Development of Superconducting Single-Photon Detectors for Quantum Information Applications

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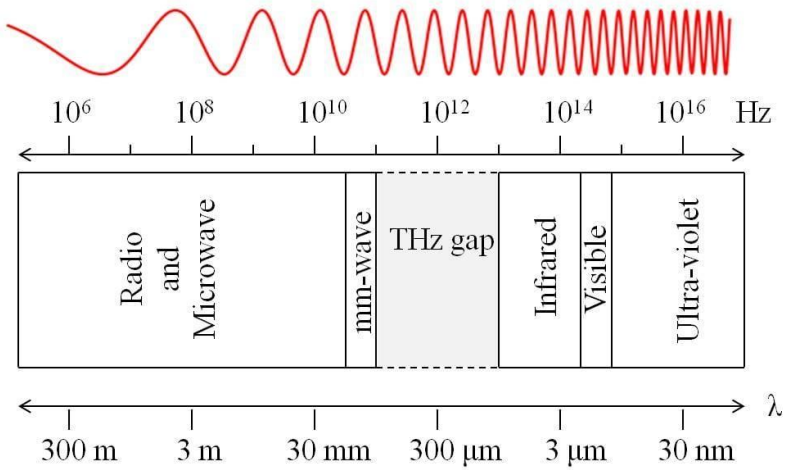
A single-photon detector is a device that is able to produce a measurable output signal, distinguishable from noise, due to a single photon incident on the detector's input plane

Single-Photon Sources and Detectors Dictionary
https://doi.org/10.6028/NIST.IR.8486r1



λ = 1550 nm
$E_{ph} = hc/\lambda = 1.3\ 10^{-19}$ J

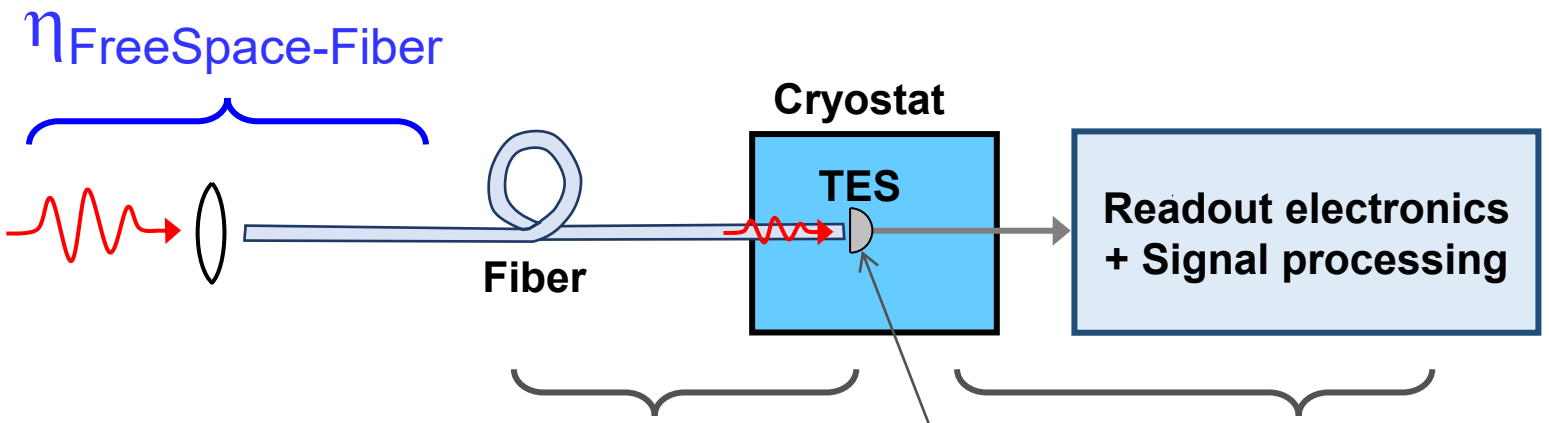
Single-Photon Detector Performance metrics

- System Detection Efficiency (SDE)
- Energy Resolution/Photon-Number Resolution (PNR)
- Timing jitter
- Recovery time (Count Rate)
- Dark/Background count rate (DCR)
- Tunable wavelength

Other considerations

- Operating Temperature
- Scalability (multi-pixel arrays, low readout-circuit complexity)

System Detection Efficiency (SDE)

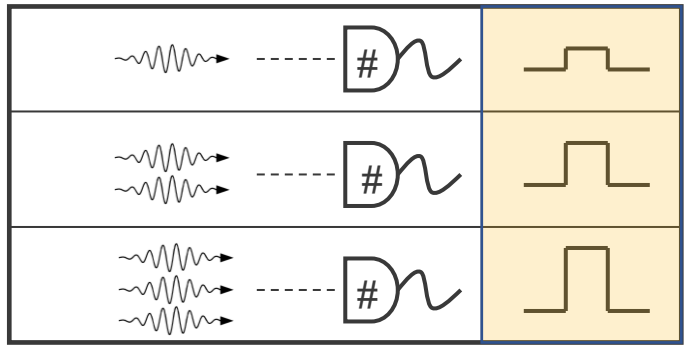


$$\eta_{Fiber-Detector} \times \eta_{QE} \times \eta_{Trigger} = \eta_{System}$$

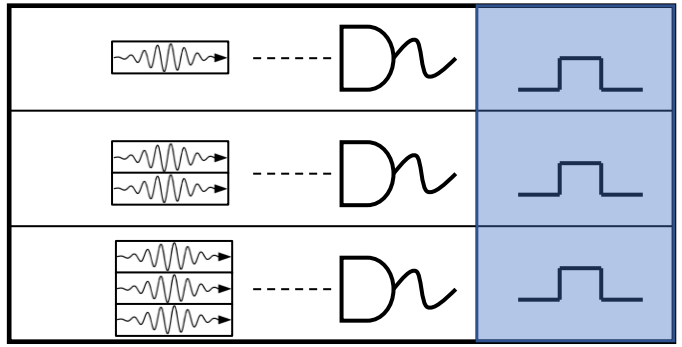
$$\eta_{QE} = \eta_{Absorb} \times \eta_{Intrinsic}$$

Photon-number resolving (PNR)

Photon Number Resolving
Output signal proportional to photon number

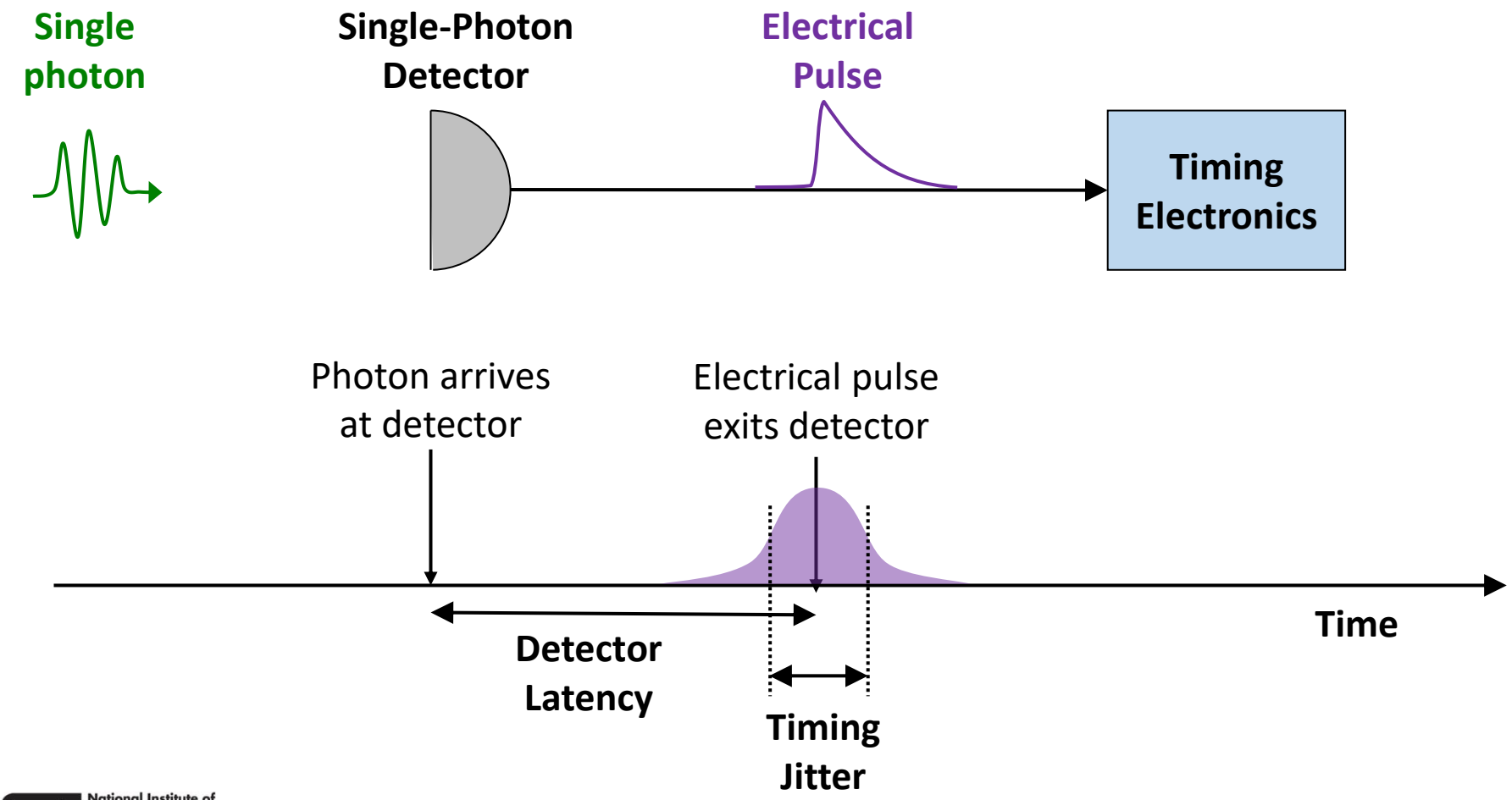


Conventional (Click Detector)
Same output signal for varying photon number input



Timing Jitter

Timing jitter is a measure of the variation in **detector latency**

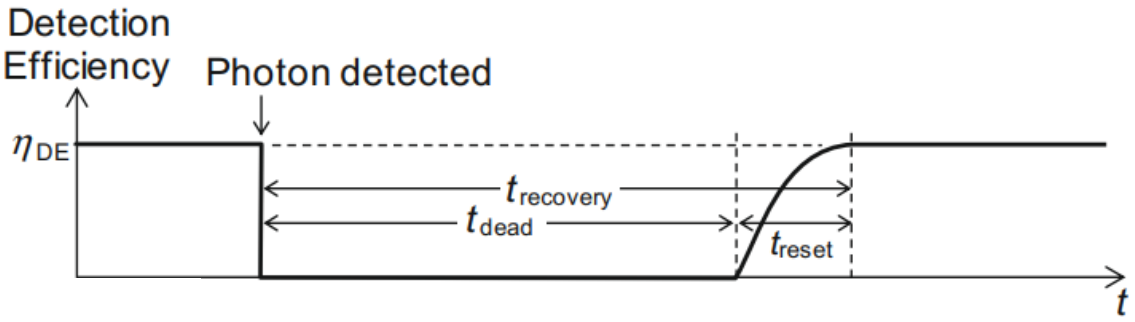


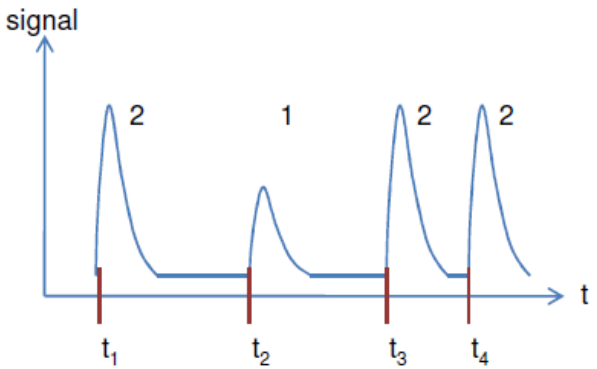
- Uncertainty in determining the photon arrival time
- Depends on rise time, pulse size, amplitude noise, bandwidth of electronics

Recovery Time (Count Rate)

- Time it takes the detector to be ready to count the next event
- Sets a limit on the maximum count rate
- For a strongly asymmetric pulse defined as the 1/e time constant of the recovery
- Ideally want recovery times within source repetition rate

$$t_{\text{recovery}} = t_{\text{dead}} + t_{\text{reset}}$$

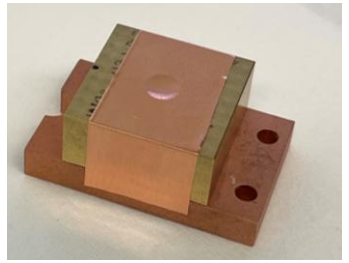


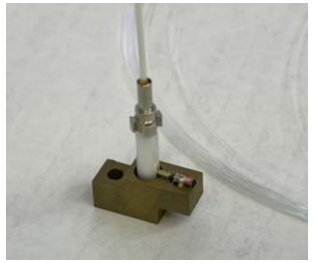


Dark Counts and Background Counts

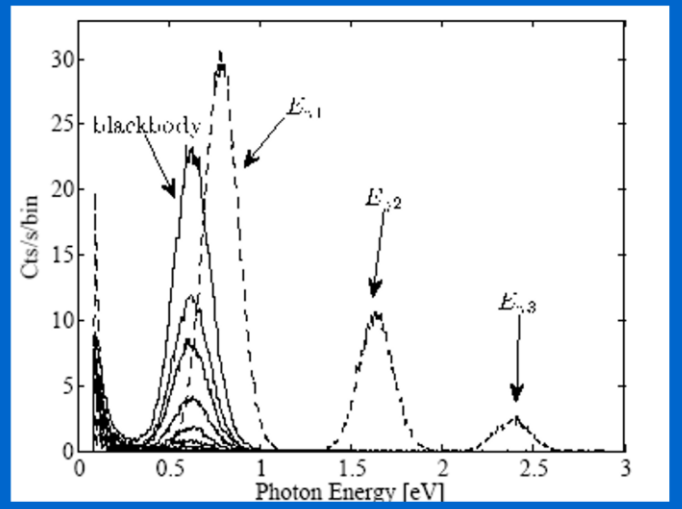
Dark Counts:

- False registering of a photon triggered by electrical or thermal fluctuations (detector operating principle)
  - Tunneling effects, afterpulsing, material defects
  - cosmic rays energy depositions, ambient radioactivity, quantum fluctuations
  - **< 1 cnt/day for superconducting SPD**





Histogram of detected 1550 nm photons
Blackbody photons 0ºC to 70ºC.

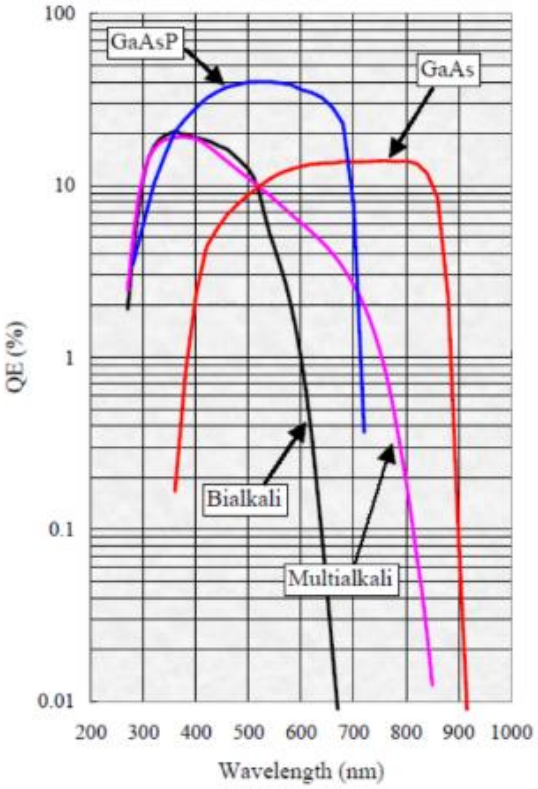


A.J. Miller et al. Proc. of the 8th Int. Conf. Quantum Comm. Meas. Comp, 445 (2007)

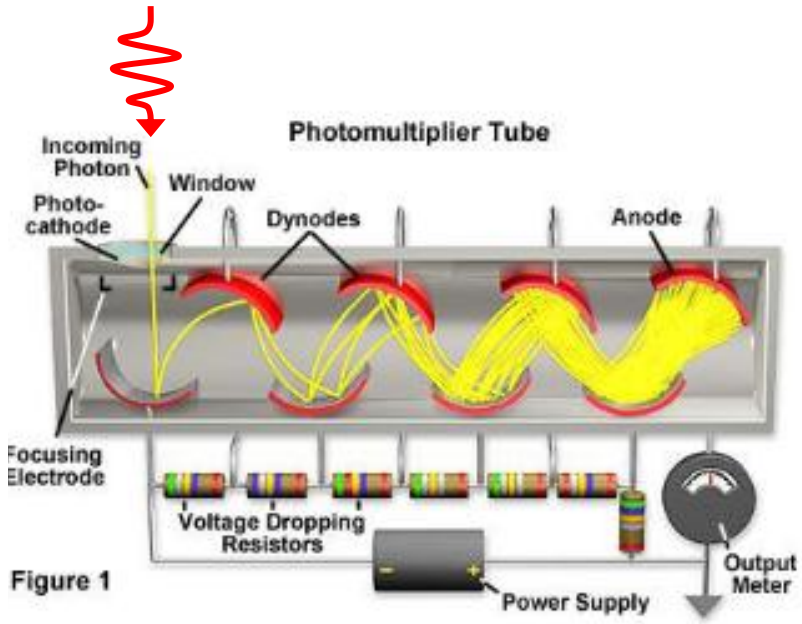
Background Counts:

- Due to unwanted photons, not noise/fluctuation
  - Photons from blackbody radiation from room temperature objects can propagate down the optical fiber, creating a background count rate.
  - External light

Photomultiplier Tube



courtesy K. Dhimitri, Hamamatsu



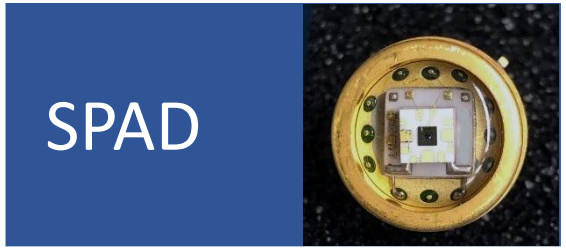
PMT

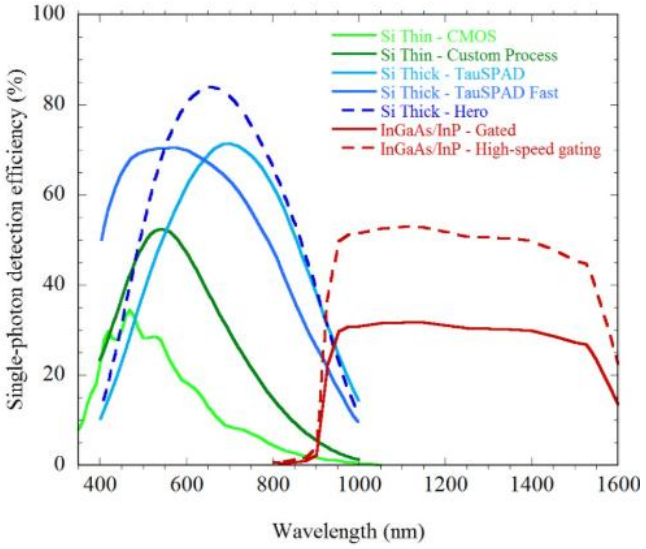
Efficiency	≤ 40 %
Energy Resolution	Yes
Recovery Time	50 ns
Timing Jitter	50 ps
Dark Counts	< 200 cps
Wavelength Range	UV-VIS
Operating Temperature	RT

- Oldest SPD technology
- Works best in the UV/blue
- Large area devices (> 8 mm diam)

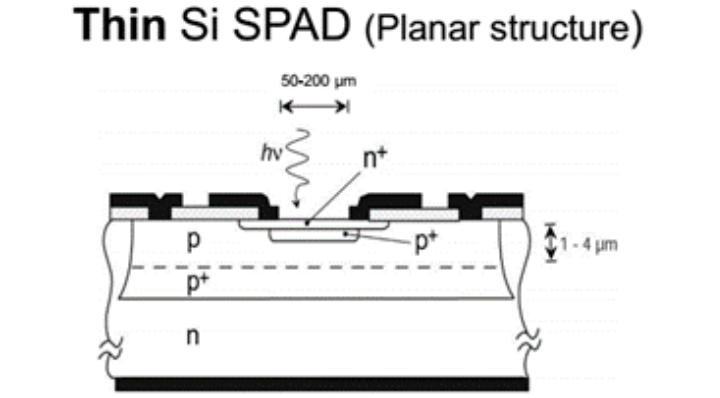
- Applications: Spectrophotometers; Medical diagnosis; Environmental measurements; LIDAR; High Energy Physics

Single-Photon Avalanche Photodiode





courtesy J. Bienfang, NIST



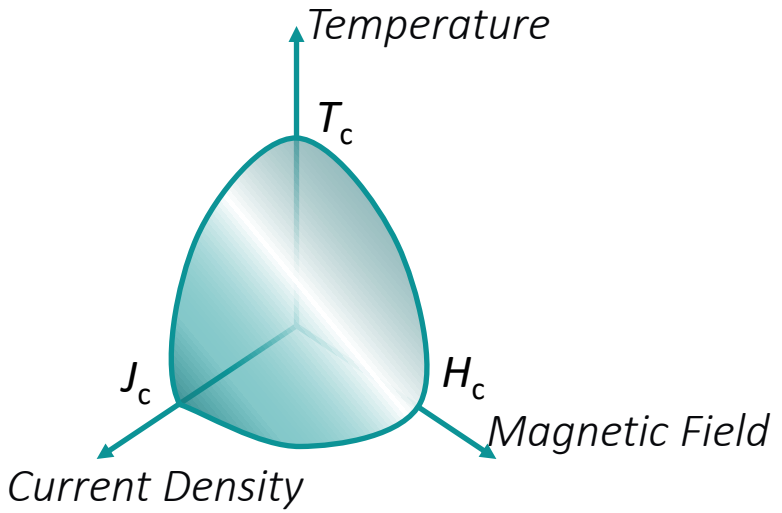
lower jitter (10's of ps)
lower detection efficiency

