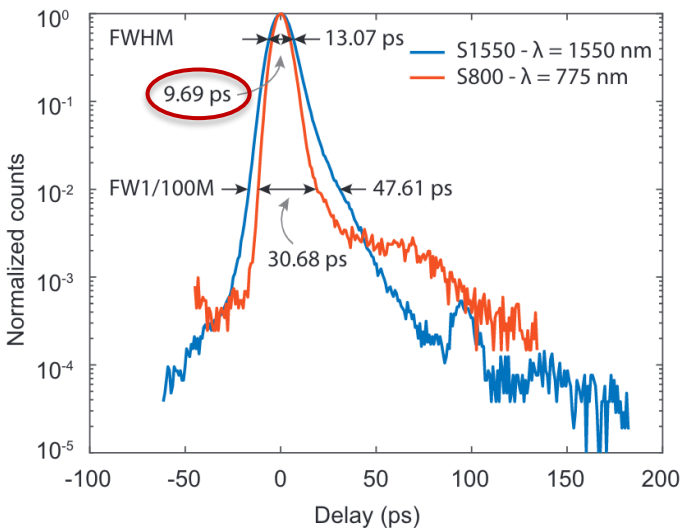
Combined metrics for Quantum Communication

High efficiency



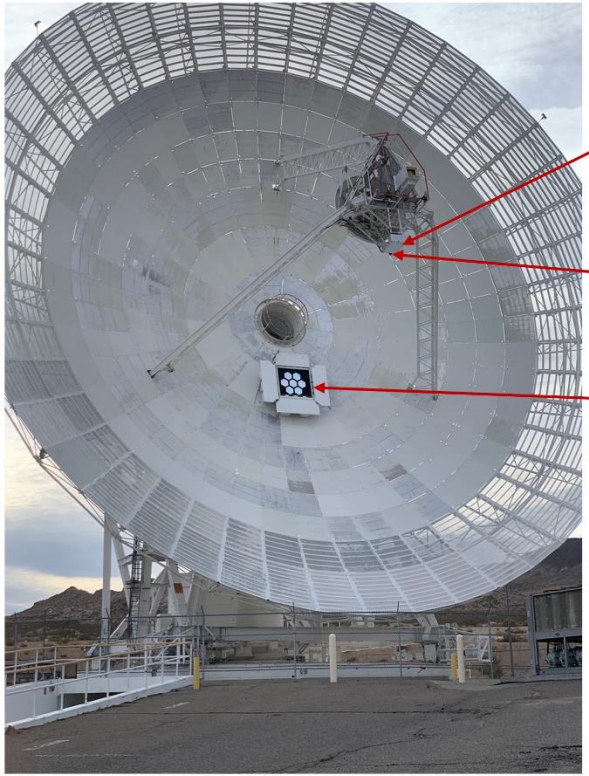
Low noise

