Superconducting Nanowire Single Photon Detector Arrays

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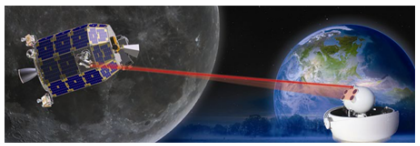
Superconducting nanowire single photon detector (SNSPD) arrays - applications

- spectroscopy from the visible to mid-infrared
- spatial imaging at the single-photon level
- "photon-starved" communications



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WSi SNSPDs at NIST/JPL

Why is WSi an ideal material for SNSPD arrays?

	$a\text{-}W_xSi_{1-x}$	NbN or NbTiN
Application	SNSPDs	Superconducting electronics/SNSPDs
Bulk T_c	5 K	16 K
Dep. method	(Co)sputtering	Reactive sputtering
Dep. temperature	RT	RT-800 °C
Structure	Amorphous	Polycrystalline
Substrate	*Thermal/PECVD SiO_2, HSQ, Si*	$MgO/Al_2O_3/Si/SiO_2$
Nanowire Width	*150-200 nm*	50-100 nm
Yield	*~70% (with >85% SDE)*	Dependent on substrate/film quality

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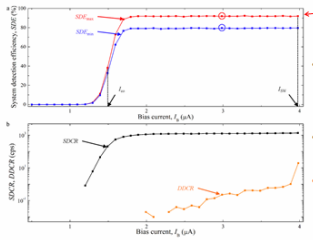
High System Detection Efficiency (SDE) with WSi SNSPDs



93.2 ± 0.4%

- Highest system detection efficiency 93.2 ± 0.4%, consistently > 85%
- Dark count rates ~0.1 cps
- Saturation of SDE over 50% of bias range

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Considerations for the design of large arrays

1. Design of the cryogenic system
   - For an NxN array, N^2 coaxial cables or superconducting combiner circuit such as SFQ logic
2. High SNSPD yield
3. High system detection efficiency

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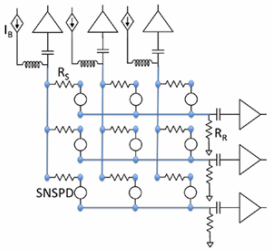
Row-Column Readout Scheme

- reduces number of coax from N^2 to 2N
- N column bias/readout lines
- N row readout lines



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Row-Column Readout Scheme

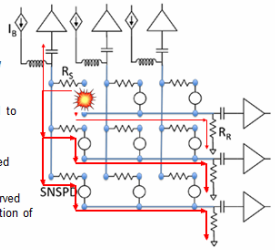
Bias current I_B supplies current to all N pixels in a column.

Current flows through series resistor R_S at each pixel, then to ground through a row resistor R_R

Photon detection at pixel causes current to be diverted to column readout (positive voltage pulse)

Some leakage current diverted to other pixels in the column

Negative voltage pulse observed at row amplifier due to reduction of current through R_R



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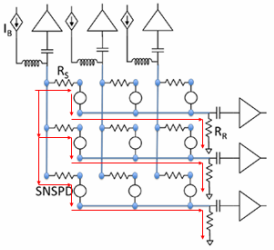
Row-Column Readout Scheme

Current returns to equilibrium in all three pixels due to the series resistor R_S



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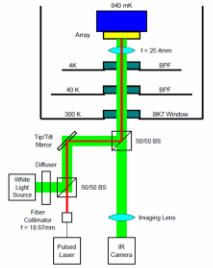
Free Space Coupling



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Photon Count Rate

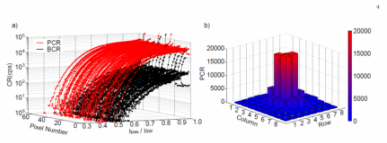

FIG. 4. a) PCR and BCR for all 64 pixels as a function of bias current applied to all 8 rows simultaneously. b) Beam image with the rows biased at $I_{bias} = 0.92I_{SW}$ showing the spatial resolution capabilities of the array and readout.

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Experimental Results – 4 pixel WSi SNSPD array

Averaged pulses from each amplifier

North row output (black trace)

South row output (red trace)

East column output (blue trace)

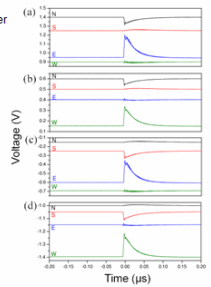
West column output (green trace)

(a) Photon detection on the SNSPD in the NE quadrant

(b) NW quadrant

(c) SE quadrant

(d) SW quadrant



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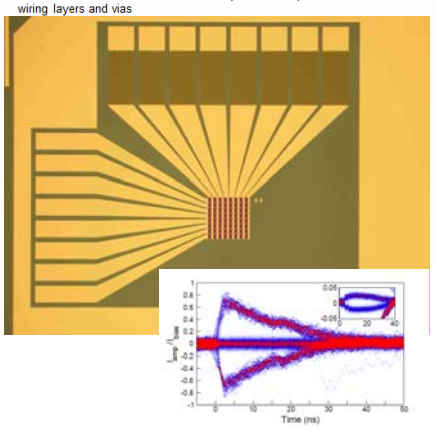
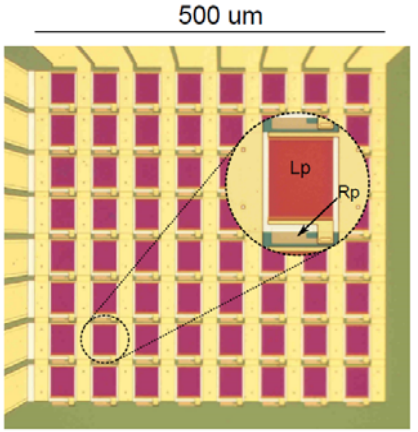
Scaling up the number of pixels

This scheme is scalable, but for N>2 requires the implementation of two wiring layers and vias