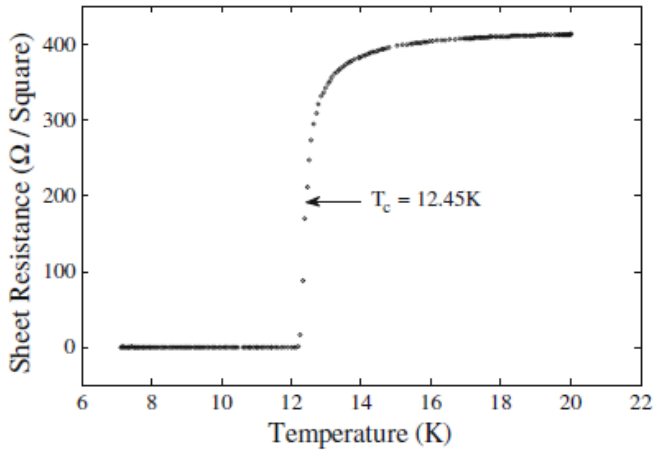
Efficiency	85 %
Energy Resolution	Some
Recovery Time	10 ns
Timing Jitter	20 ps
Dark Counts	< 100 cps
Wavelength Range	UV-NIR
Operating Temperature	RT

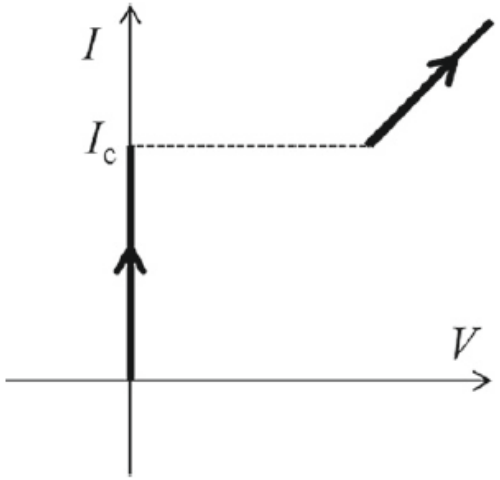
Applications: Quantum Computing: QKD; Quantum Optics; 3D Imaging, ToF Imagers; LIDAR; Biomedical Imaging

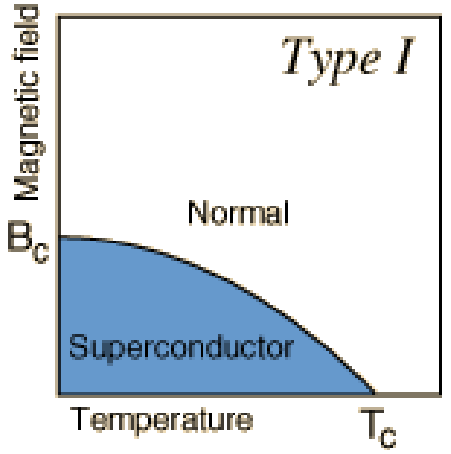
Superconductivity

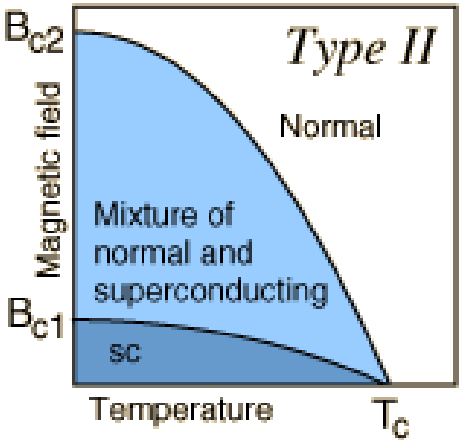
- Distinct thermodynamic phase observed only in some solids
- Exists only when the *Temperature*, external *Magnetic Field*, and the *Current Density* carried by the material are below critical values (T_c, H_c and J_c)
  - Ground State = Cooper pairs
  - Excited State = quasi-particles
  - Energy Gap $2\Delta = 3.528\ K_B\ T_c$ (meV)











Superconductivity

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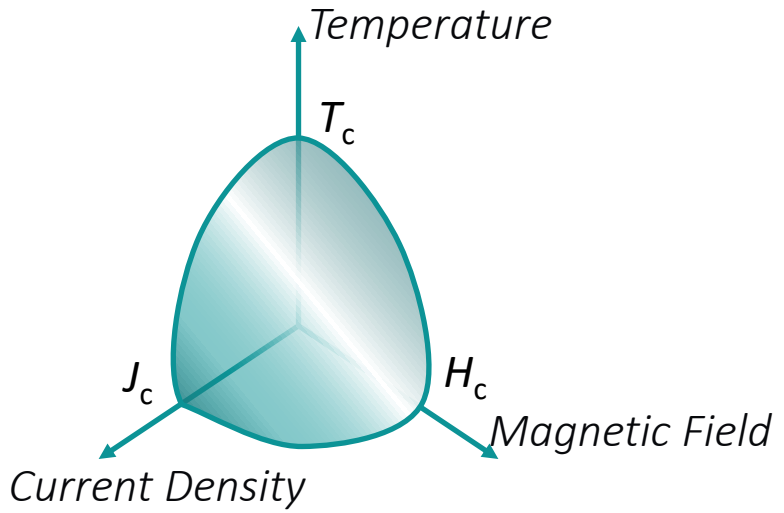
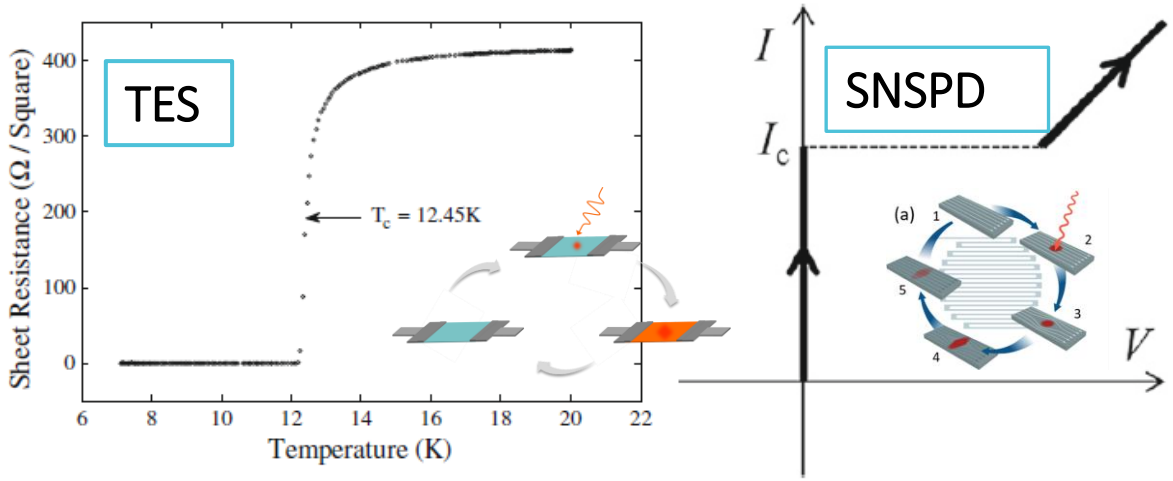
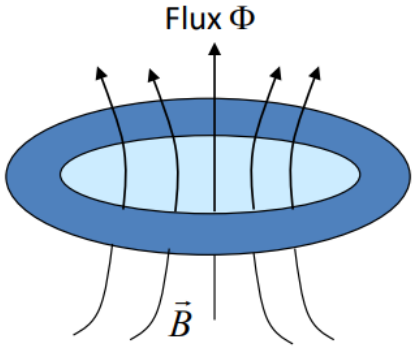




Macroscopic Quantum Effects

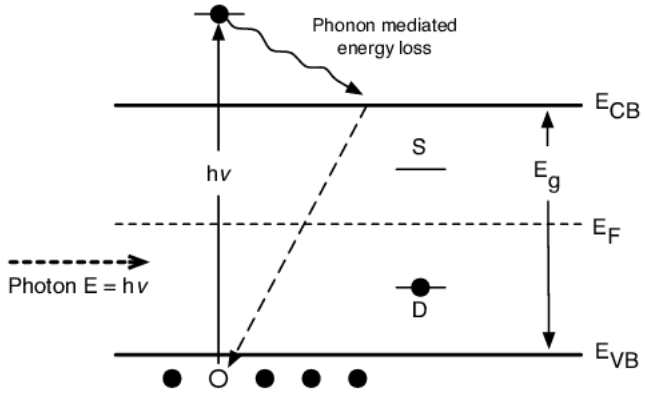


$$\Phi_0 = \frac{2\pi\hbar c}{q} = \frac{hc}{q}$$

Flux quantization $\Phi = n\Phi_0$
Josephson Effects

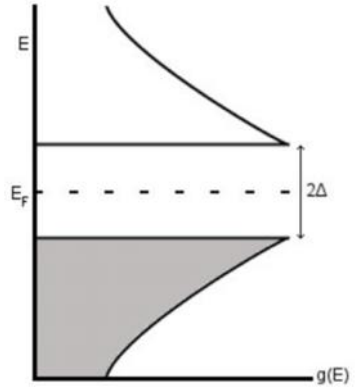
Why Superconducting Detectors?

- Superconducting detectors are the lowest noise, highest sensitivity detectors available
- They require cryogenic operation (0.05 K – 4 K).



Semiconductor Bandgap

- Si 1.12 eV
- InGaAs 0.75 eV

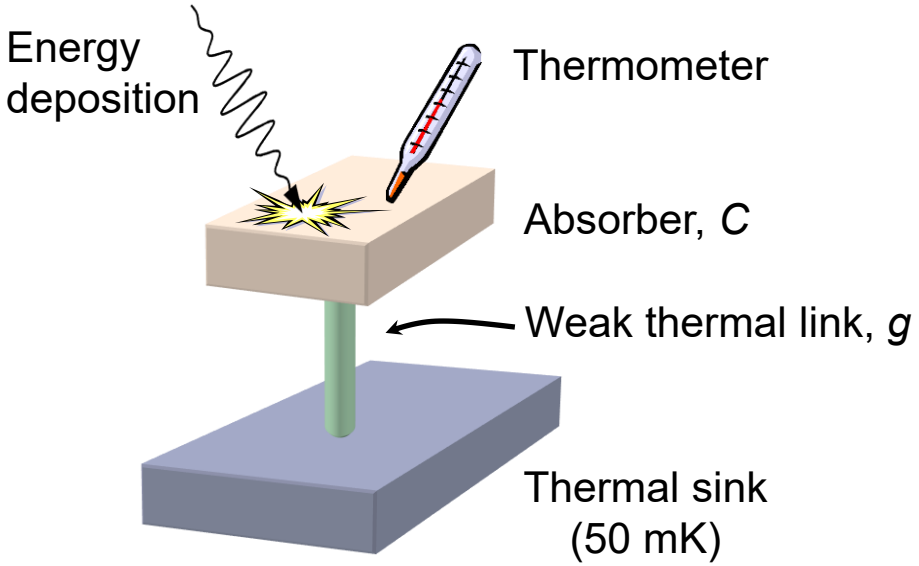


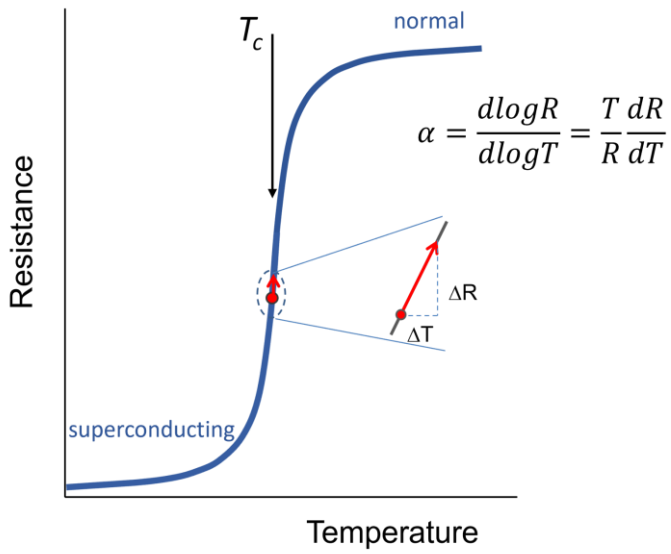
Superconducting Gap Energy

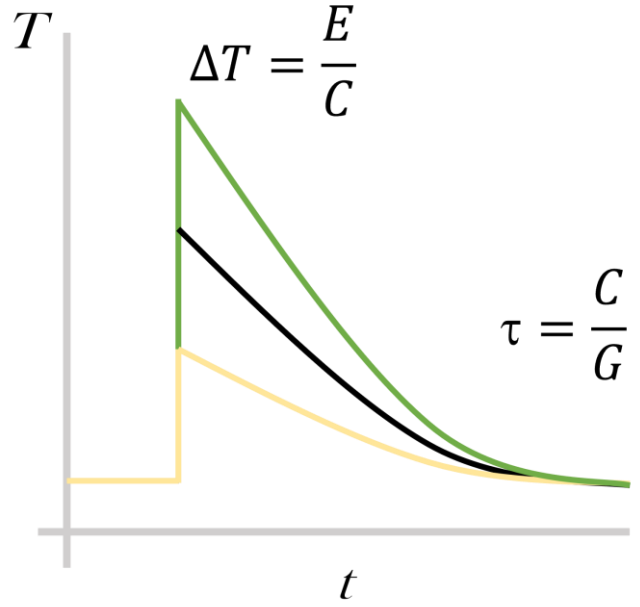
- Nb 2.32 meV
- Al 0.34 meV

Transition-Edge Sensors (TES)

C = heat capacity
G = thermal conductance



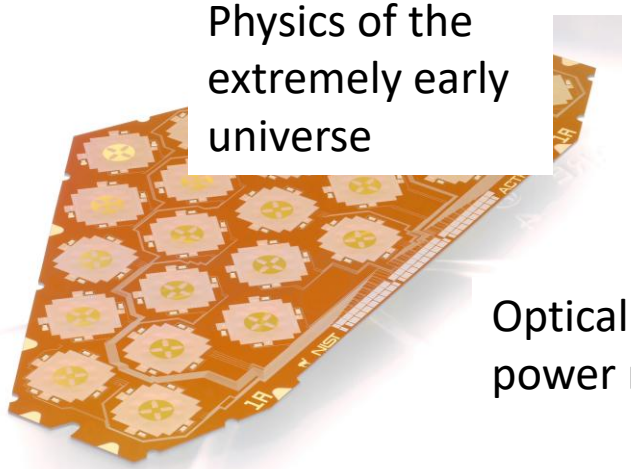




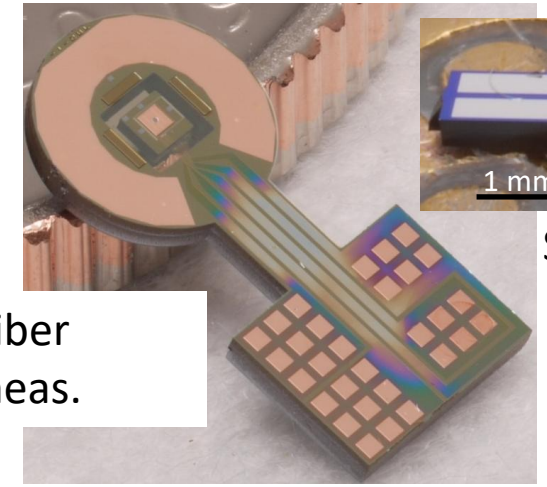
- Calorimetric principle: turn photon energy into heat and measure it
- Enables direct measurement of absorbed energy
- Operating temperature ~ 100 mK ; Thermal fluctuation noise $\Delta E \sim \sqrt{4k_B T^2 C}$

TES Devices Across the Spectrum

Physics of the extremely early universe



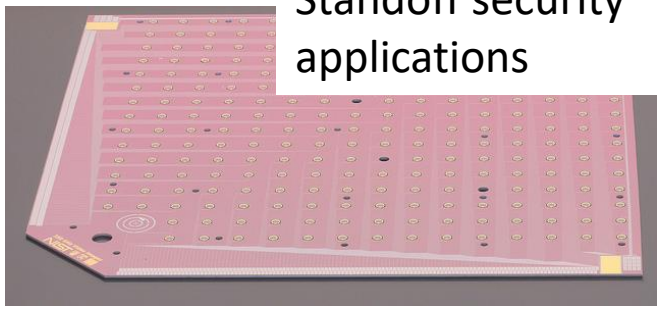
Cosmic Microwave Background (0.6 meV, 150 GHz)



Optical fiber power meas.

Single photon (0.5-2.5 eV)

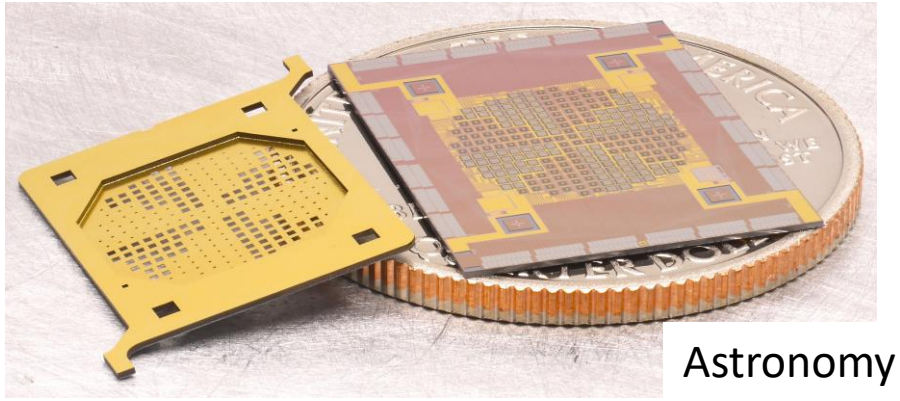
Quantum Information



Standoff security applications

THz Imaging (4 meV, 0.35 THz)

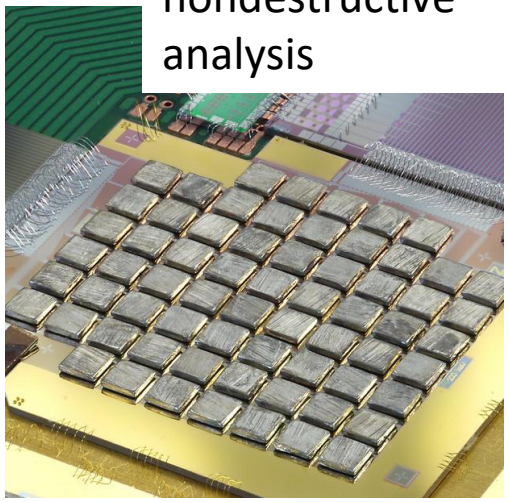
X-ray (2-10 keV)

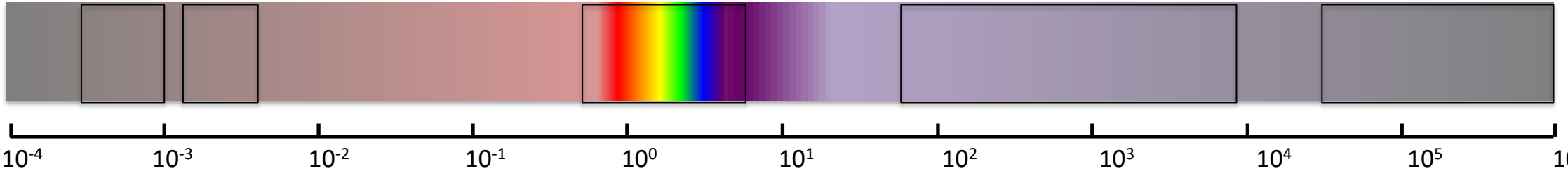


Astronomy

Gamma-ray (100's keV)

Nuclear nondestructive analysis





Optical Transition-Edge Sensor (TES)

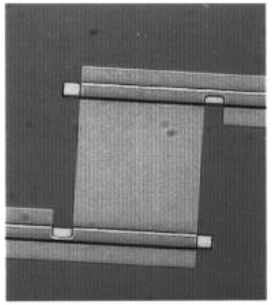
APPLIED PHYSICS LETTERS VOLUME 73, NUMBER 6 10 AUGUST 1998

Detection of single infrared, optical, and ultraviolet photons using superconducting transition edge sensors

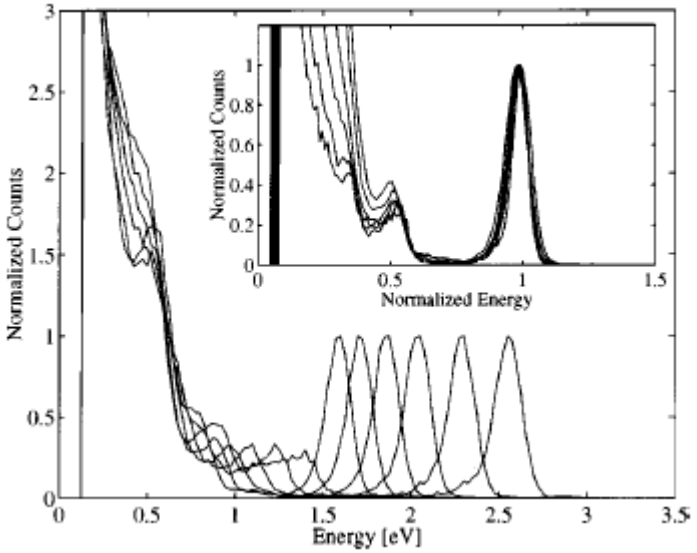
B. Cabrera,[a] R. M. Clarke, P. Colling, A. J. Miller, S. Nam, and R. W. Romani
Physics Department, Stanford University, Stanford, California 94305-4060

(Received 2 March 1998; accepted for publication 8 June 1998)

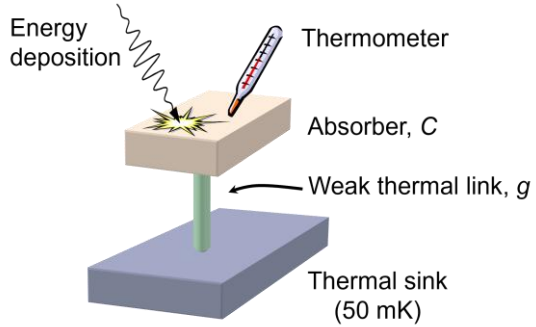
We have demonstrated the use of superconducting transition edge sensors for the wide-band detection of individual photons from the mid infrared (IR), through the optical, and into the far ultraviolet (UV). These tungsten transition edge sensors are squares about 18 μm on a side and detect single photon events above a threshold of 0.3 eV (4 μm wavelength), with an energy resolution of 0.15 eV full width at half maximum, and with a risetime (falltime) of .5 μs (60 μs). The calibration data extend up to the UV cutoff of the fiber optic feed at 3.5 eV (350 nm). © *1998 American Institute of Physics*. [S0003-6951(98)03032-0]