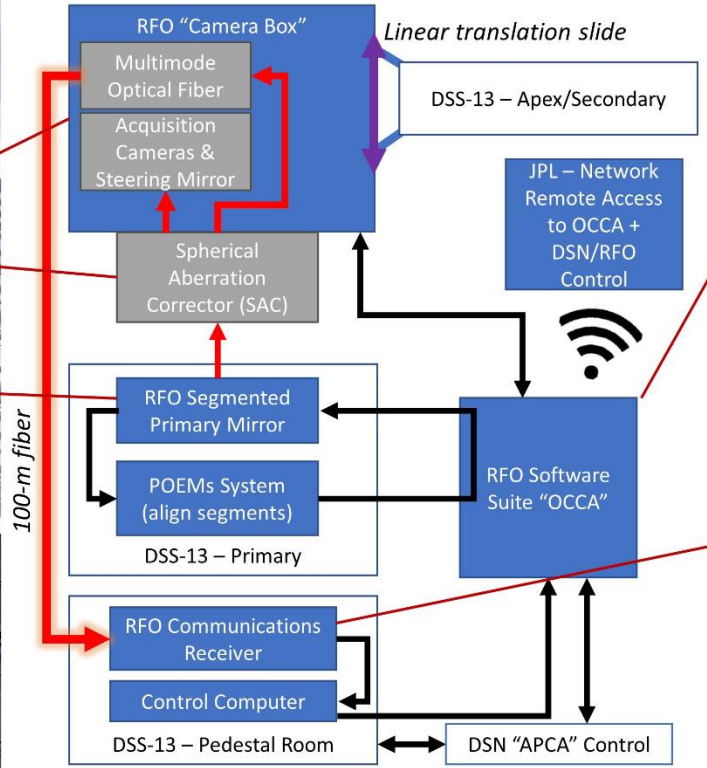
Low timing jitter

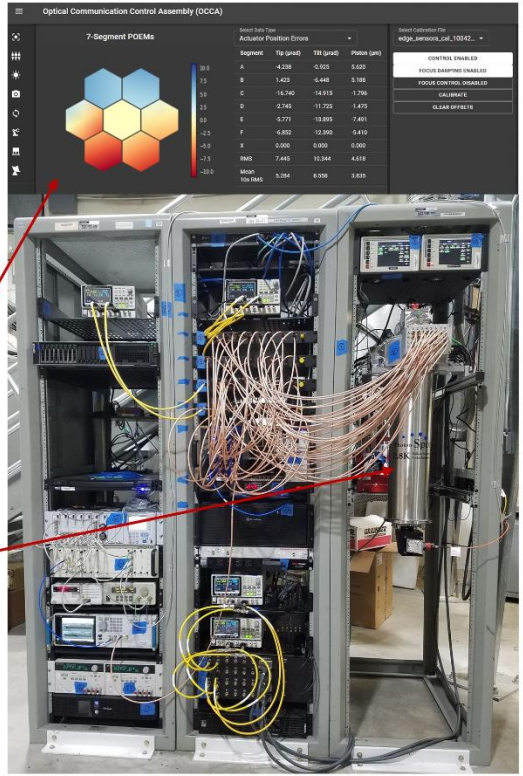


Mueller, Korzh, Runyan *et al,* ***Optica* 8,** 1586 (2021)