W sensor and
Al voltage rails



The entire micro-calorimeter is in the superconducting film



e^- in W

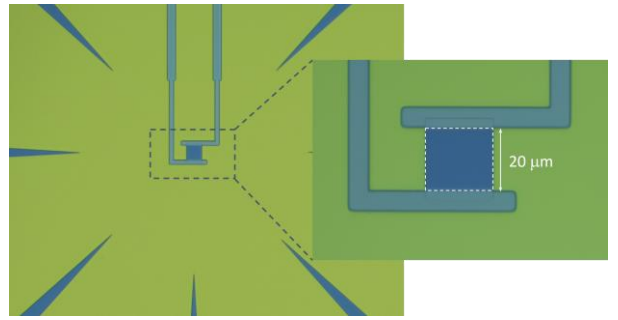
e^- in W

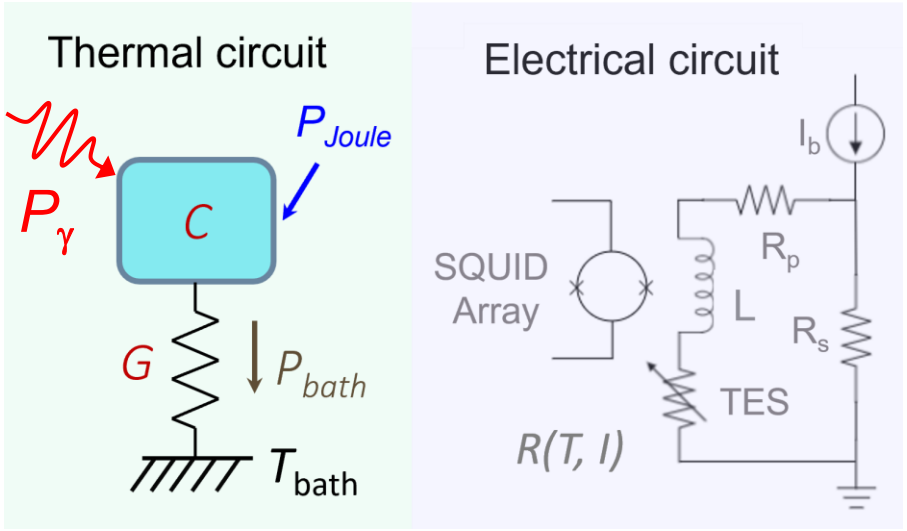
e^- - ph decoupling

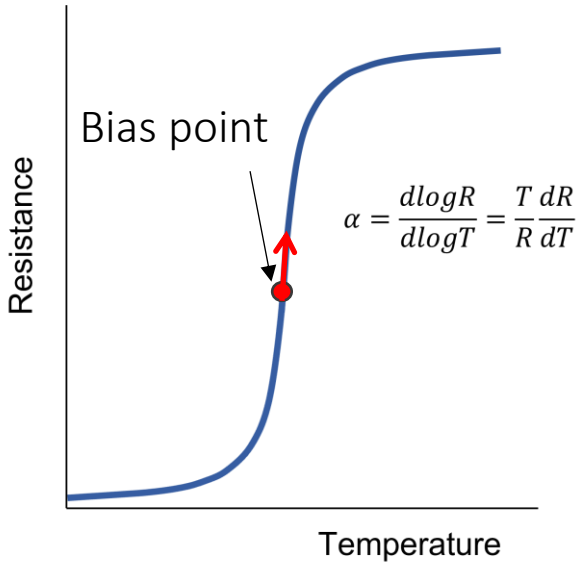
phonons in W

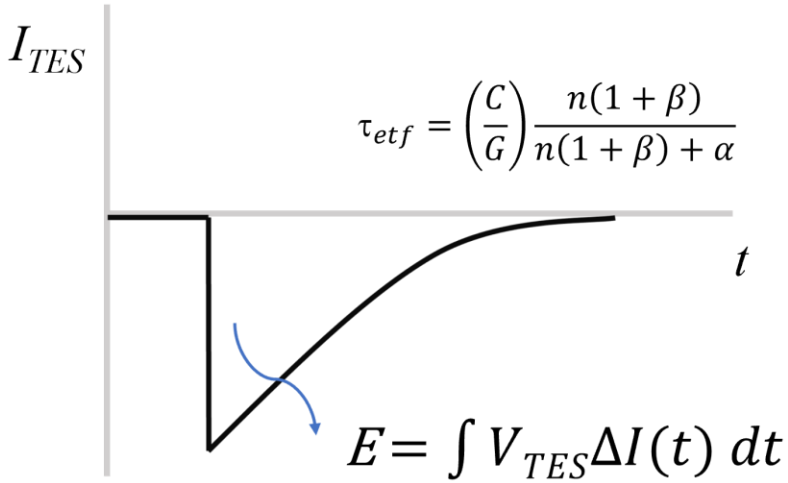
Optical Transition-Edge Sensor (TES)

Electrical and Thermal circuit: Electrothermal Feedback





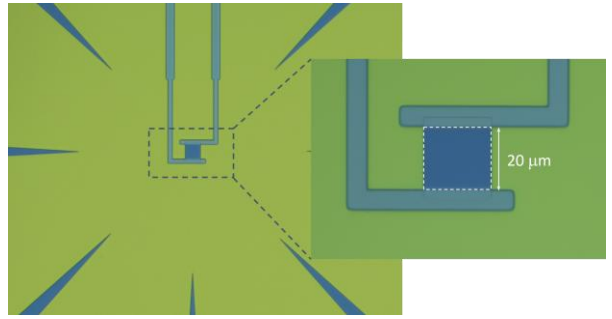




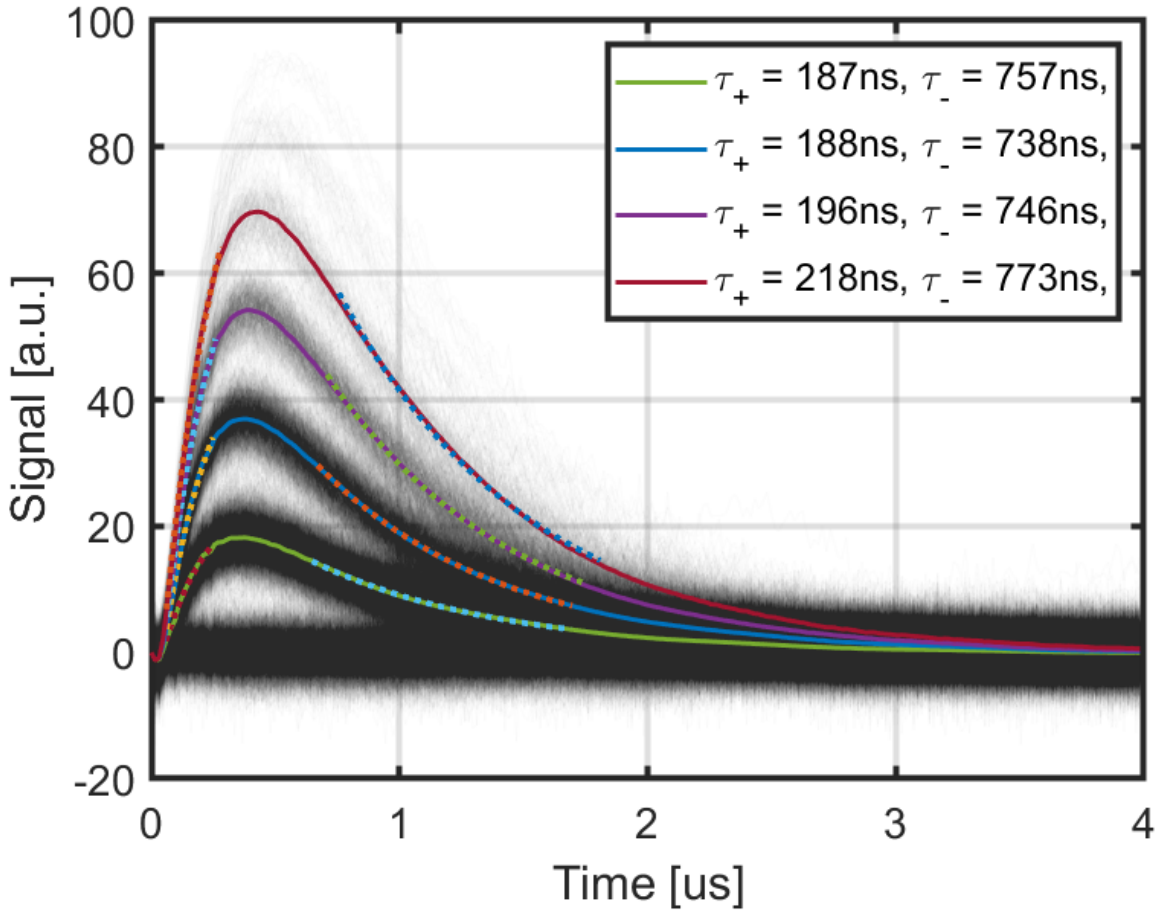
K.D. Irwin and G.C. Hilton, Cryogenic Particle Detection, Topics in Applied Physics, Vol. 99, (2005)

- Voltage bias keeps e^- in superconducting-to-normal transition via Joule heating ($R_{TES} \neq 0$)
- The heat in excess of Joule heating at equilibrium is removed through a drop in the Joule power dissipation
- Enables direct measurement of photons energy (integral of the current change * voltage bias)

Optical TES Output Signal



100,000 TES traces in response to 1550 nm pulsed laser



n=4 3.2 eV

n=3 2.4 eV

n=2 1.6 eV

n=1 0.8 eV

n=0

- Output signal is proportional to incoming photon energy
- Enables direct measurement of absorbed energy
- Rise time of ~100 ns
- Pulse duration ~1-2 µs
- Essentially no Dead time
- TES materials: W, Ti, Hf, Ir, TiAu/AuTi, TiAg…

Optical Transition-Edge Sensor (TES)

Quantum Cryptography
Quantum Optics
Quantum Metrology

APPLIED PHYSICS LETTERS VOLUME 83, NUMBER 4

Demonstration of a low-noise near-infrared photon counter with multiphoton discrimination

Aaron J. Miller,[a] Sae Woo Nam, and John M. Martinis
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Alexander V. Sergienko
Quantum Imaging Laboratory, Boston University, 8 Saint Mary's Street, Boston, Massachusetts 02215

(Received 20 February 2003; accepted 5 June 2003)

We have demonstrated a system capable of directly measuring the photon-number state of a single pulse of light using a superconducting transition-edge sensor microcalorimeter. We verify the photon-number distribution of a weak pulsed-laser source at 1550 nm. Such single-photon

PHYSICAL REVIEW A **68**, 063817 (2003)

Direct observation of photon pairs at a single output port of a beam-splitter interferometer

Giovanni Di Giuseppe,[1,*] Mete Atatüre,[2,†] Matthew D. Shaw,[1,‡] Alexander V. Sergienko,[1,2] Bahaa E. A. Saleh,[1] Malvin C. Teich,[1,2] Aaron J. Miller,[3] Sae Woo Nam,[3] and John Martinis[3]
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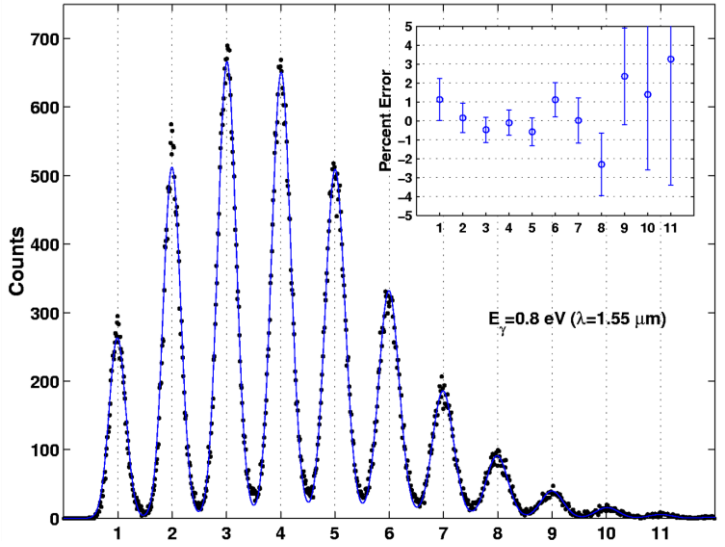
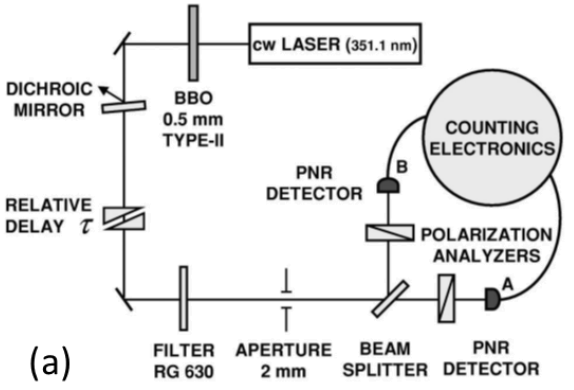
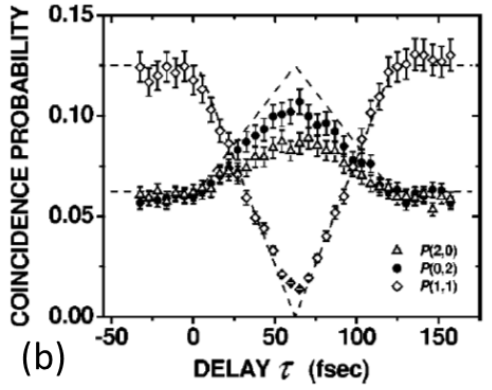
(Received 22 May 2003; published 16 December 2003)

Quantum theory predicts that two indistinguishable photons incident on a beam-splitter interferometer exit together (the pair emerges randomly from one port or the other). We use a special photon-number-resolving energy detector for a direct observation of this quantum-interference phenomenon. Simultaneous measurements from two such detectors, one at each beam-splitter-interferometer output port, confirm the absence of cross coincidences. Photon-number-resolving detectors are expected to find use in other quantum-optics and quantum-information-processing experiments.

1550 nm Weak Coherent Source

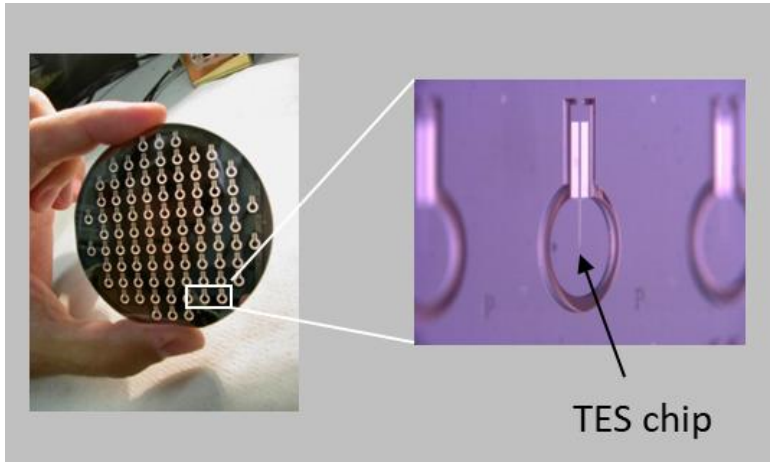


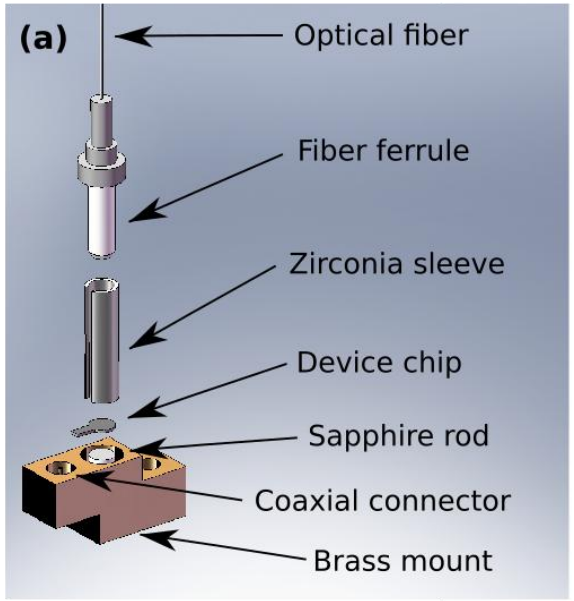




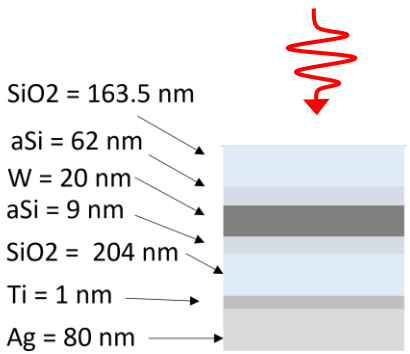
Optical TES System Detection Efficiency (SDE)

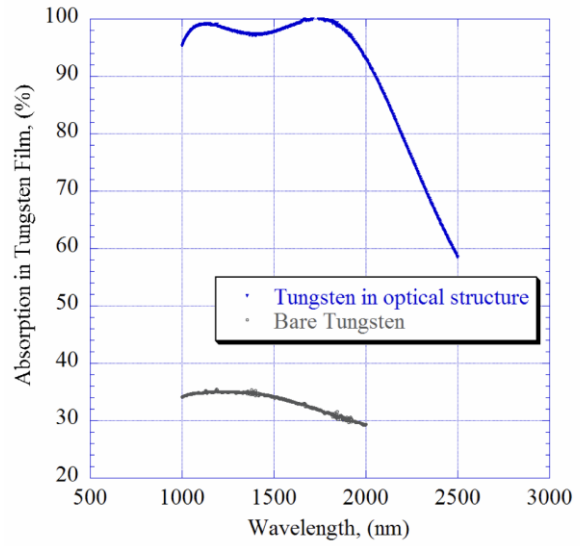
- Coupling Efficiency
- Absorption



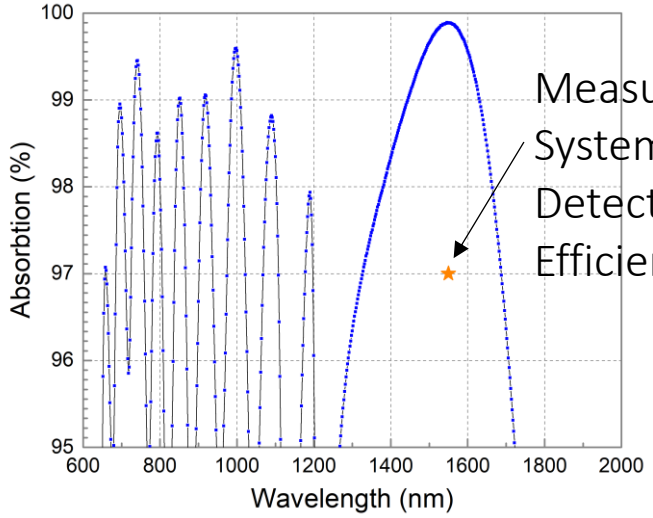


Miller et al., Opt. Express 19 (10), 9102 (2011)





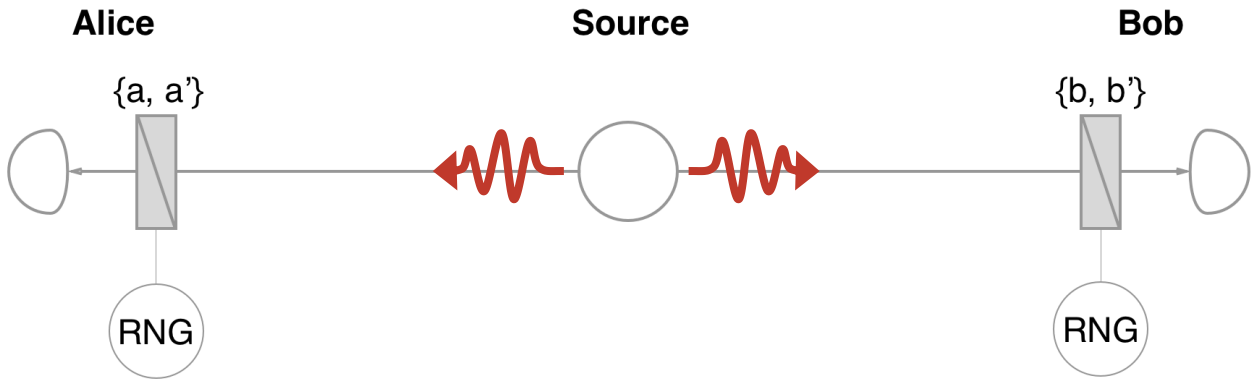
Lita et al, Opt. Exp. (2008)



System Detection Efficiency (SDE)	> 98 % @ 1550 nm	Larsen, M.V. et al. Nature 642, (2025).
	≥ 95% @ 1550 nm	Lita, A. E., et al., *Opt. Express* (2008) Peizhan Li et al., JLTP (2024)
	≥ 98% @ 860 nm	Fukuda, D. et al., *Opt. Express* (2011)

Loophole-Free Bell Test rules out local realism (2015)

A major step in entanglement verification and distribution was the experimental implementation of loophole-free Bell tests, executed with photonic and matter qubits.



B. Hensen *et al.*, "Loophole-free Bell Inequality Violation Using Electron Spins Separated by 1.3 Kilometres," Nature 526, 682 (2015)

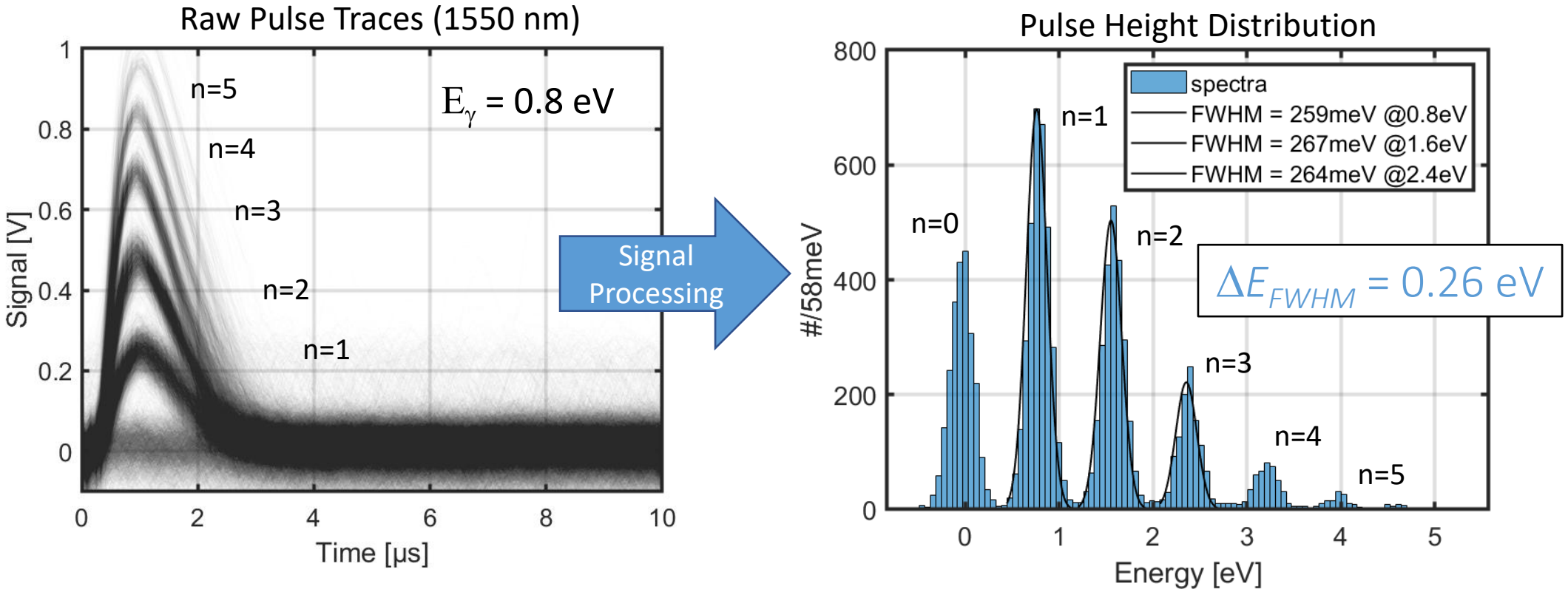
M. Giustina *et al.*, "Significant-Loophole-Free Test of Bell's Theorem with Entangled Photons," Phys. Rev. Lett. 115, 250401 (2015)

L. K. Shalm *et al.*, "Strong Loophole-Free Test of Local Realism," Phys. Rev. Lett. 115, 250402 (2015)

W Optical TES
λ = 810nm
τ ~ 1 μs; Δt_σ ~100 ns
SDE > 95%

SNSPD
λ=1550nm
τ ~ 50 ns; Δt_σ ~ 100 ps
SDE > 90%

TES Photon-Number Resolution



Use optimum matched filter post-processing for improved signal-to-noise ratio

TES Photon-Number Resolution

How high a photon number is distinguishable with a TES?

- Photon energy E_γ and ΔE_{FWHM}
- Device design/Saturation energy

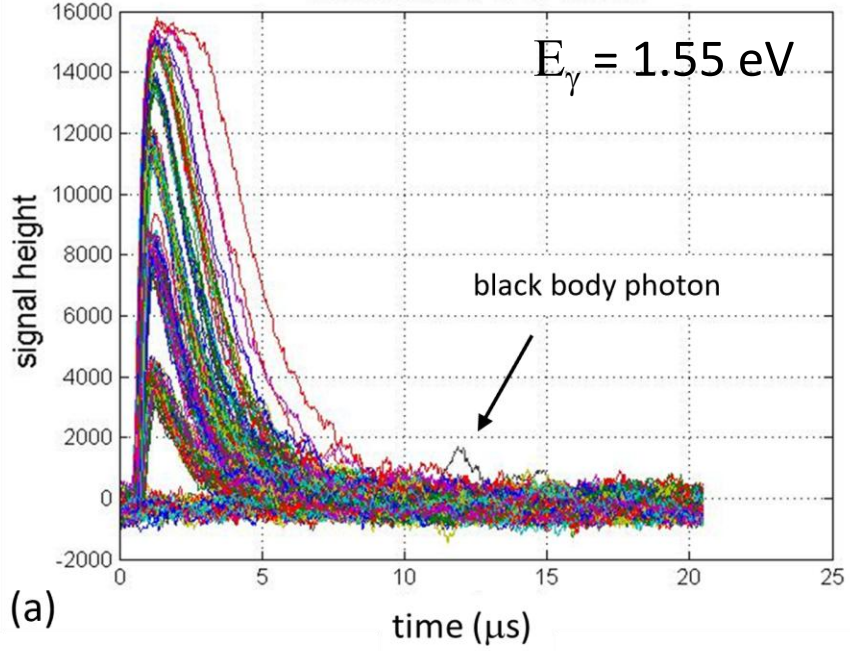
$$\Delta E_{FWHM} \approx 2\sqrt{2ln2}\sqrt{4k_B T_c^2 \frac{C}{\alpha}\sqrt{n/2}}$$

$$E_{sat} \approx T_c C/\alpha$$

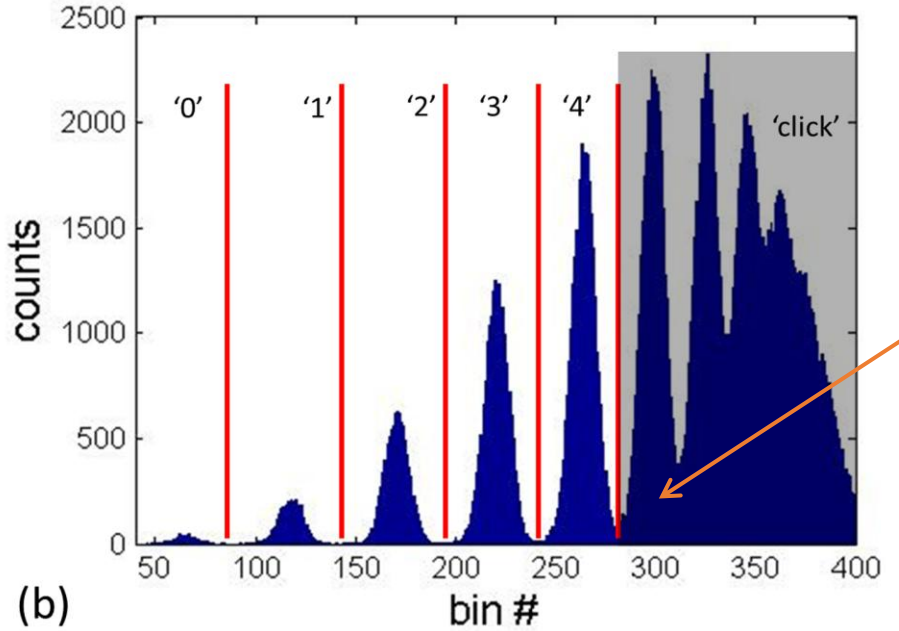
How accurately can we distinguish photon numbers?

- Photon number peaks separation (Error < 1% -> peaks separation > 6 σ)

Raw traces from 800 nm laser pulses



Pulse Height Distribution

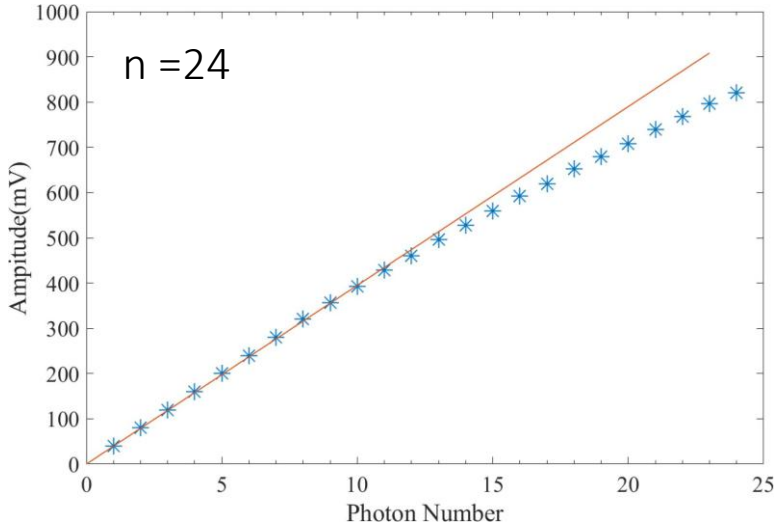


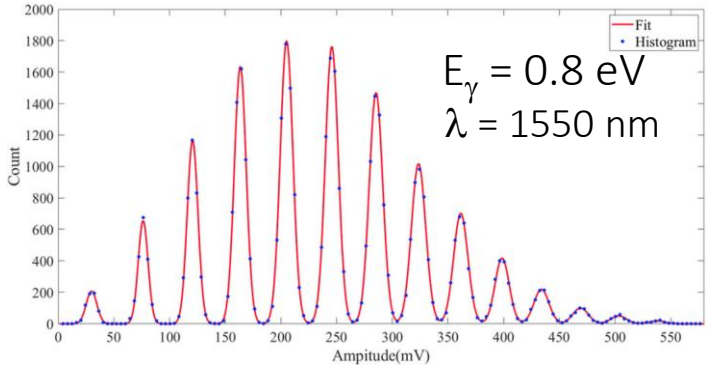
Above a certain photon energy, TES is no longer operating in a linear regime

T. Gerrits et al., Superconducting Devices in Quantum Optics (2016)

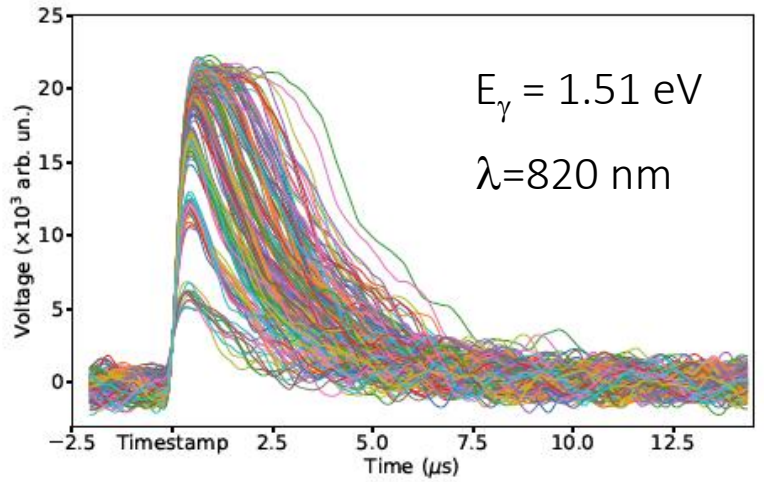
TES Photon-Number Resolution

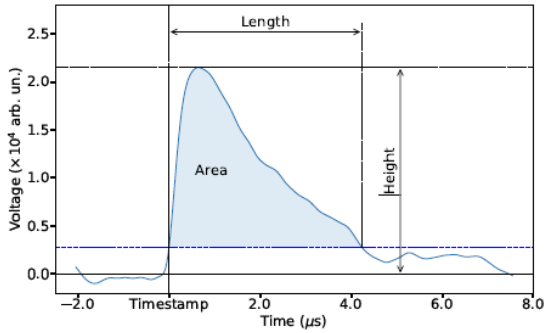
Extend PNR beyond linear operation regime

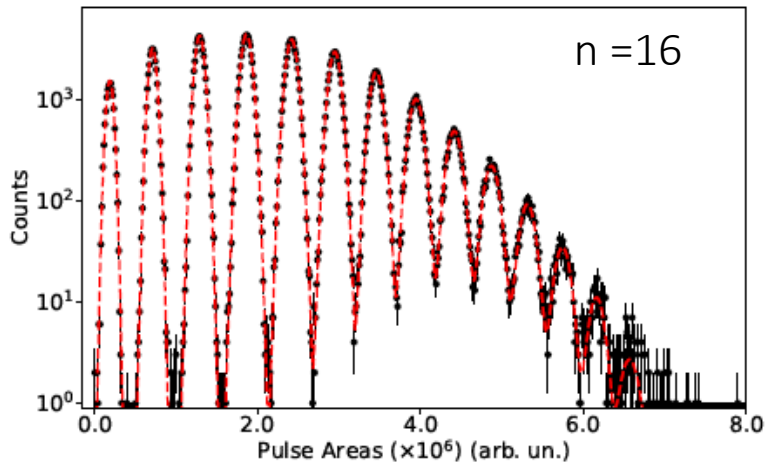




Hong-Fan Zhang et al., IEEE Transactions on Applied Superconductivity, 34, (2024)







Probabilities of correct Photon number assignment

$n < 10$, $p > 99\%$

$10 > n < 16$, $p > 90\%$

$\Delta E_{FWHM} \leq 0.59\ eV$ (1.51 *eV*)

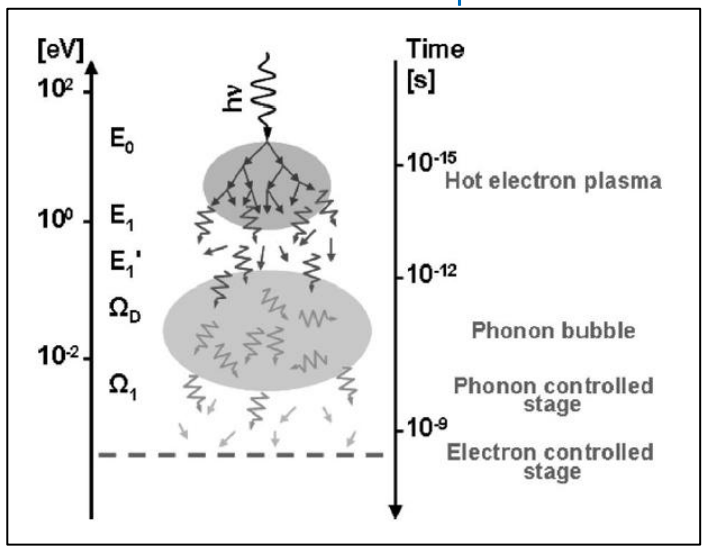
$\Delta E_{FWHM} \leq 0.31\ eV$ (0.8 *eV*)

L.A. Morais et al., Quantum 8, 1355 (2024)

Optical TES Energy Resolution Optimization

- Downconversion phonon noise and energy collection efficiency

Schematic photon energy downconversion in a superconductor



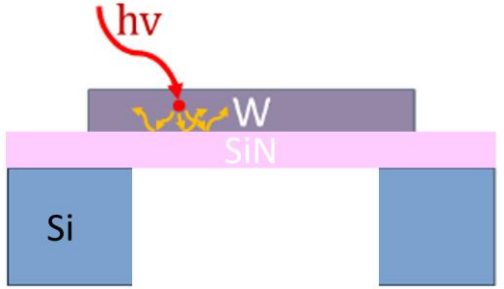
*A.G. Kozorezov, et. al., Physical Review B **75** (2007)*

$$\Delta E_{\text{Irwin/Hilton \& Kozorezov}} \approx 2.355\sqrt{\frac{4k_B T_c E_{max}}{1+\beta}\sqrt{\frac{nF(T_c,T_b)}{1-(T_b/T_c)^n}}\frac{\sqrt{\xi}}{\kappa^2}+J(E)E}$$

Energy collection efficiency: κ

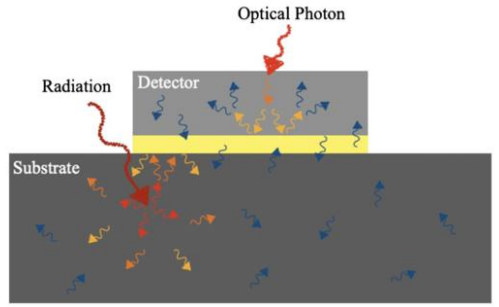
Downconversion Phonon Noise: *J(E)*

- Fabrication on membranes allow escaped phonons to be recollected in the sensor before reaching the substrate



*Lita, A.E. et al., JLTP **151**, 125 (2008)*

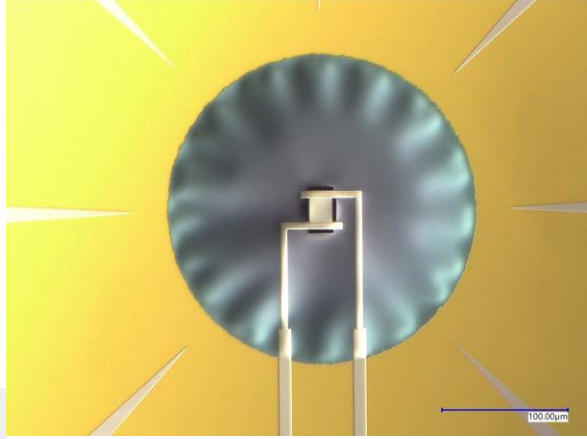
- Acoustically mismatched substrates block high energy phonons to escape detector material.



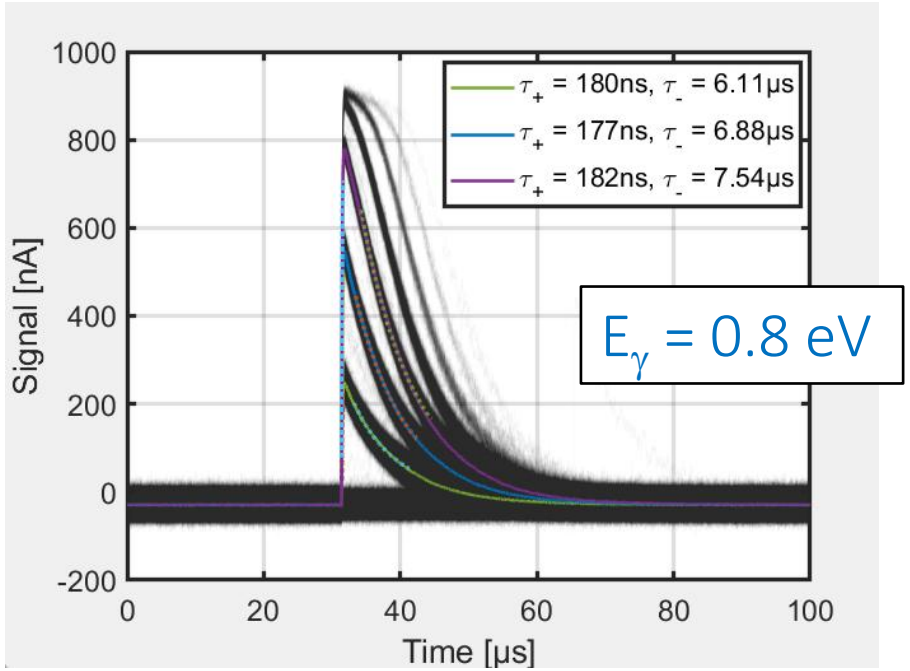
Zobrist N., et al. PRL 129(1):017701 (2022)