Second ground receiver in California

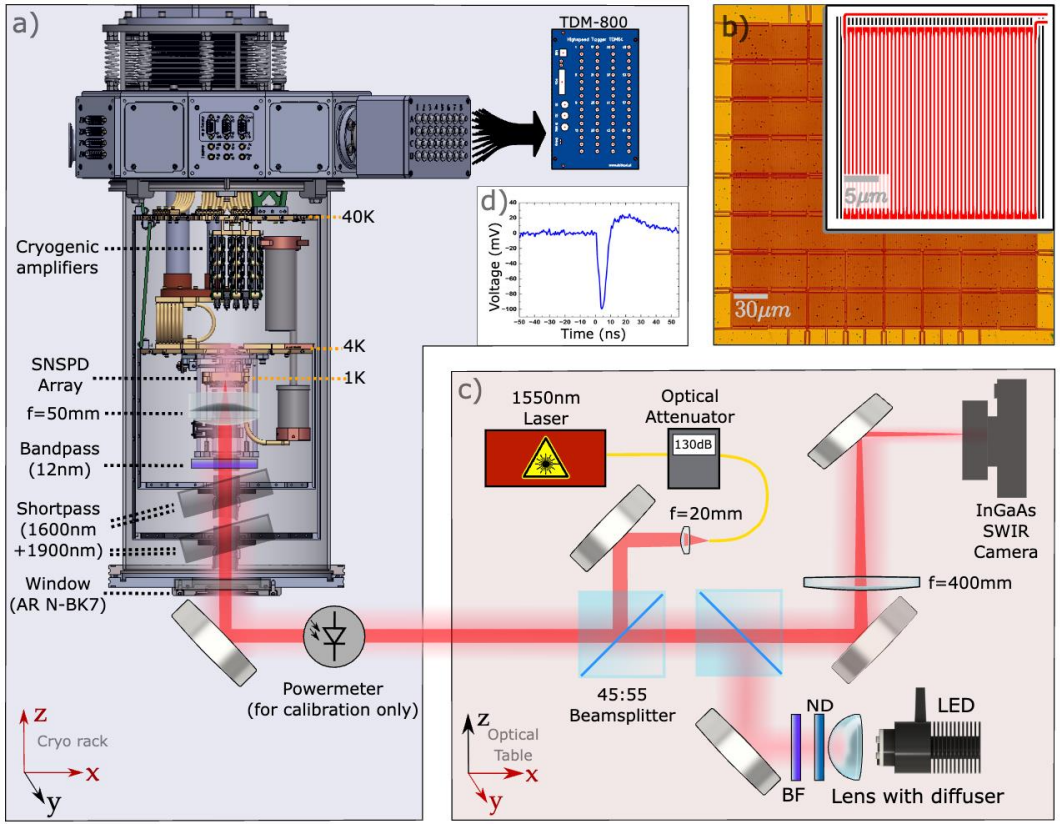




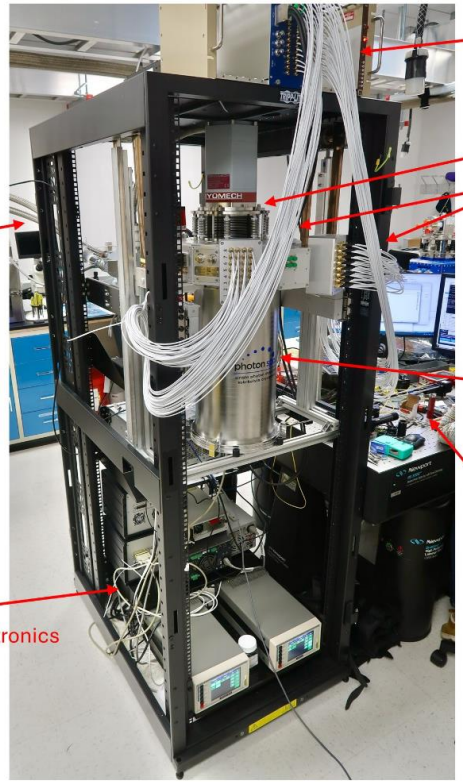


Allmaras, J., Korzh, B., Beyer, A., & Wollman, E. (2023). *Large-area SNSPD array for RF/optical hybrid 7-segment pathfinder receiver*. https://www.spiedigitallibrary.org/proceedings/Download?urlId=10.1117%2F12.2655467

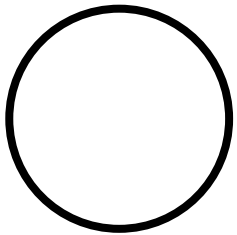
Another JPL/industry design



Fleming, F., McCutcheon, W., Wollman, E. E., Beyer, A. D., Anant, V., Korzh, B., Allmaras, J. P., Narváez, L., Leedumrongwatthanakun, S., Buller, G. S., Malik, M., & Shaw, M. D. (2025). High-efficiency, high-count-rate 2D superconducting nanowire single-photon detector array. *Optics Express*, *33*(13), 27602–27614. https://doi.org/10.1364/OE.559868