Optical TES device optimization

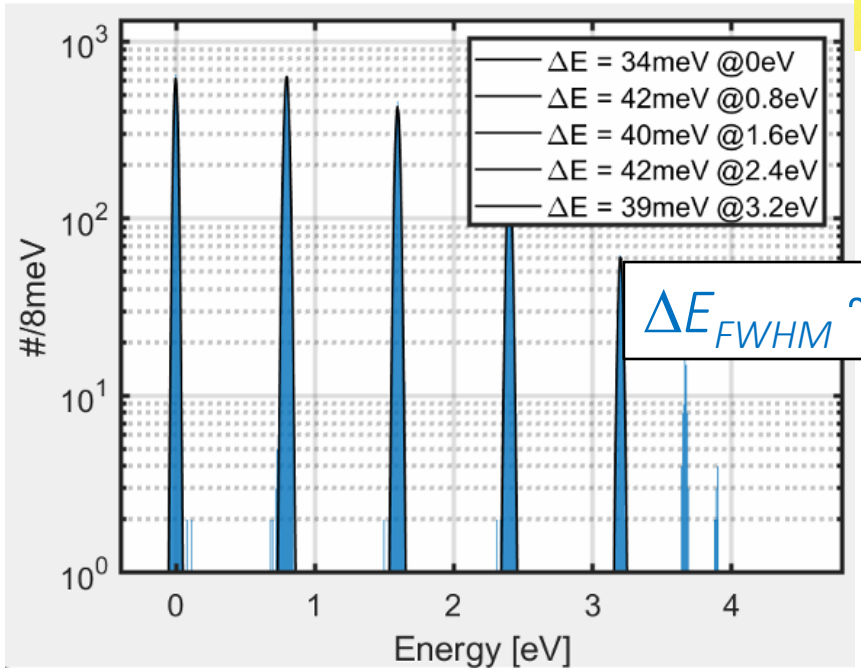
- Energy Resolution and Speed tradeoff



R = E/ΔE = 20 1550 nm



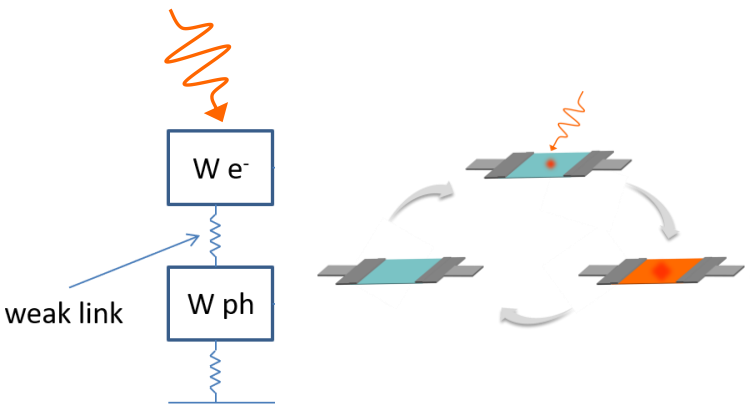
E_γ = 0.8 eV

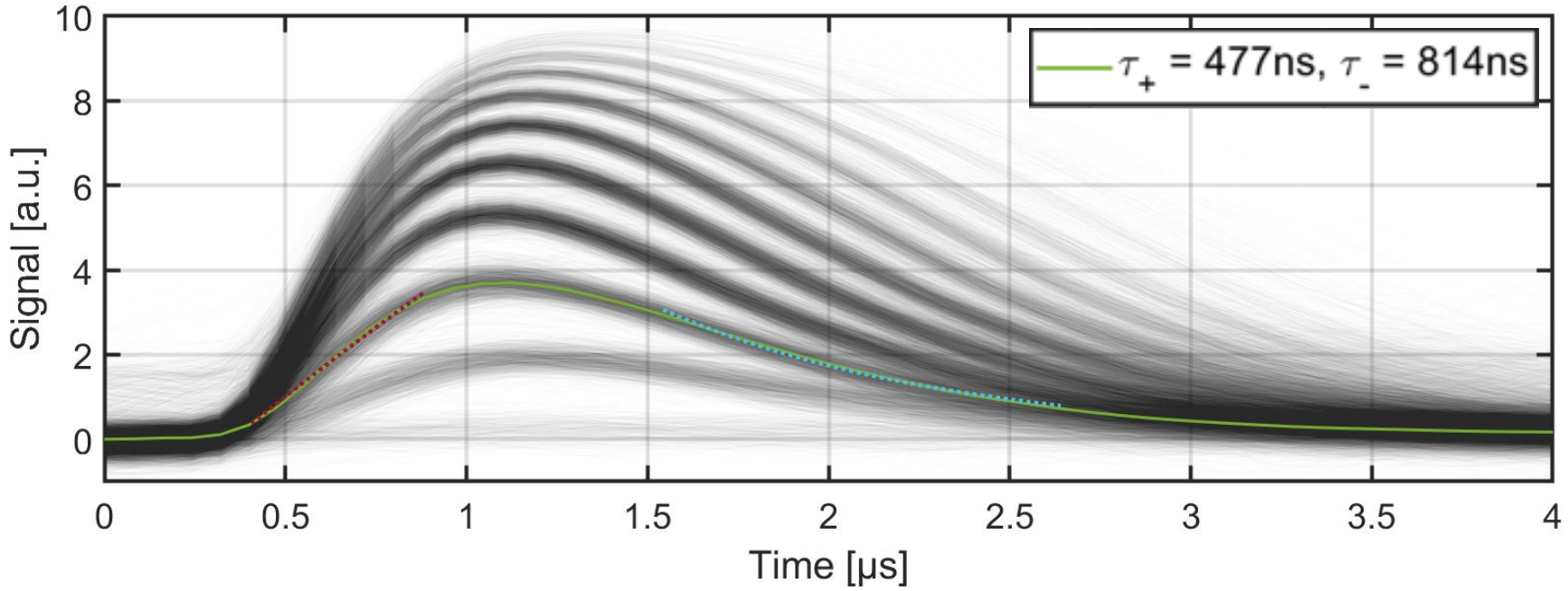


ΔE_{FWHM} ~ 0.040 eV

- Record Energy resolution at 1550 nm
- Longer device recovery time

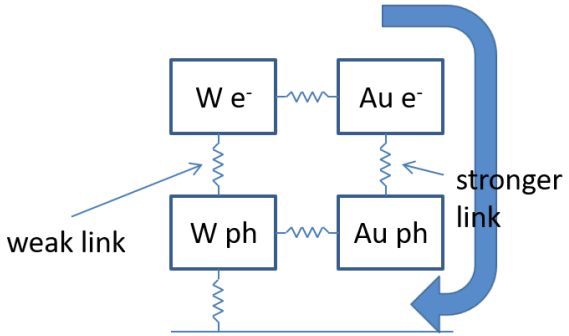
Optical TES Recovery Time

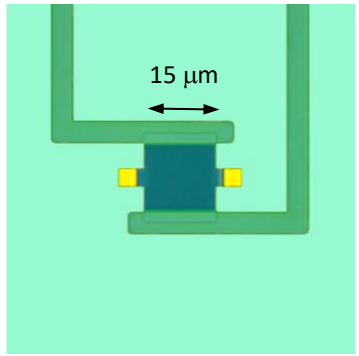




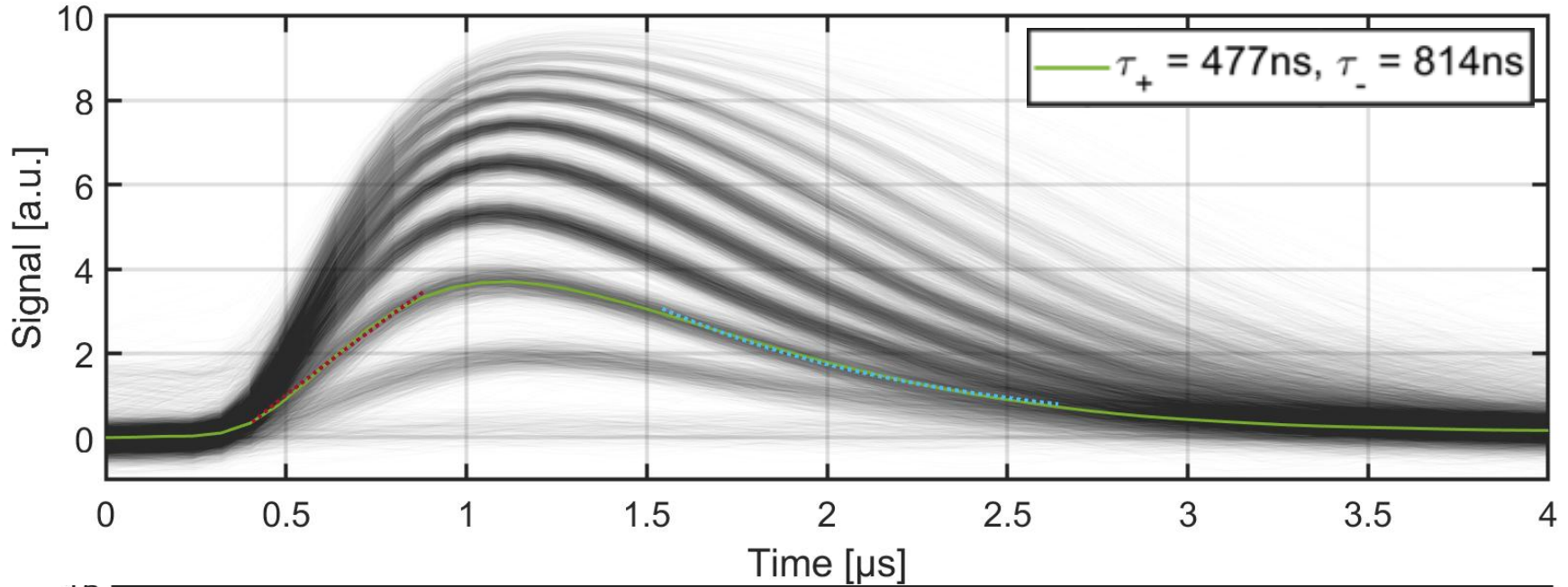
Optical TES Recovery Time

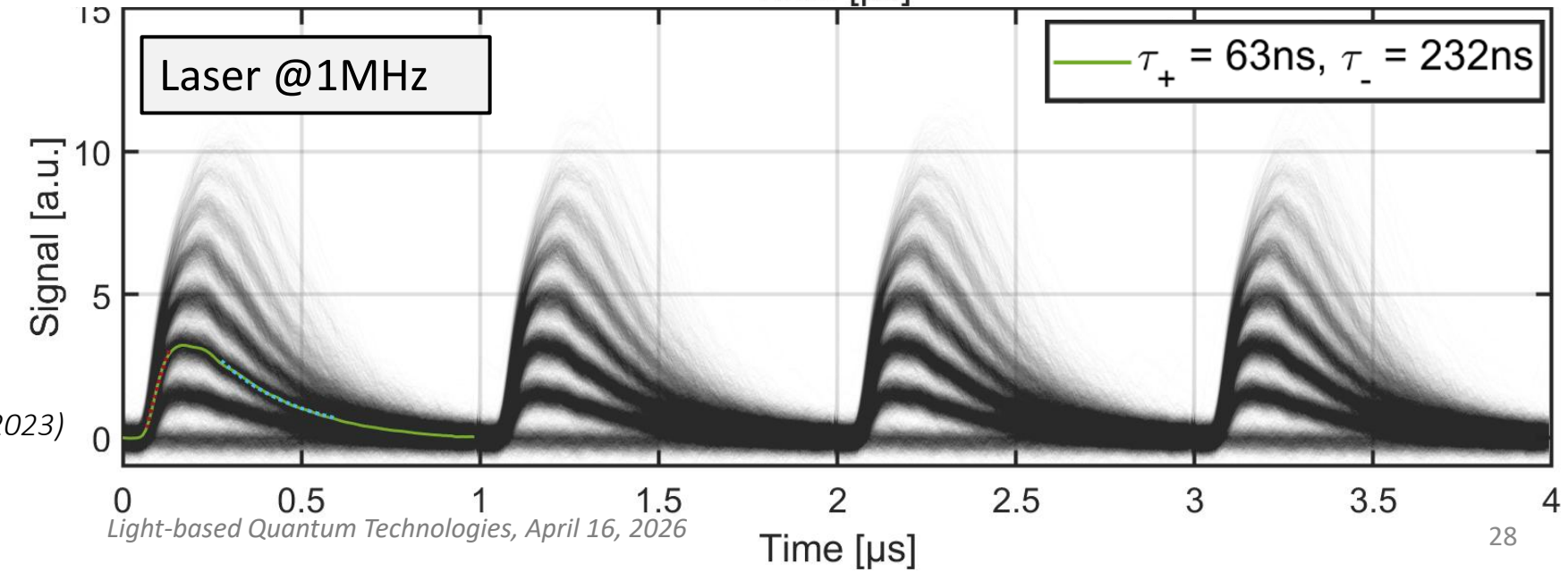
Thermal link engineering
High bandwidth readout





Hummatov R. et al, J. Appl. Phys. 133, 234502 (2023)



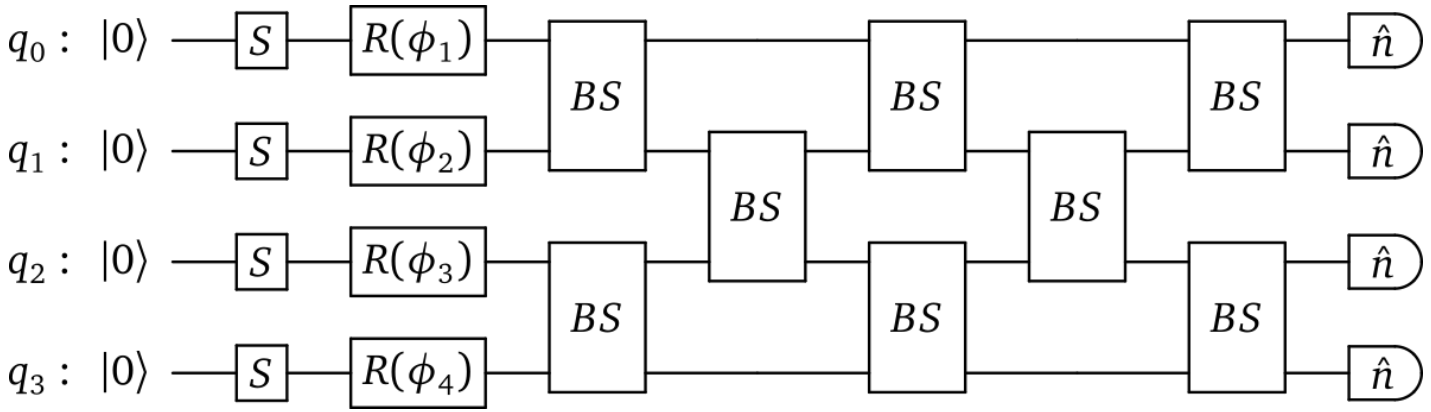


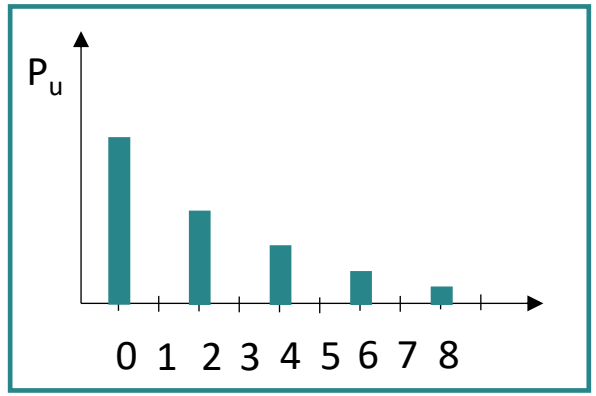
Photonic Quantum Computing

Continuous Variable (CV) States

$$|\psi\rangle = c_0|0\rangle + c_1|1\rangle + \ldots + c_n|n\rangle + = \sum_{n=0}^{\infty} c_n|n\rangle$$

Gaussian Boson Sampling (GBS) – generates qubit states (CV)





Courtesy of Xanadu

n photon sources

linear interferometer composed of beam splitters and phase shifters

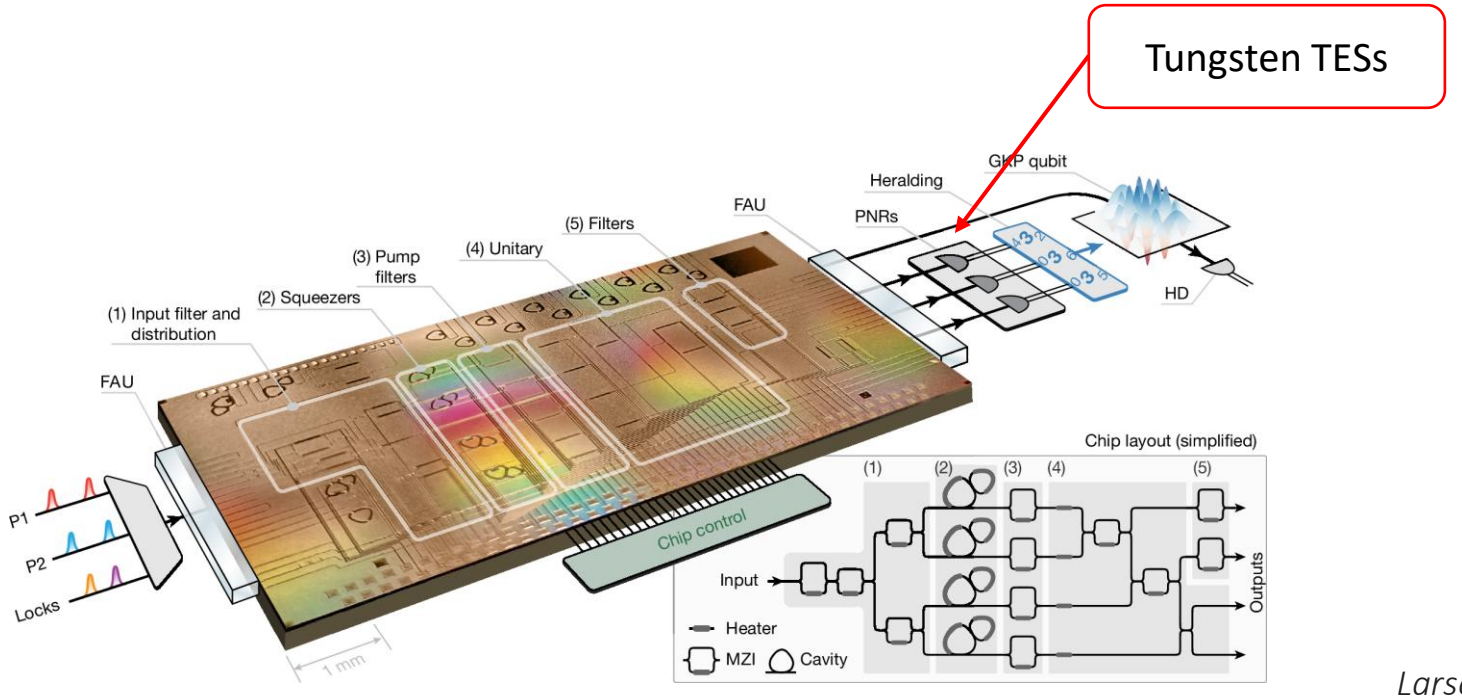
PNR detectors

- Information encoded in a continuous variable such as the amplitude and phase of a non-classical light state: squeezed light
- PNR detectors are heralding qubit states at the remaining output modes of the GBS device

Photonic Quantum Computing

Continuous Variable (CV) States

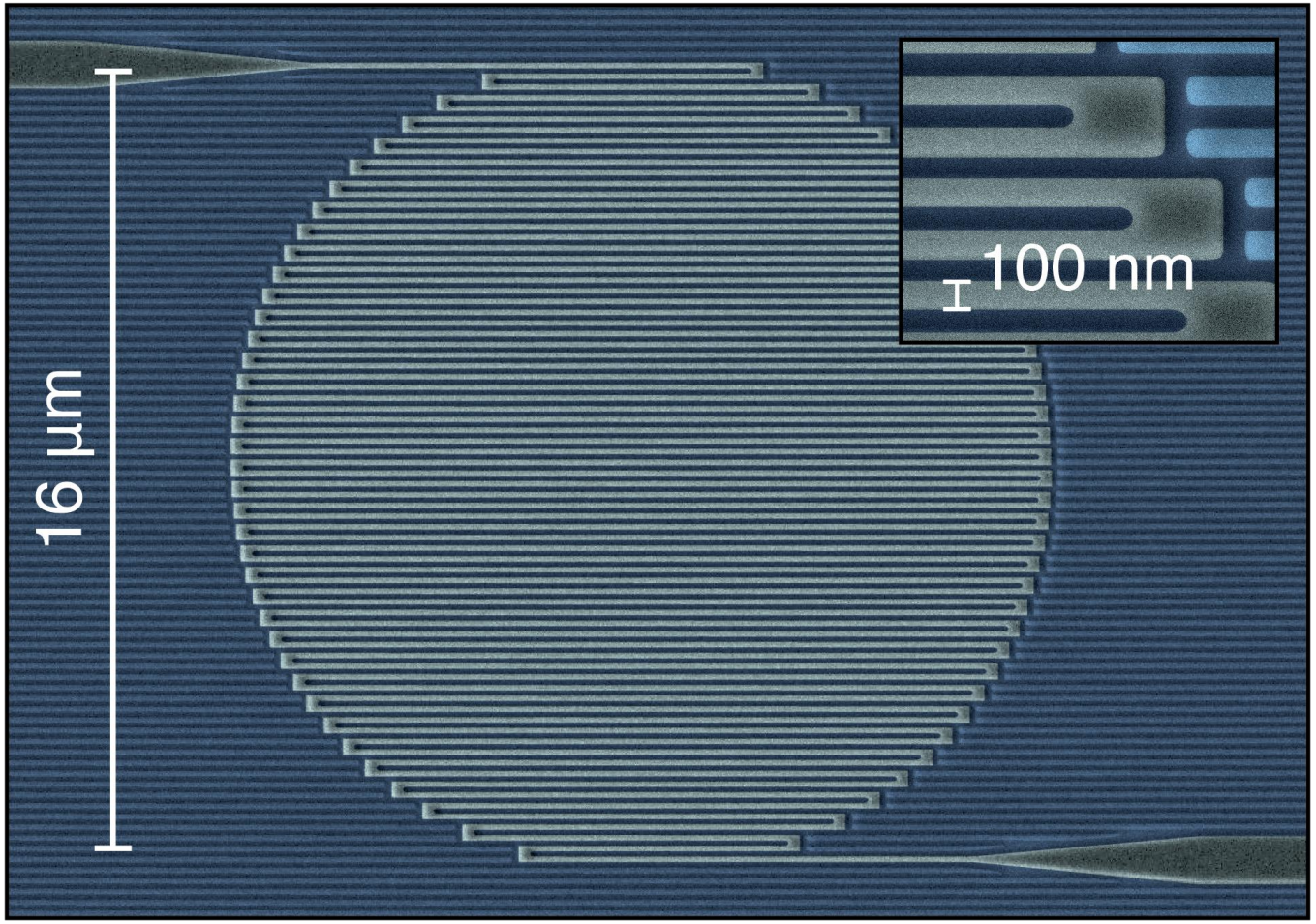
- Tungsten TES detectors are employed as the PNR detectors due to their near-unity detection efficiency, intrinsic photon-number resolution and very low dark count rates.



Larsen, M.V. et al. Nature (2025)

- Photonic quantum advantage machine with all gates programmable
- Demonstrate scalable generation of GKP states
- TES @ 200 kHz; DE: 96%, 98%, 99% PNR = 7 ; p_m^n > 99%

Superconducting Nanowire Single-Photon Detectors (SNSPD)



Superconducting Nanowire Single-Photon Detectors (SNSPD)

APPLIED PHYSICS LETTERS VOLUME 79, NUMBER 6 6 AUGUST 2001

Picosecond superconducting single-photon optical detector

G. N. Gol'tsman,[a] O. Okunev, G. Chulkova, A. Lipatov, A. Semenov, K. Smirnov, B. Voronov, and A. Dzardanov
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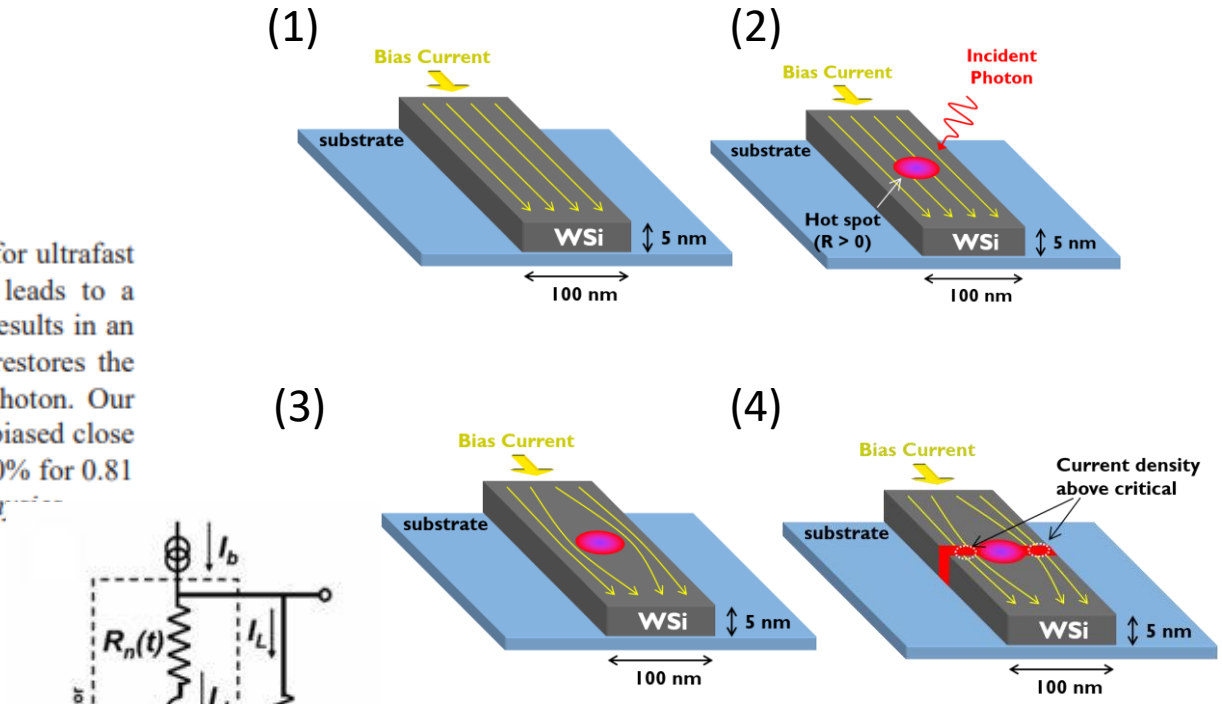
Department of Electrical and Computer Engineering and Laboratory for Laser Energetics, University of Rochester, Rochester, New York 14627-0231

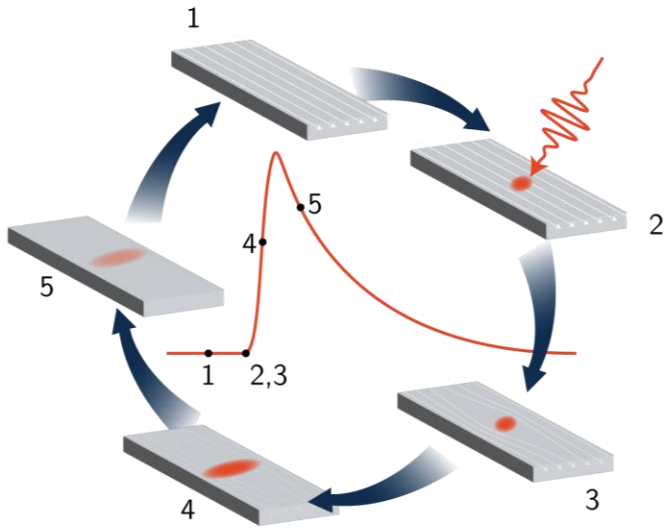
(Received 22 January 2001; accepted for publication 1 June 2001)

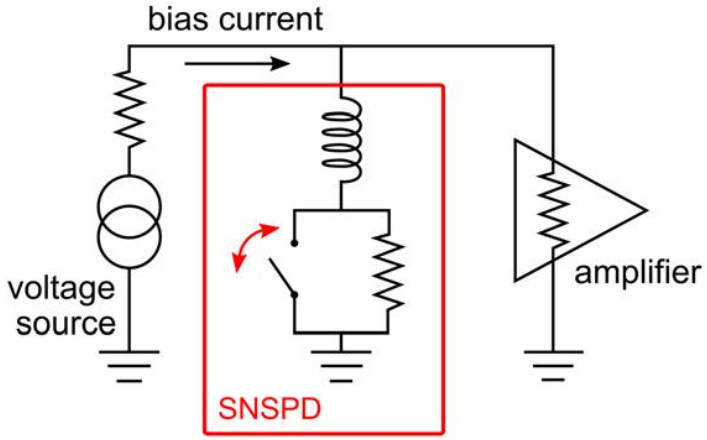
We experimentally demonstrate a supercurrent-assisted, hotspot-formation mechanism for ultrafast detection and counting of visible and infrared photons. A photon-induced hotspot leads to a temporary formation of a resistive barrier across the superconducting sensor strip and results in an easily measurable voltage pulse. Subsequent hotspot healing in ~30 ps time frame, restores the superconductivity (zero-voltage state), and the detector is ready to register another photon. Our device consists of an ultrathin, very narrow NbN strip, maintained at 4.2 K and current-biased close to the critical current. It exhibits an experimentally measured quantum efficiency of ~20% for 0.81 μm wavelength photons and negligible dark counts. © *2001 American Institute of Ph*

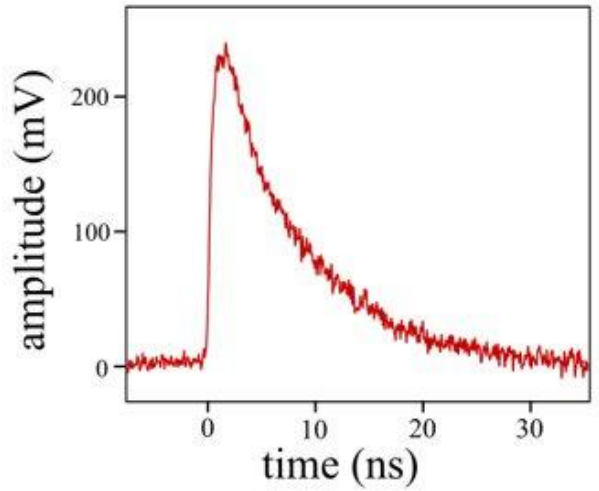
[DOI: 10.1063/1.1388868]



Superconducting Nanowire Single Photon Detectors (SNSPD)

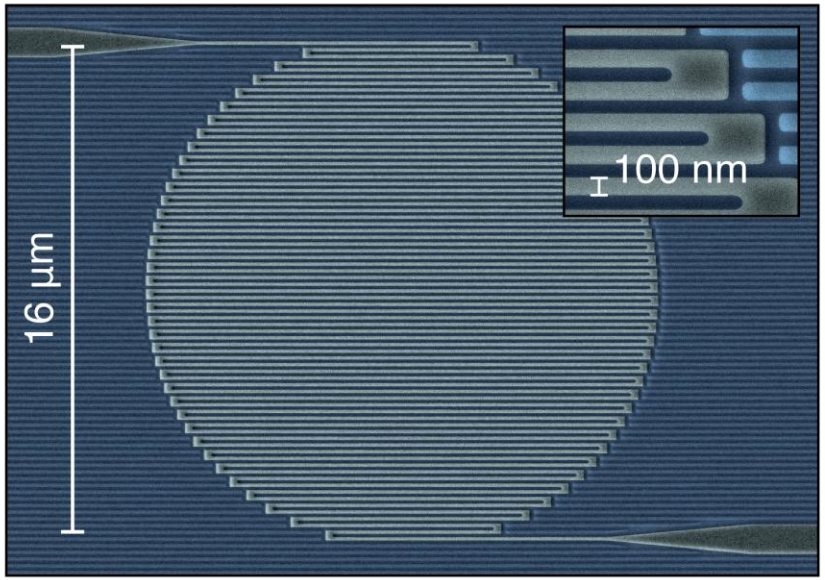


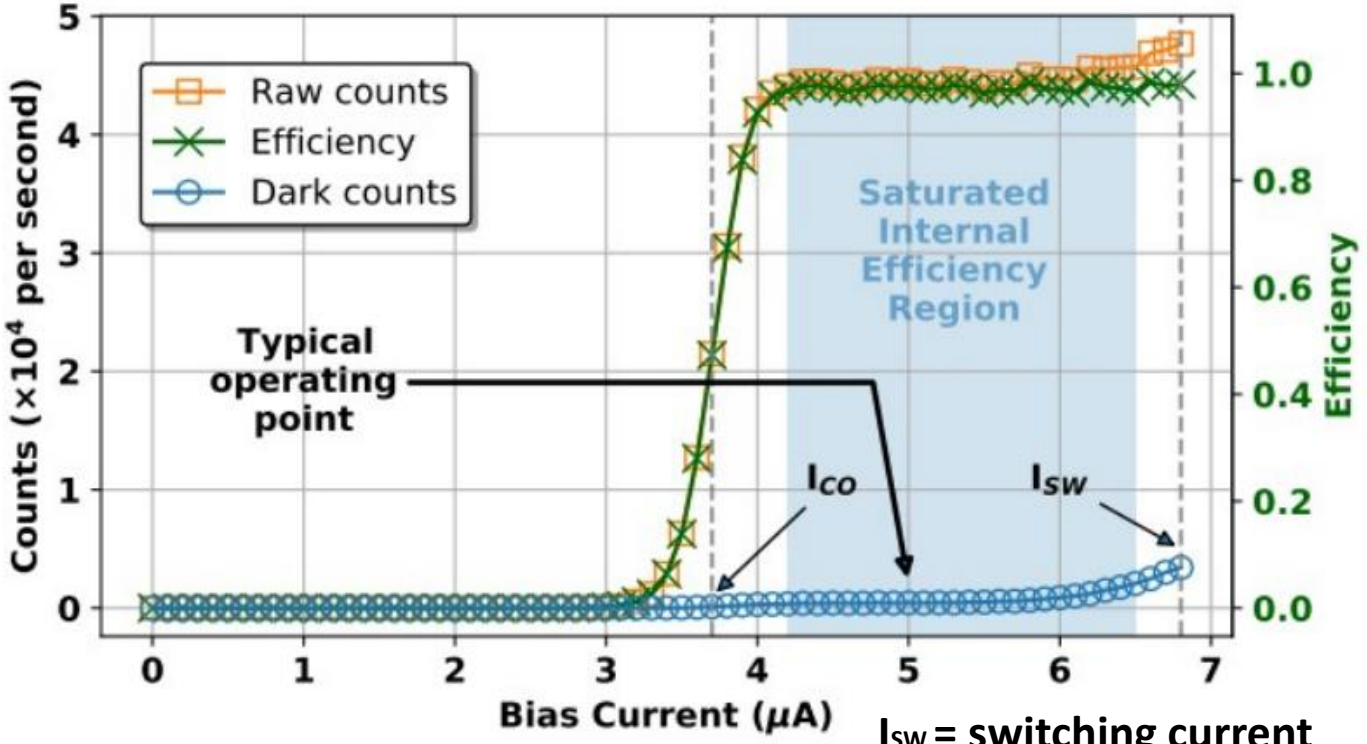




- Superconducting wire current biased close to critical current, I_c
- Very fast, like a switch
- Rise time < 100 ps
- Pulse duration ~1-100ns
- Truly digital detection mechanism – reduced drift and zero read noise
- No energy resolution
- Operating temperature 1-4 K in most cases

Basic SNSPD Characterization





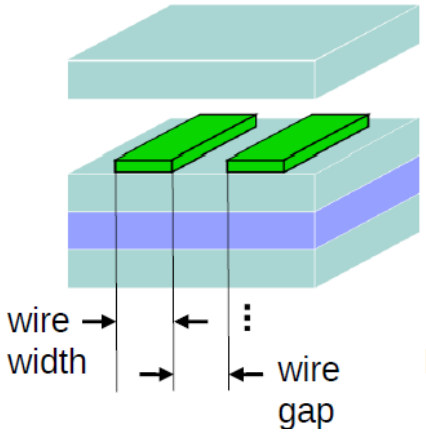
I_{sw} = switching current

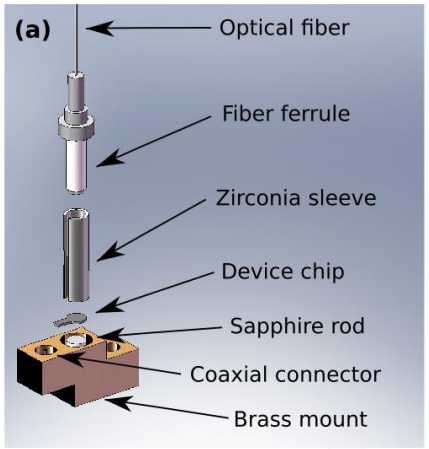
I_{co} = cut-off current

SNSPD materials:

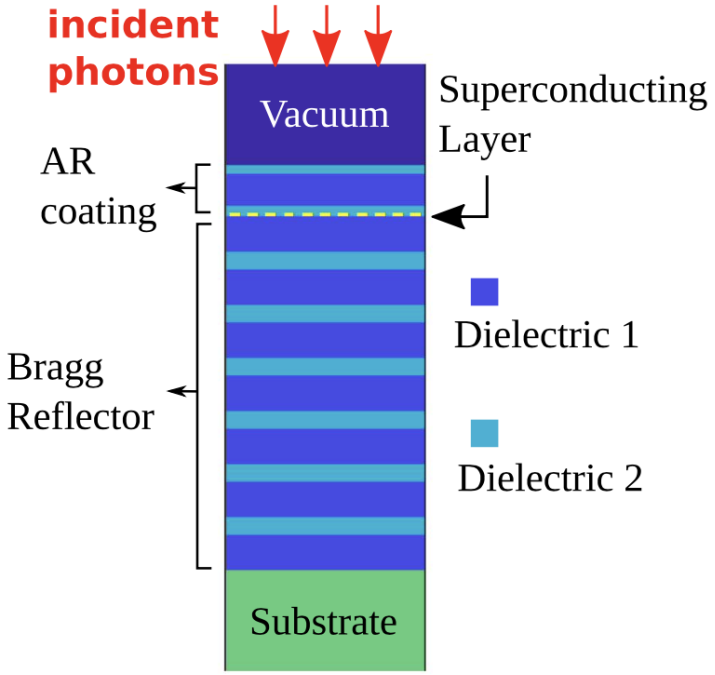
- WSi 3.5 K, MoSi 6 K (amorphous)
- NbN ~10 K , NbTiN ~10 K (polycrystalline)
- MgB_2 ~ 20 K (polycrystalline); *Charaev, I, et al. Nat Commun 15, 3973 (2024)*

System Detection Efficiency (SDE)

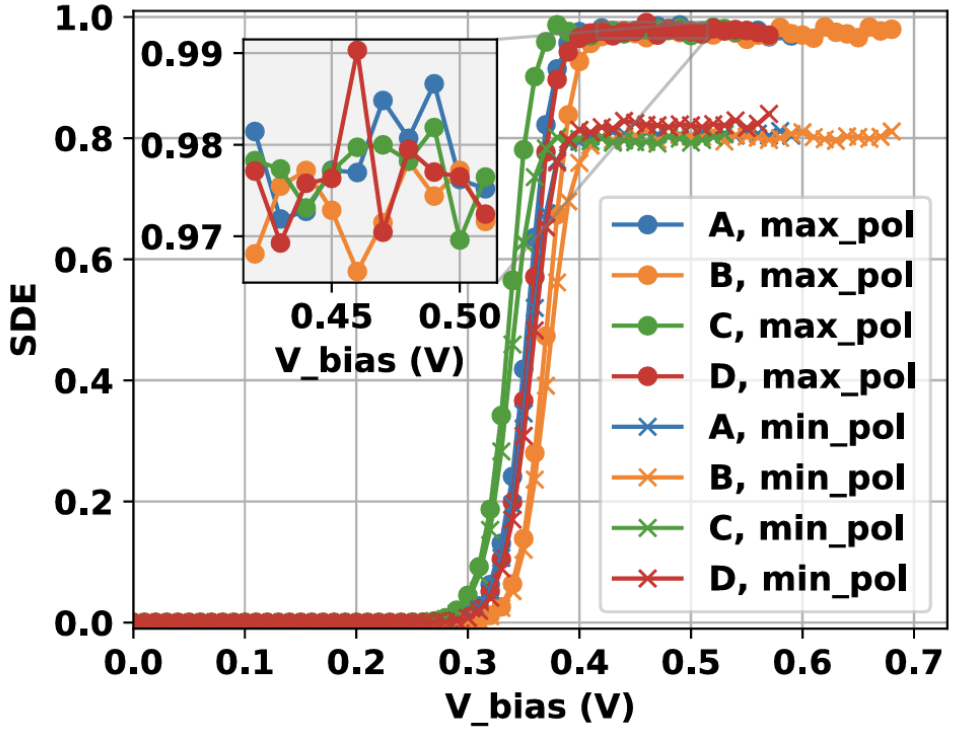




Miller et al., Opt. Express (2011)



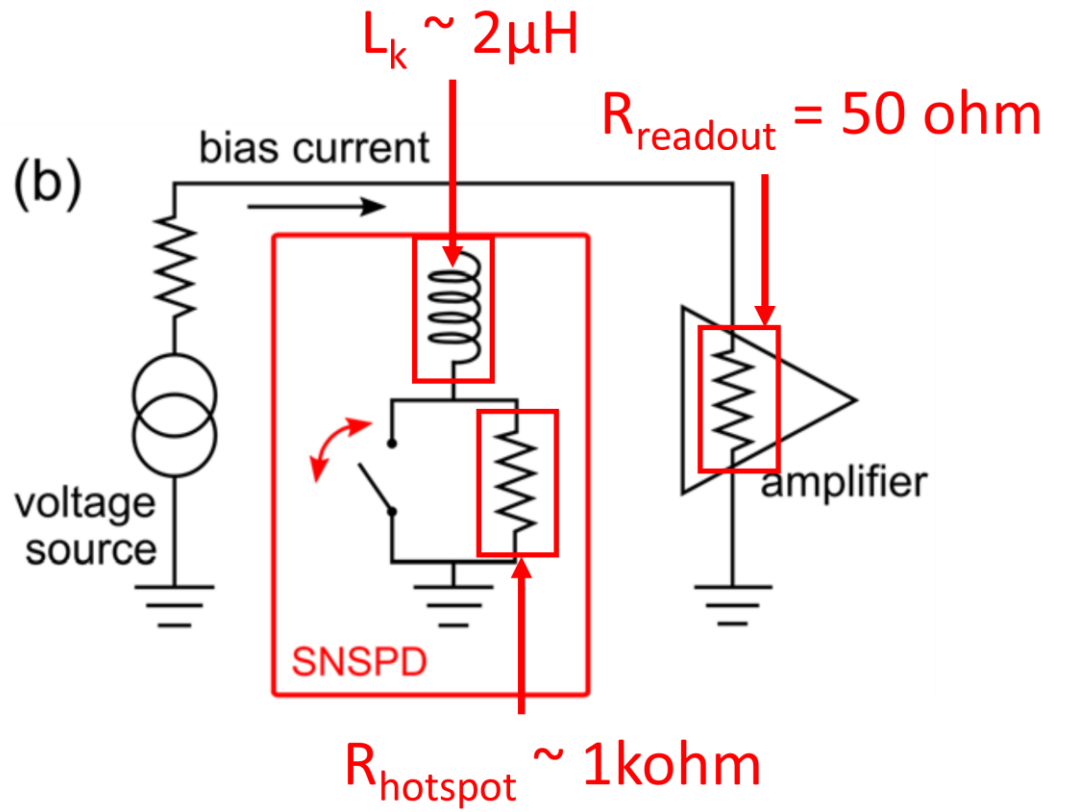
System detection efficiency at 1550 nm

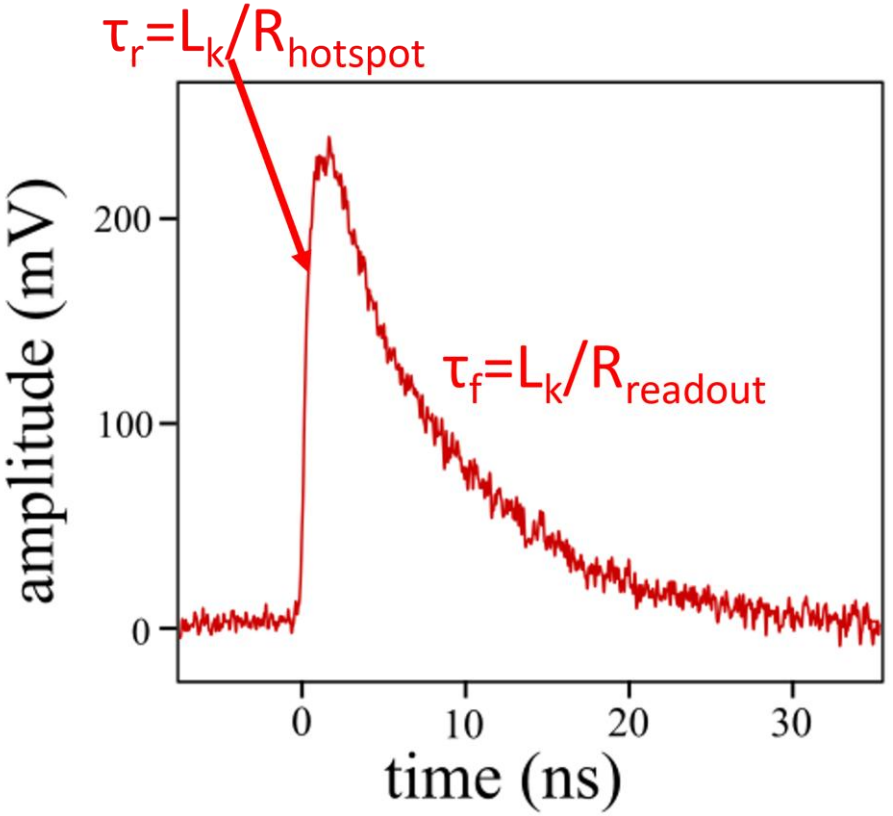


D. Reddy, *Optica* **7,** 1649 (2020)

System Detection Efficiency (SDE) @ 1550 nm	≥ 98%	D. V. Reddy et al., Optica (2020) P. Hu et al., Opt. Express (2020) J. Chang et al., APL Photonics (2021)

SNSPD Rise Time and Recovery Time

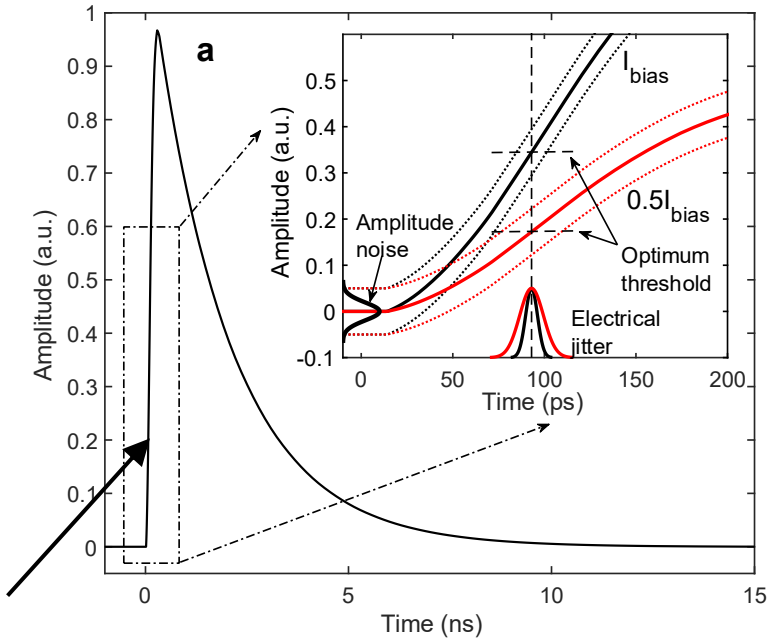




L_k is proportional to the length of the nanowire
Larger detectors will have longer “dead time”

SNSPD Timing Jitter: The Rising Edge

Timing record: ~ 4 ps jitter at 1550 nm



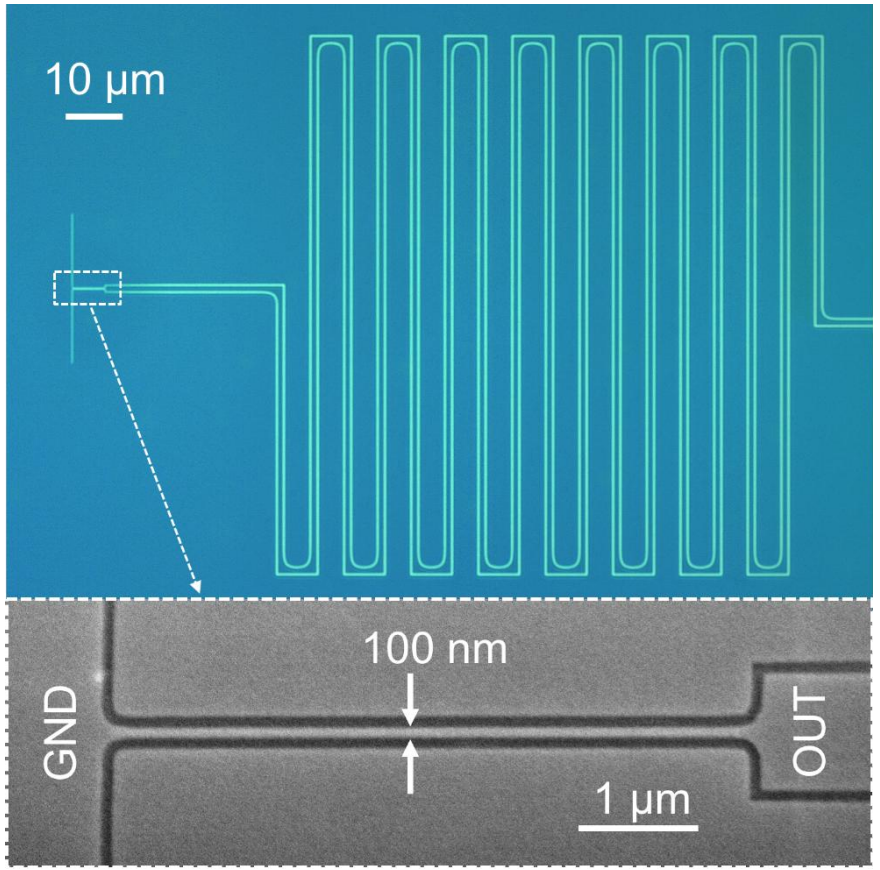
"Slew Rate" (V/ns)