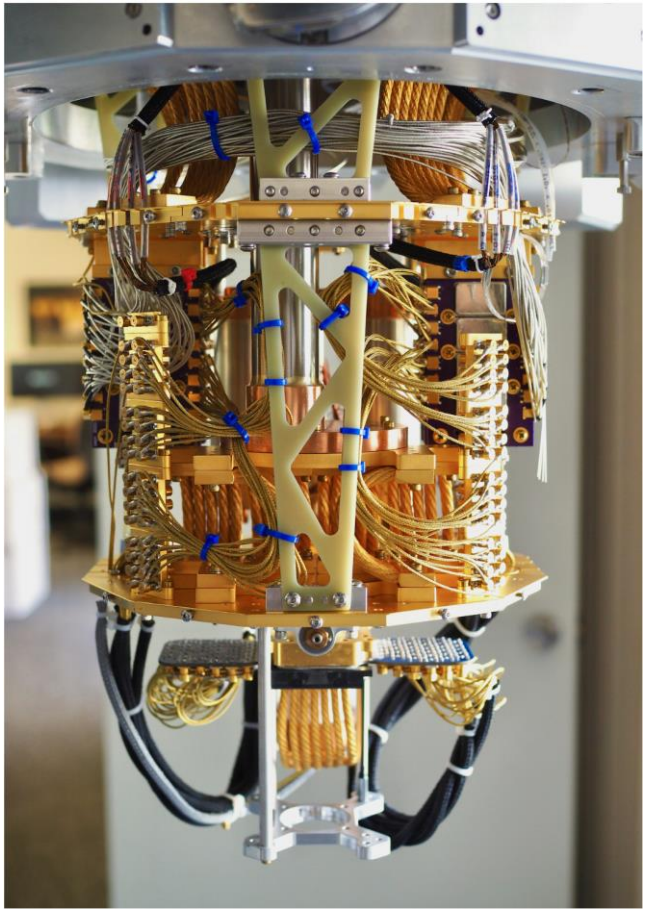


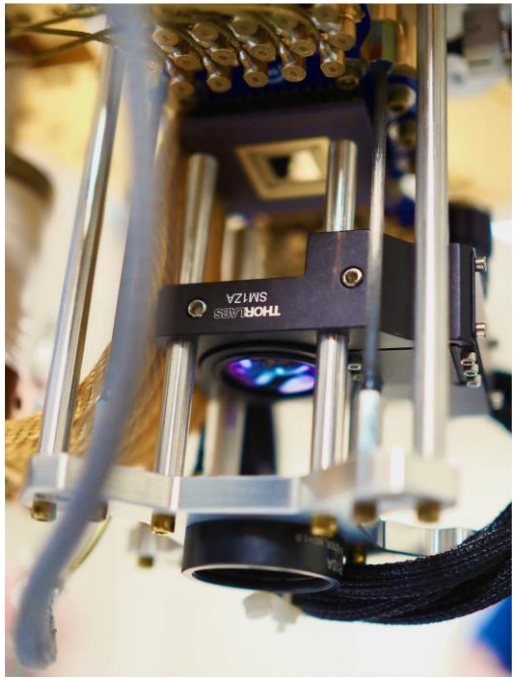
Why the?



Cans are still an issue…

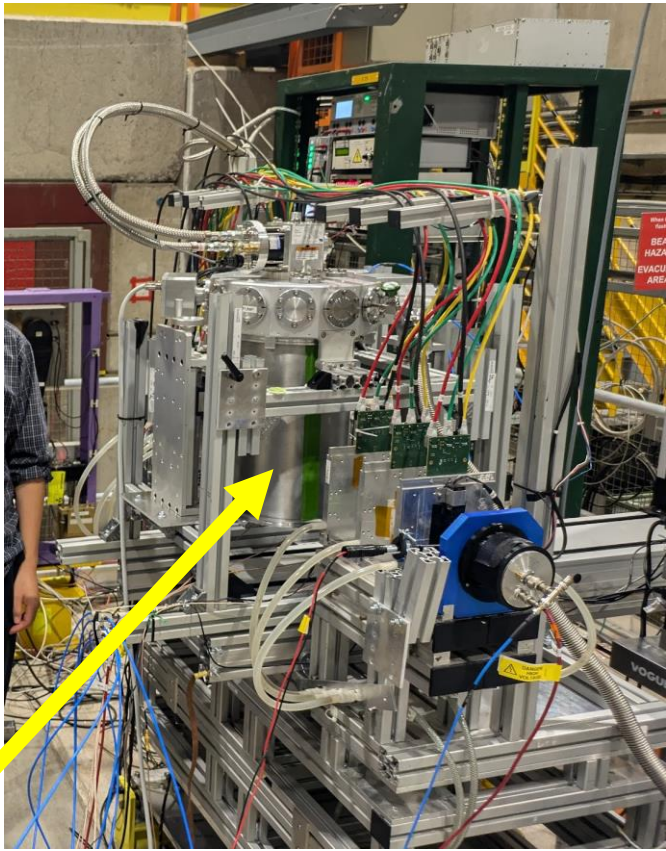
Fleming, F., McCutcheon, W., Wollman, E. E., Beyer, A. D., Anant, V., Korzh, B., Allmaras, J. P., Narváez, L., Leedumrongwatthanakun, S., Buller, G. S., Malik, M., & Shaw, M. D. (2025). High-efficiency, high-count-rate 2D superconducting nanowire single-photon detector array. *Optics Express*, *33*(13), 27602–27614. https://doi.org/10.1364/OE.559868





It does look pretty though…

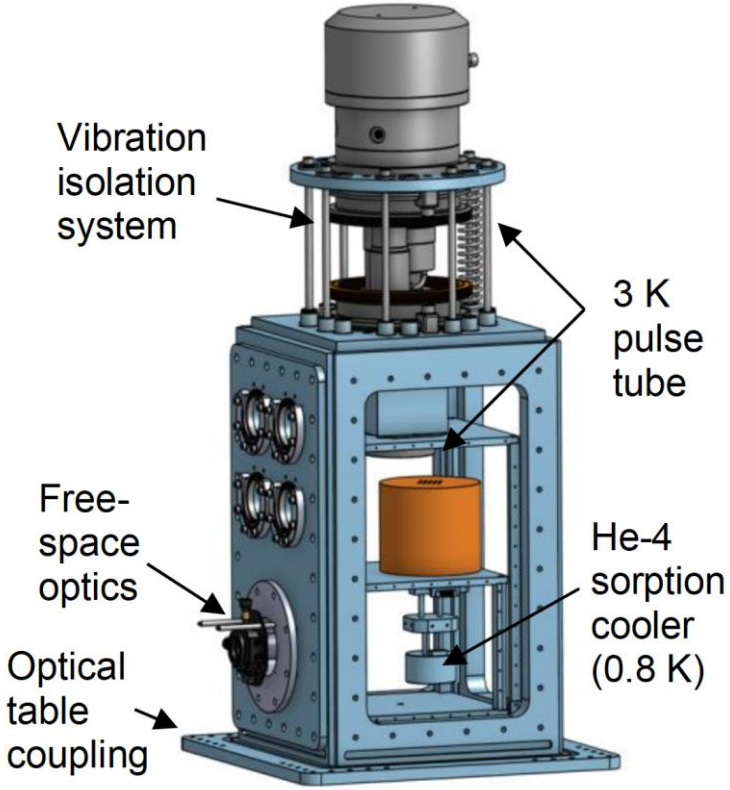
Fermilab/Caltech/UNIGE/JPL team at CERN (2025)