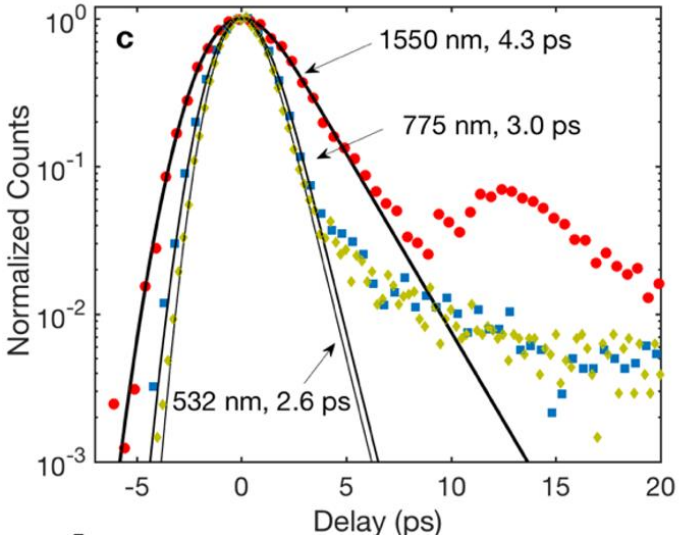
$$\sigma_T = \frac{\sigma_V}{\text{Slope}}$$

Slower Slew Rate -> Degraded Jitter

Large Inductance -> Slower Slew Rate ($\tau_r = L_k/R_{hotspot}$)

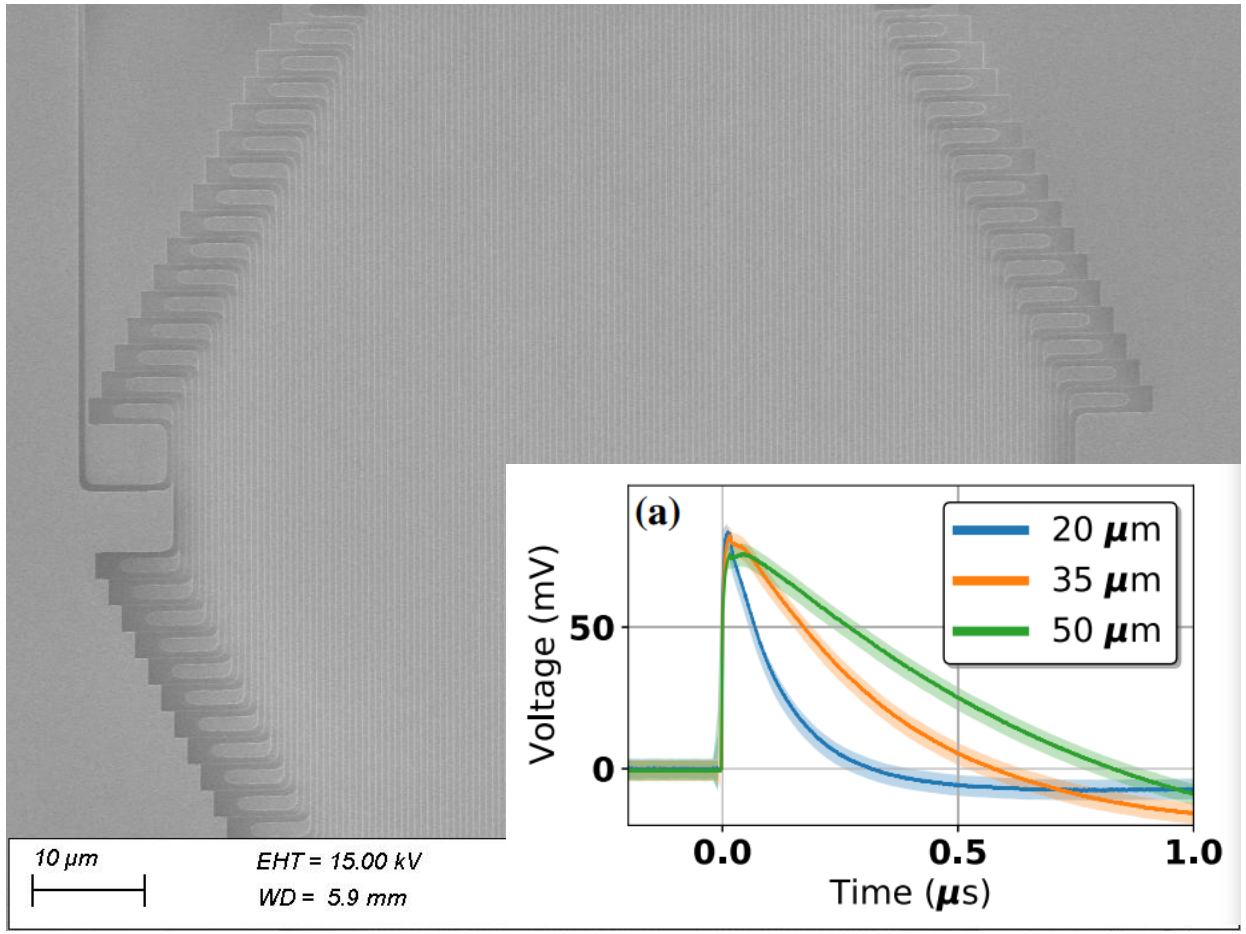
Large Area Detector -> Large Inductance



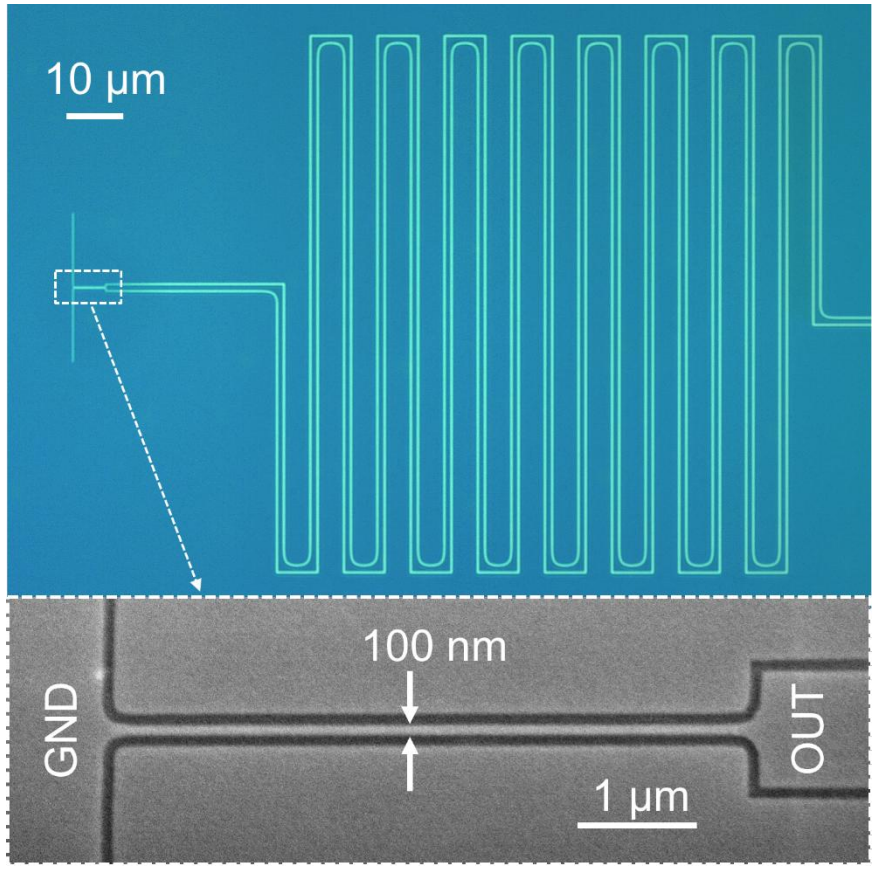


B. Korzh, *Nature Photonics* **14,** 250 (2020)

Speed/Detection Efficiency Tradeoff



D. Reddy, *Optica* **7,** 1649 (2020)

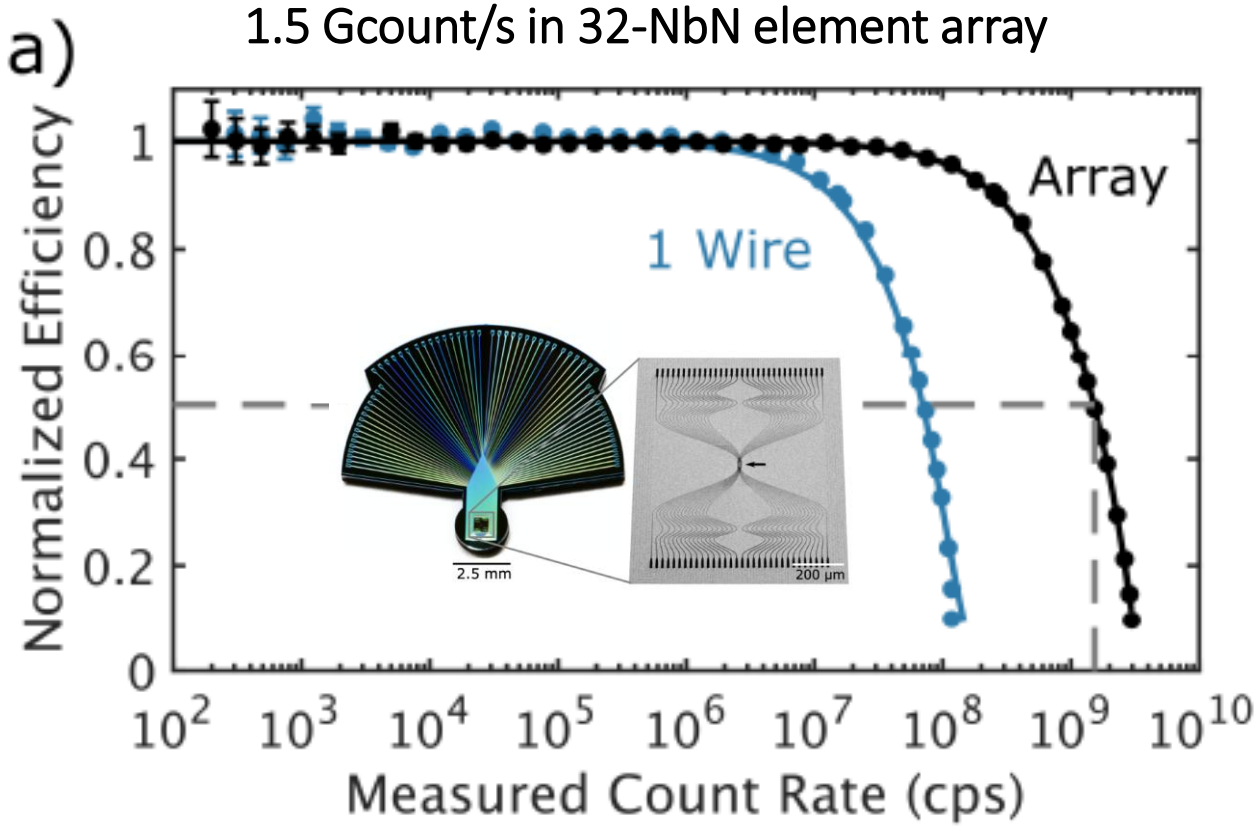


B. Korzh, *Nature Photonics* **14,** 250 (2020)

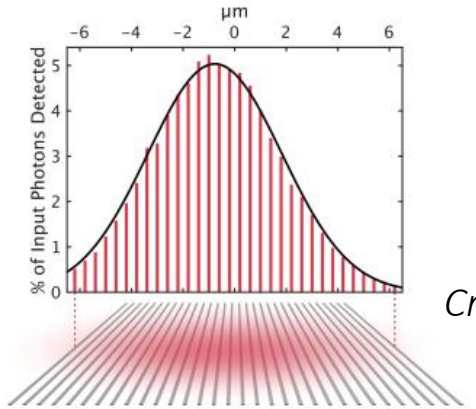
Large active area → High efficiency → High jitter, Low count rate

SNSPD Speed

1.5 Gcount/s in 32-NbN element array



PEACOQ array sampling SMF-28 optical fiber mode



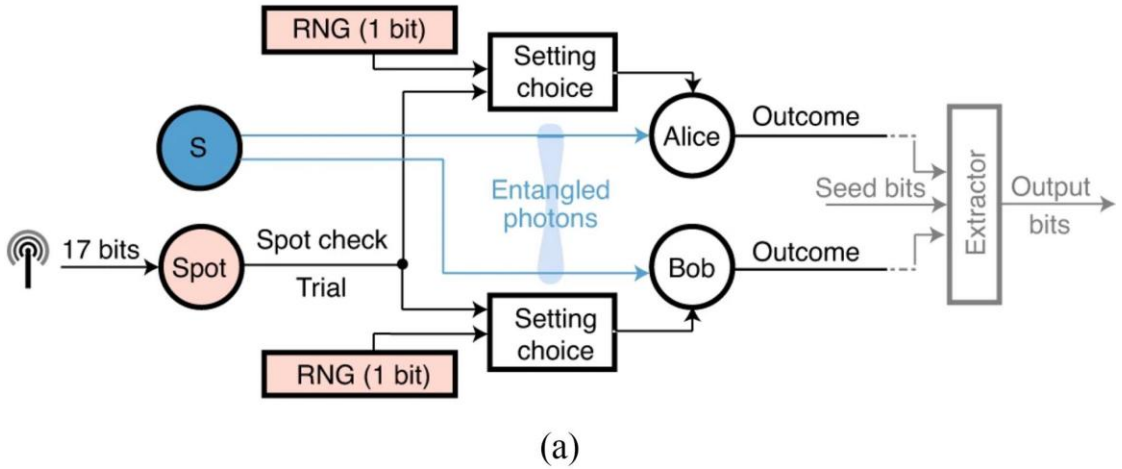
Craiciu et al. (Optica 2023)

- Detection efficiency 78 % at 1550 nm
- Timing jitter < 50 ps FWHM
- Count rate 1.5 Gcount/s
- Dark count rate 158 counts/s

- Maximize count rate using multiple interleaved meanders; SNAP parallel readout
- Thermal relaxation of the hotspot: amorphous films (WSi, MoSi) ~10-20 ns ; NbTiN ~3 ns

Quantum-Certified Random Number Generation

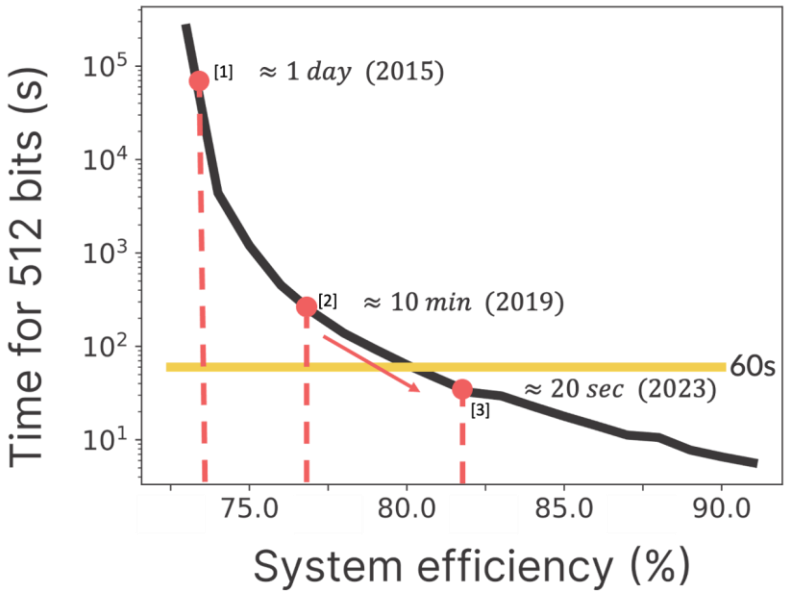
Randomness generation based on setup used in the loophole-free Bell violation experiment



(a)

Shalm, L.K *et al. Nat. Phys.* **17**, 452–456 (2021)

Kavuri, G.A., *et al. Nature* **642**, 916–921 (2025)



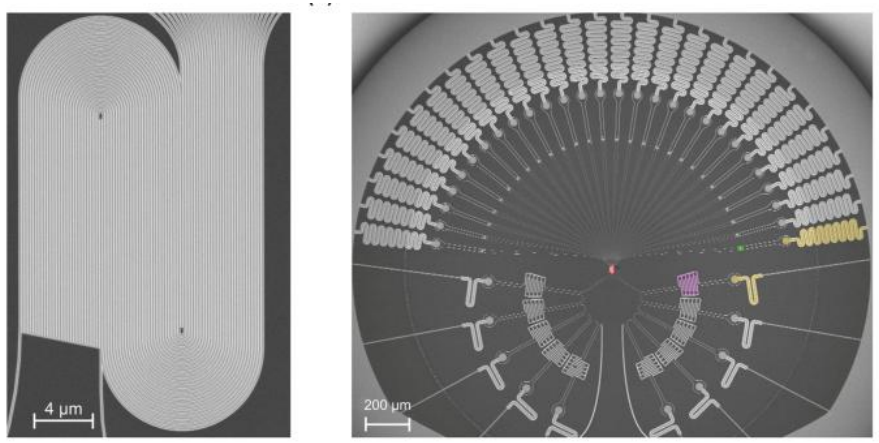
SNSPD QE ~ 98%
System entangled pair-DE ~ 86%

- Measurements satisfy the conditions of a Bell test: the resulting bits are proven to be fundamentally random by Quantum mechanics
- Photon pair rate is kept low (PNR may reduce error rate slightly :limit double pair generation)
- Faster detectors : higher source rates (GHz)

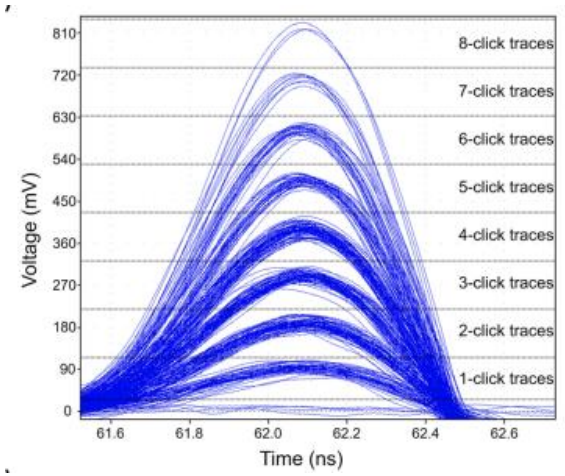
Quasi-Photon-Number Resolution

- Spatially multiplexed threshold detectors
- Approaches perfect PNR when the number of detectors is much larger than the number of photons

Parallel-SNSPD Architecture



Fast PNR discrimination up to 8 photons

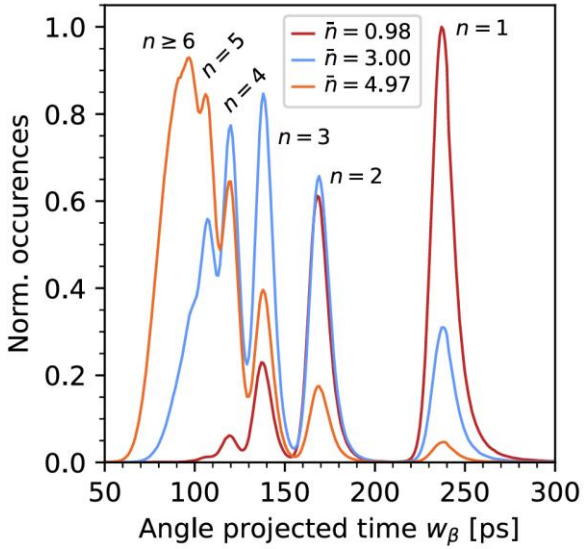


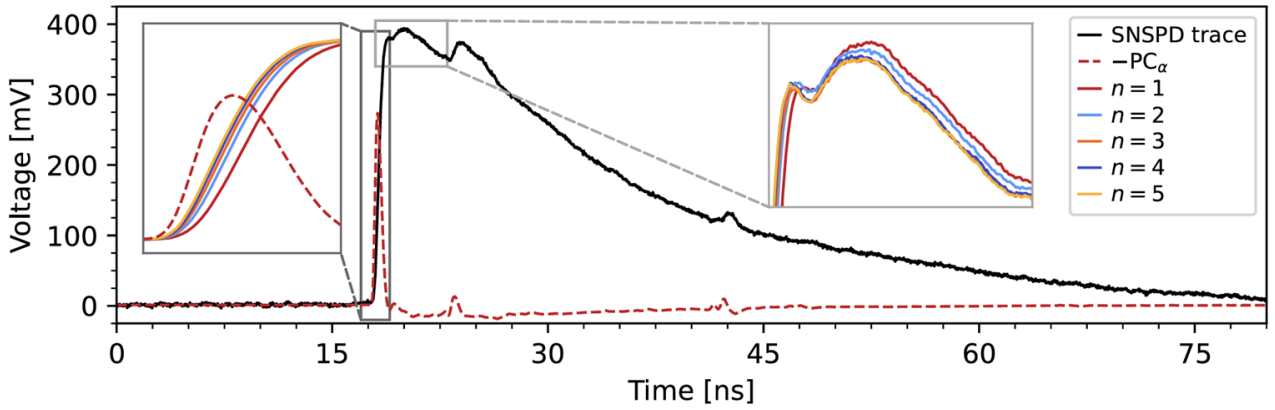
SDE at 1550 nm :
1-photon efficiency 88%
2-photon efficiency 75%
3-photon efficiency 62%
timing jitter < 80 ps
Speed 200 Mcps

Stasi L. et al., : ACS Photonics 2025, 12, 320−329

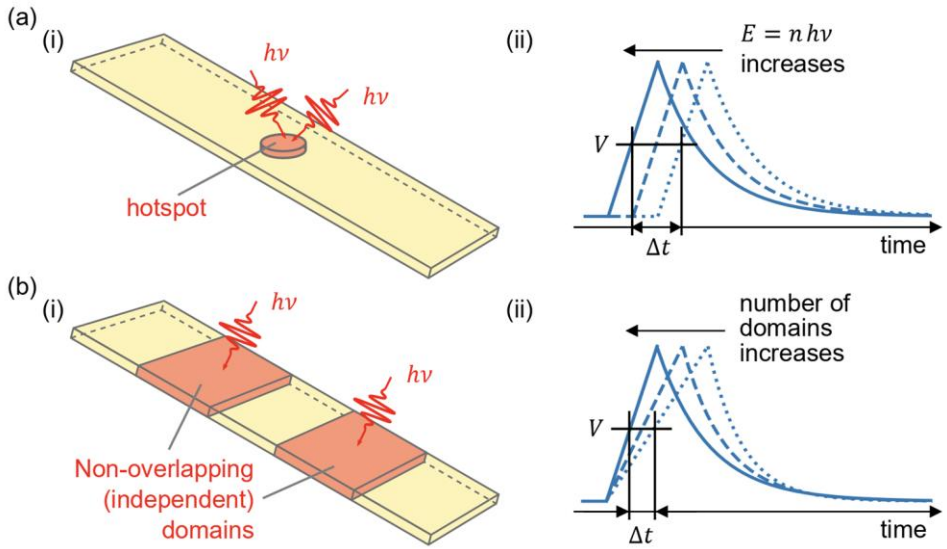
Photon-number resolution with SNSPSs

- Pulse rising edge and amplitude contains PNR information
- Unambiguous discrimination between one- and two-photon events





Schapeler T. et al., Phys. Rev. Applied 22, 014024 (2024)

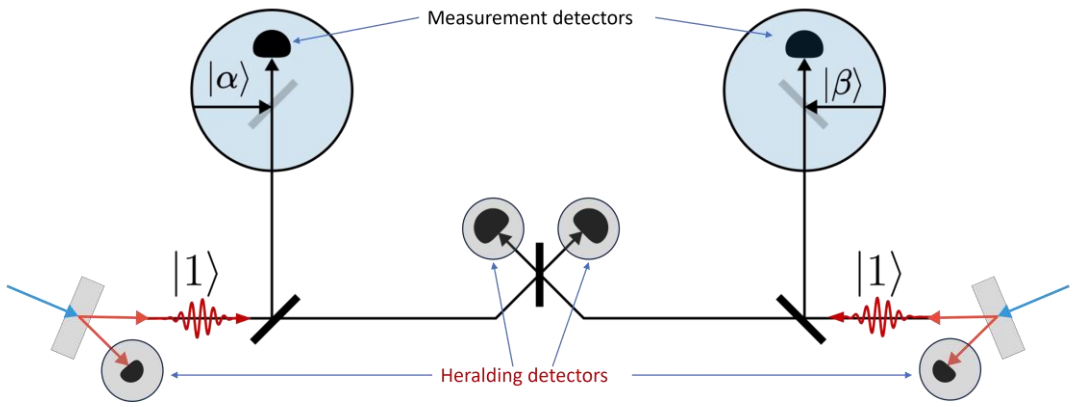


Sidorova M. et al., APL Photon. 10, 086113 (2025)

Single-Photon Detectors for Quantum Networking

QN

All-photonic path entanglement swapping

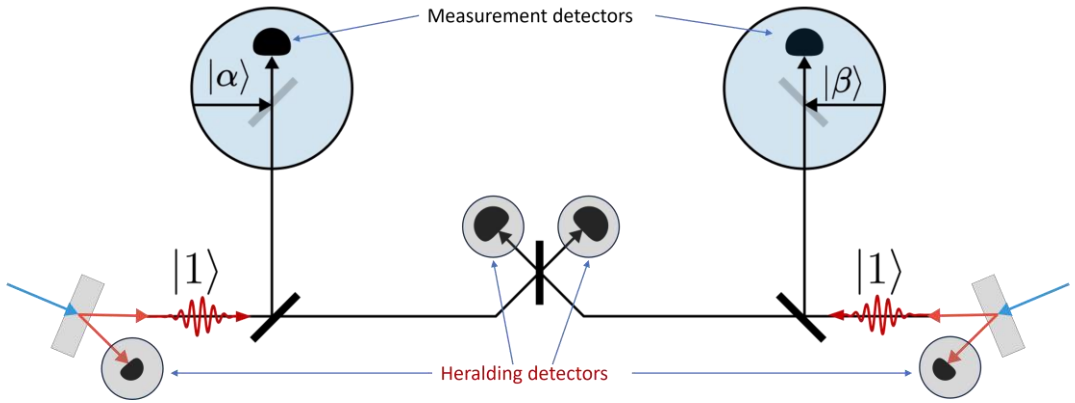


- Quantum communication protocol that entangles two independent photons that have never interacted, using only optical components and measurements
- Requires precise synchronization between pulses and so timing jitter can be a major limitation for distributing entangled photons

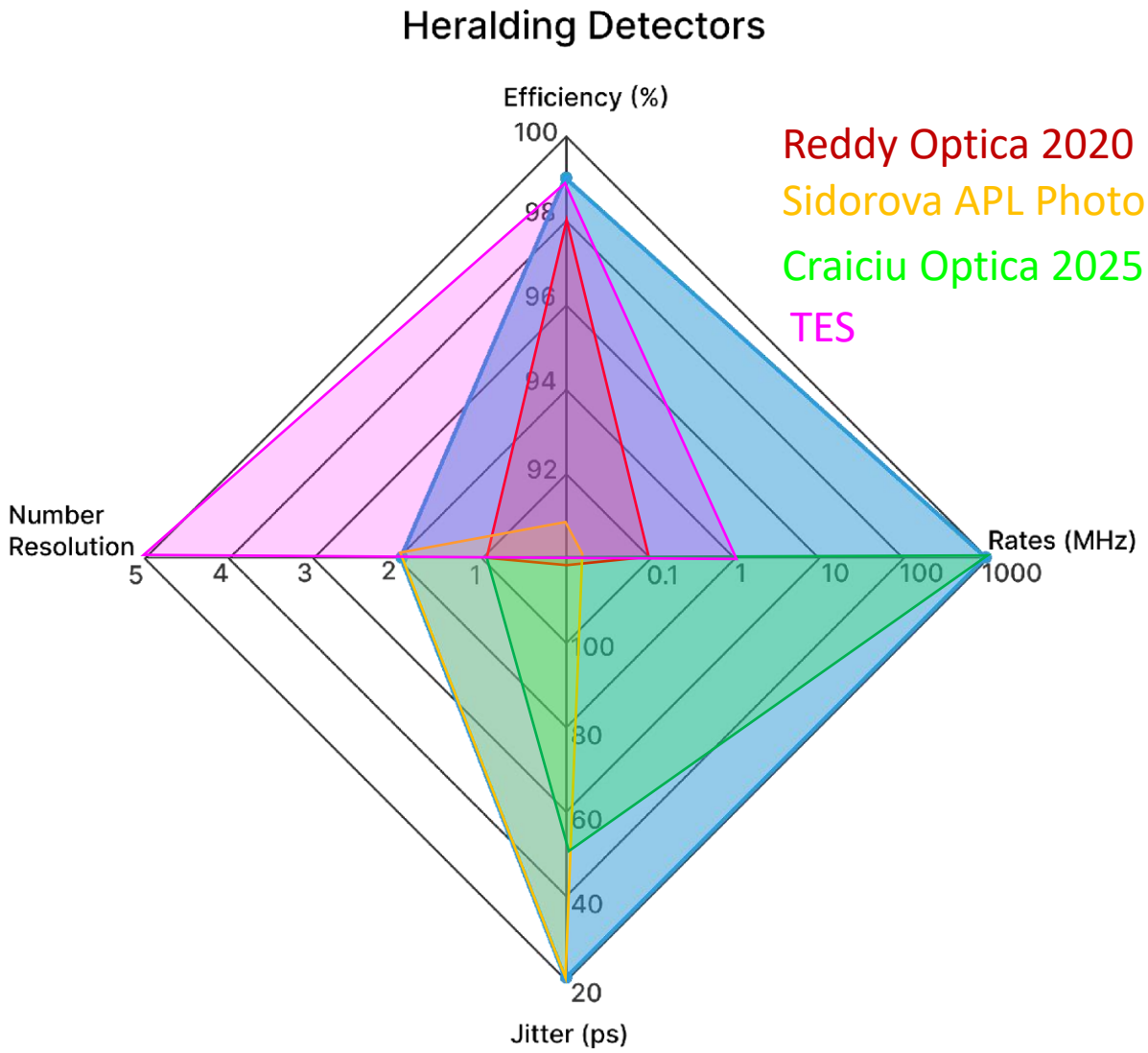
K. Shalm , MJ Stevens NIST

Single-Photon Detectors for Quantum Networking

All-photonic path entanglement swapping

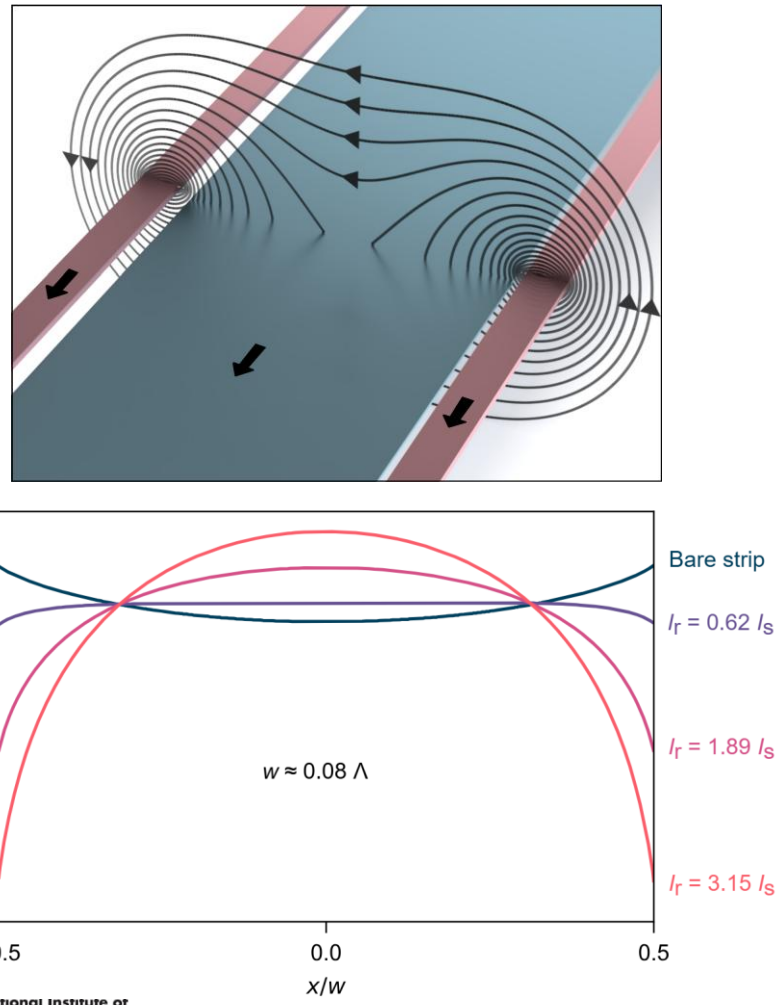


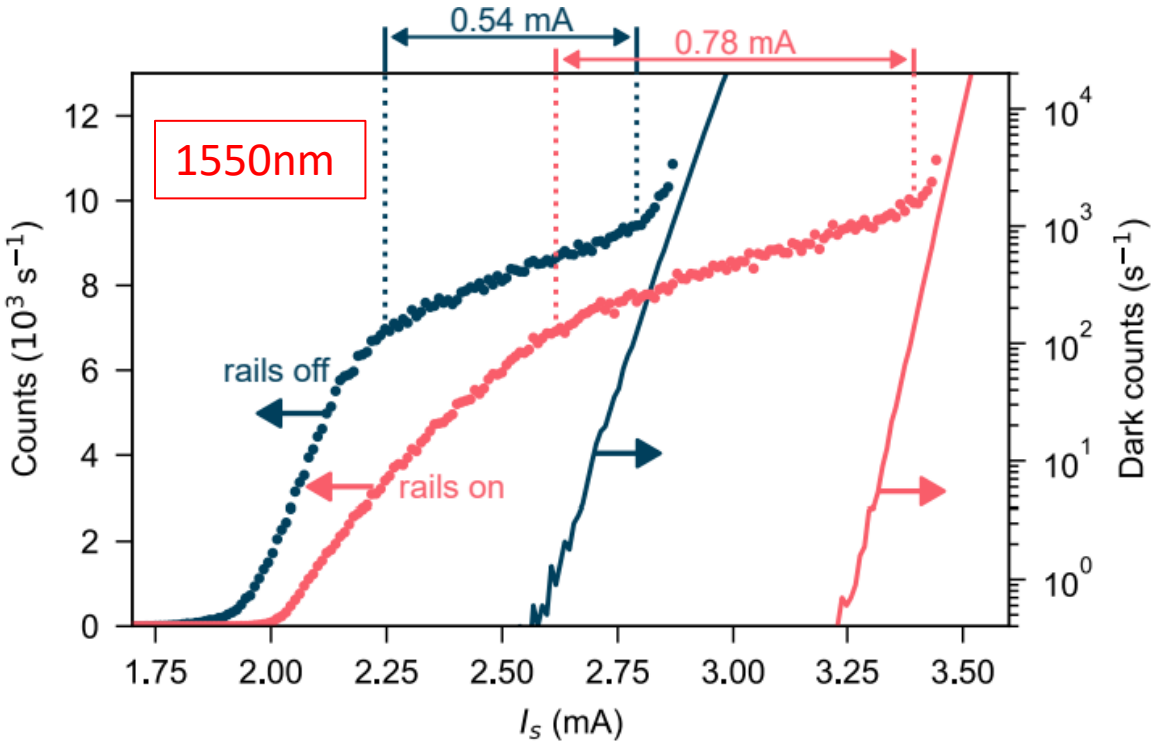
K. Shalm , MJ Stevens NIST



SNSPD Wide Wires

First demonstration of ***0.1mm***-wide SNSPD!
SNSPD-rail architecture pushes the detector to its performance limit

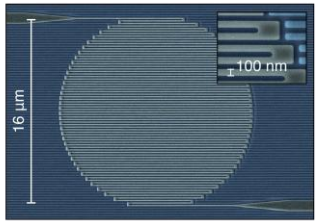


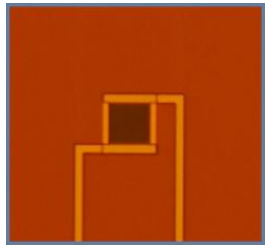


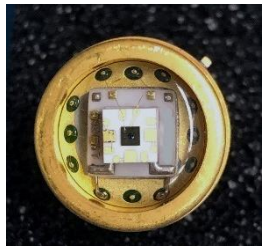
Parzuchowski, Kristen M., et al. *arXiv:2601.15971* (2026).

- Plateau length extended by **> 40%**
- Dark counts reduced by **10^{10}**

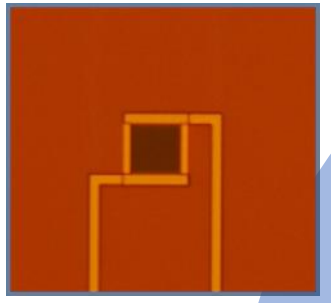
Single-Photon Detectors







	SNSPD	TES	SPAD	PMT
Efficiency	≥ 98 %	≥ 98 %	85 % Si	≤ 40 %
Energy Resolution	Some	Yes	Some	Yes
Recovery Time	10 ns	200 ns	10 ns	50 ns
Timing Jitter	< 10 ps	4 ns	20 ps	50 ps
Dark Counts	< 1 cnt/day	< 1 cnt/day	< 100 cps	< 200 cps
Wavelength Range	UV-MIR	UV-NIR	UV-NIR	UV-VIS
Operating Temperature	1-4 K	100 mK	RT	RT



Best photon number resolution

Energy resolution < 0.1 eV

Very cold (0.1 K)

TES

Fast (ns)

Complex readout

Modest arrays

≥ 98% Efficiency

Near zero dark counts

UV-VIS-IR

Some photon number resolution

No energy resolution

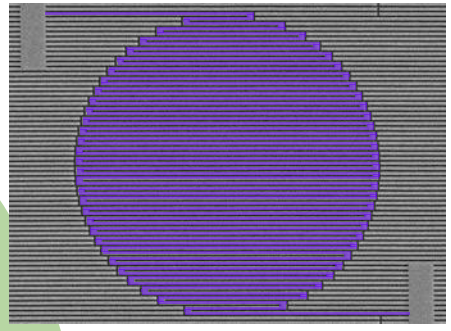
SNSPD

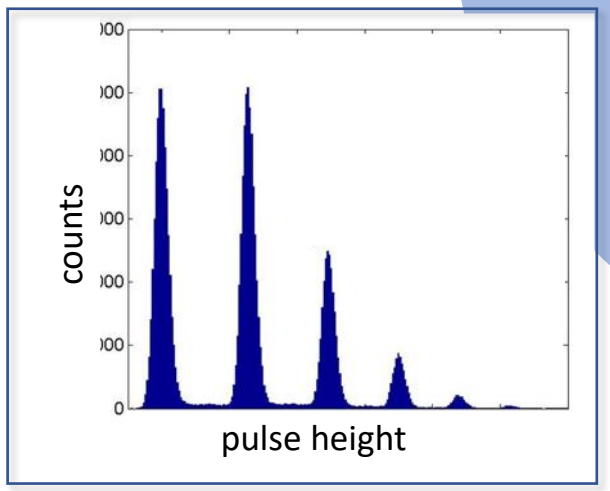
Cold (1-4 K)

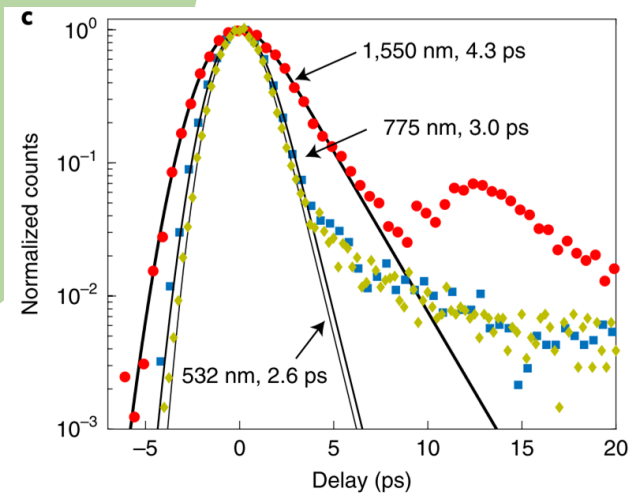
Very Fast (ps)

Simple readout

Large arrays

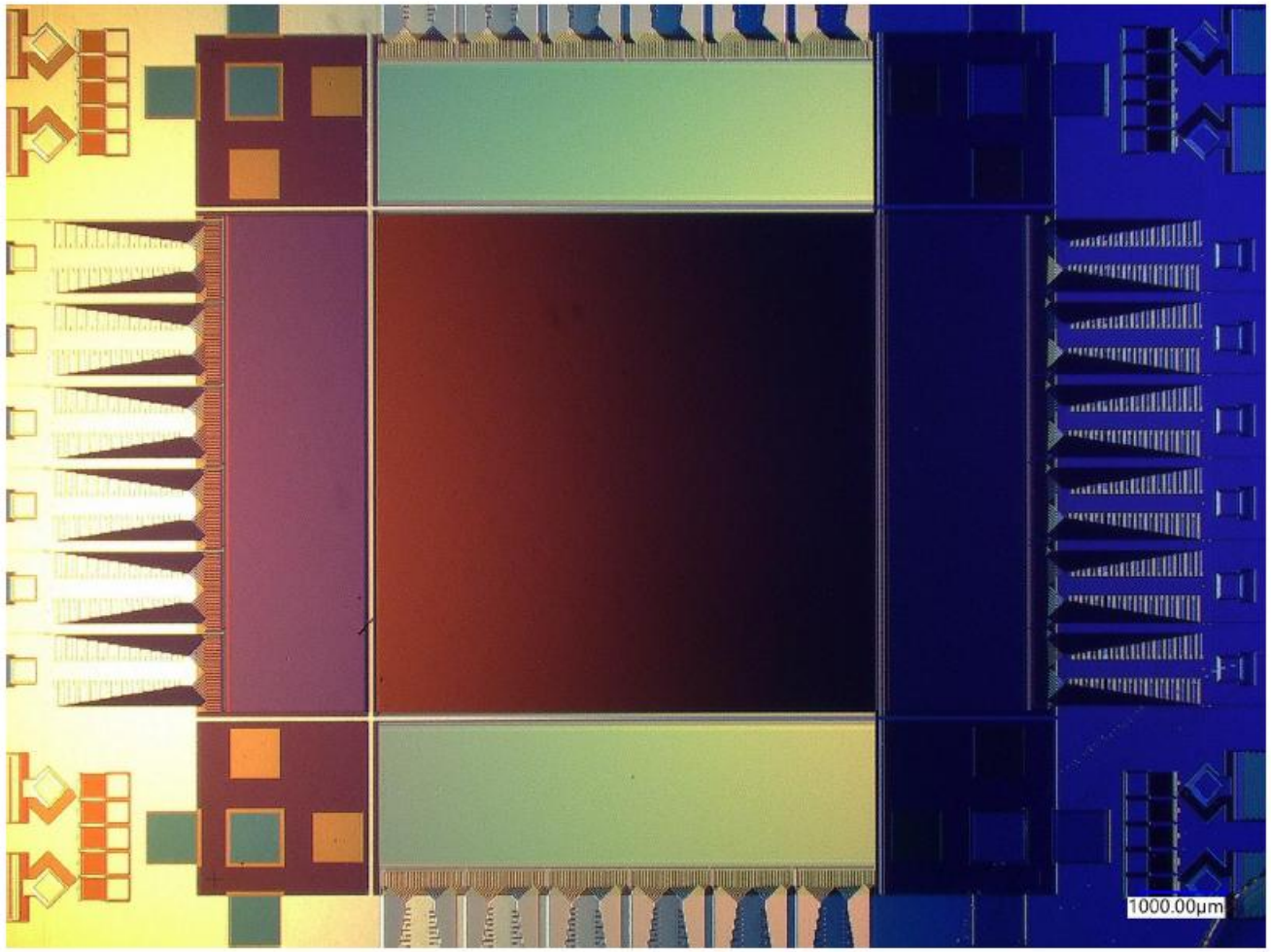




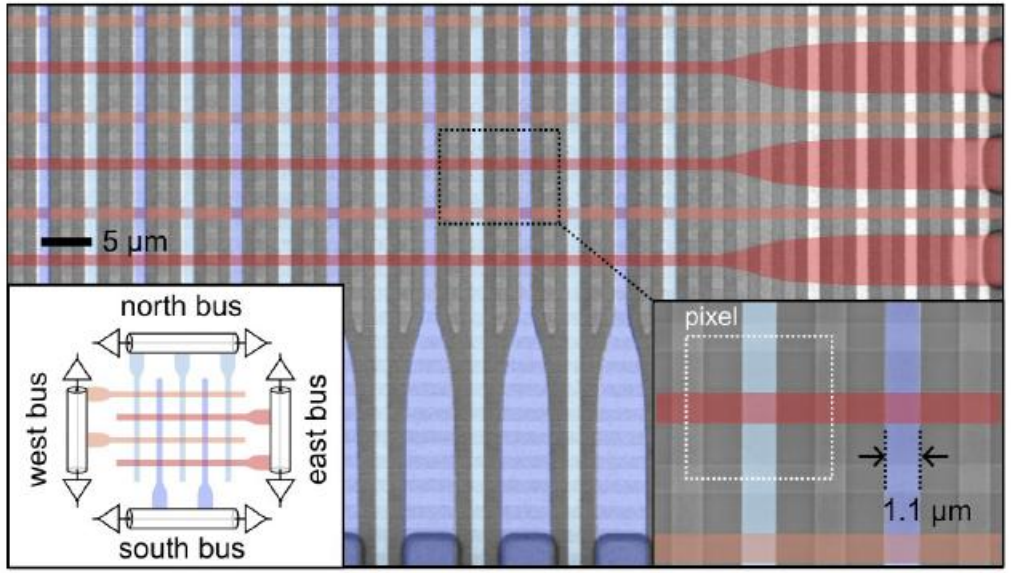


Faint Photonics & Quantum Nanophotonics

0.4 Megapixel SNSPD camera for Vis and Near-IR Imaging



- Array size: 800 x 500
- Active area: 4mm x 2.5mm
  - Pixel size: 5µm x 5µm
- Requires 8 coax
- Operated @ T = 0.8 K
- 0.13 cps dark counts across whole array



B.G. Oripov et al., *Nature* 622, 730–734 (2023).