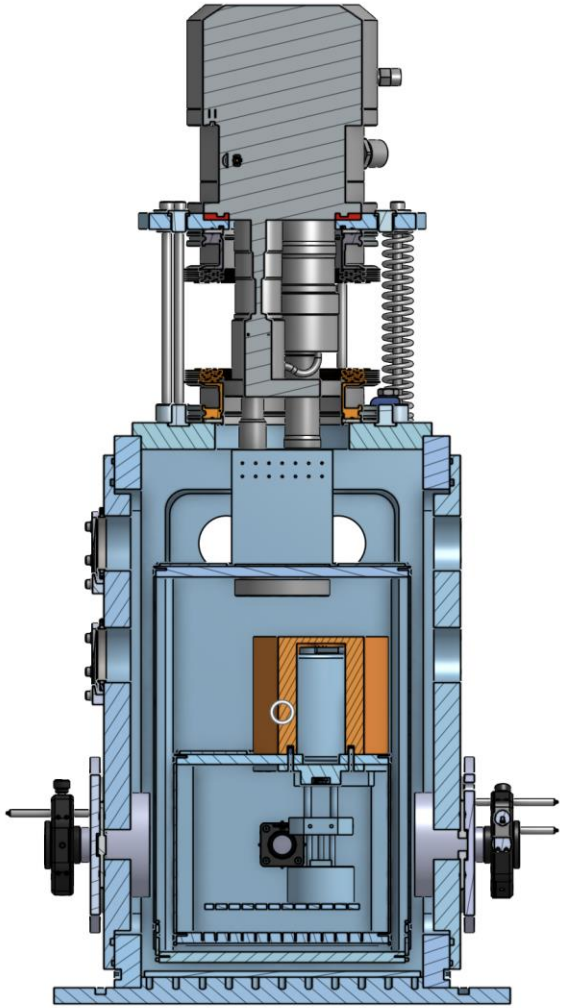


The PhotonSpot 0.8 K system

New UNIGE design

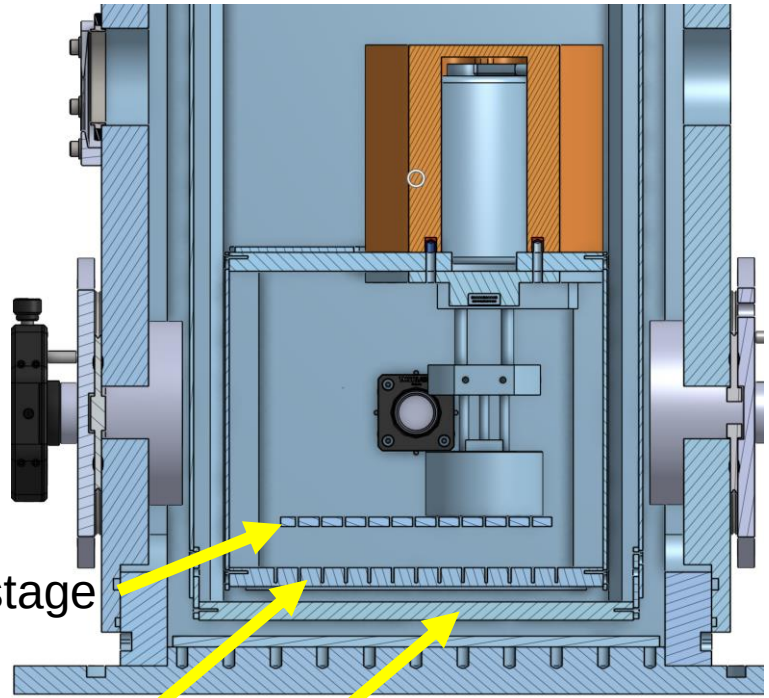
‘Bottom referenced’ cryostat with panels





New proposed UNIGE design

He-4 version of sorption

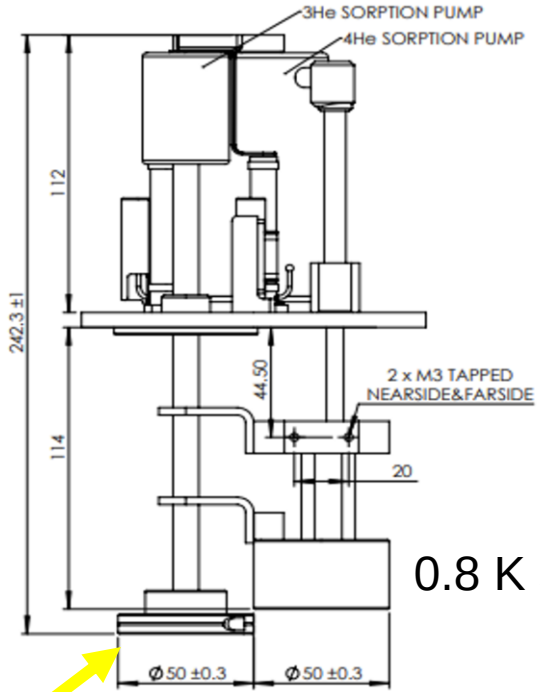


0.8 K stage

3 K stage

40 K stage

He-3 version of sorption



0.8 K stage

0.25 K stage

Assembly in process

Machining and welding at the University of Geneva, Physics Machine Shop