High-efficiency UV SNSPDs from Amorphous MoSi

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June 8, 2016

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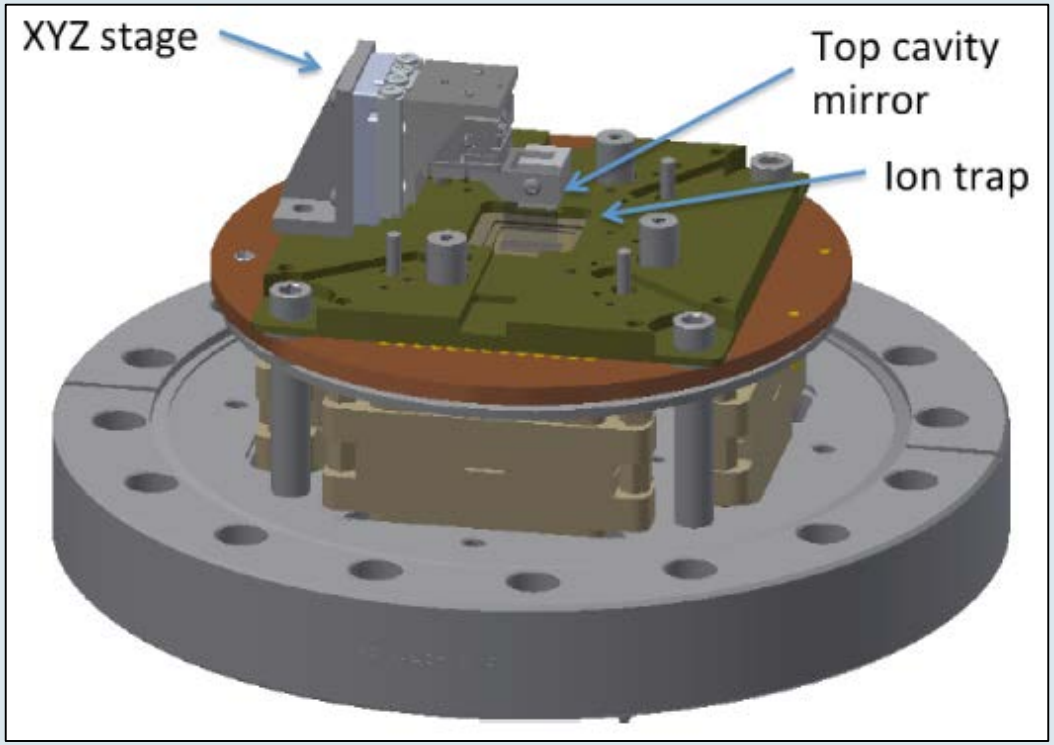
EPICS
(Extreme-Performance Ion trap-Cavity System)

Collaboration between Duke, Sandia, Jet Propulsion Laboratory, and NIST



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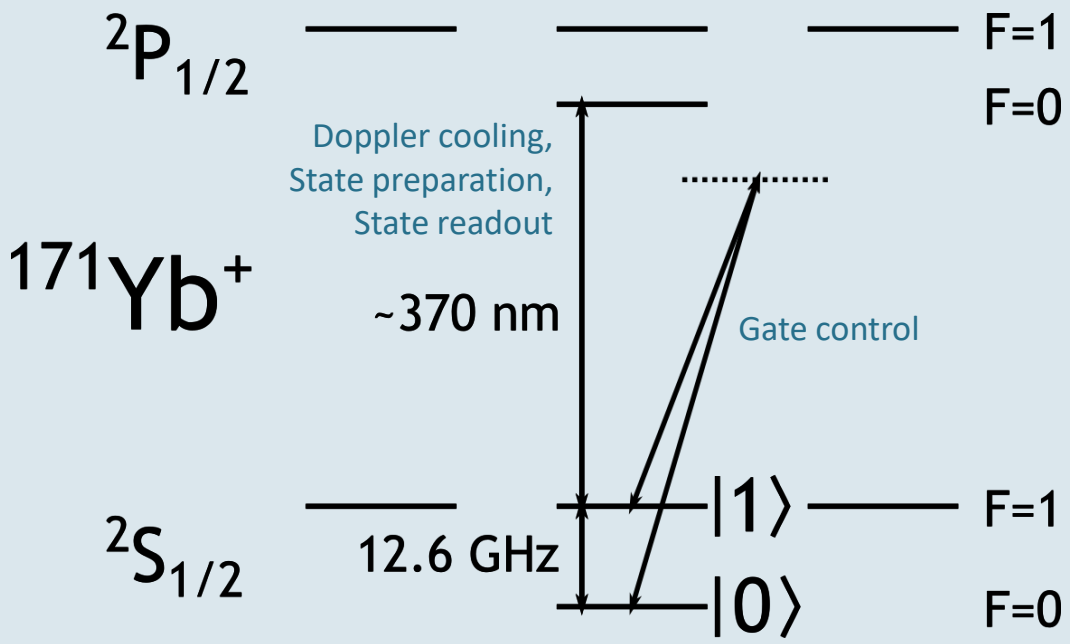
Hyperfine ion qubits



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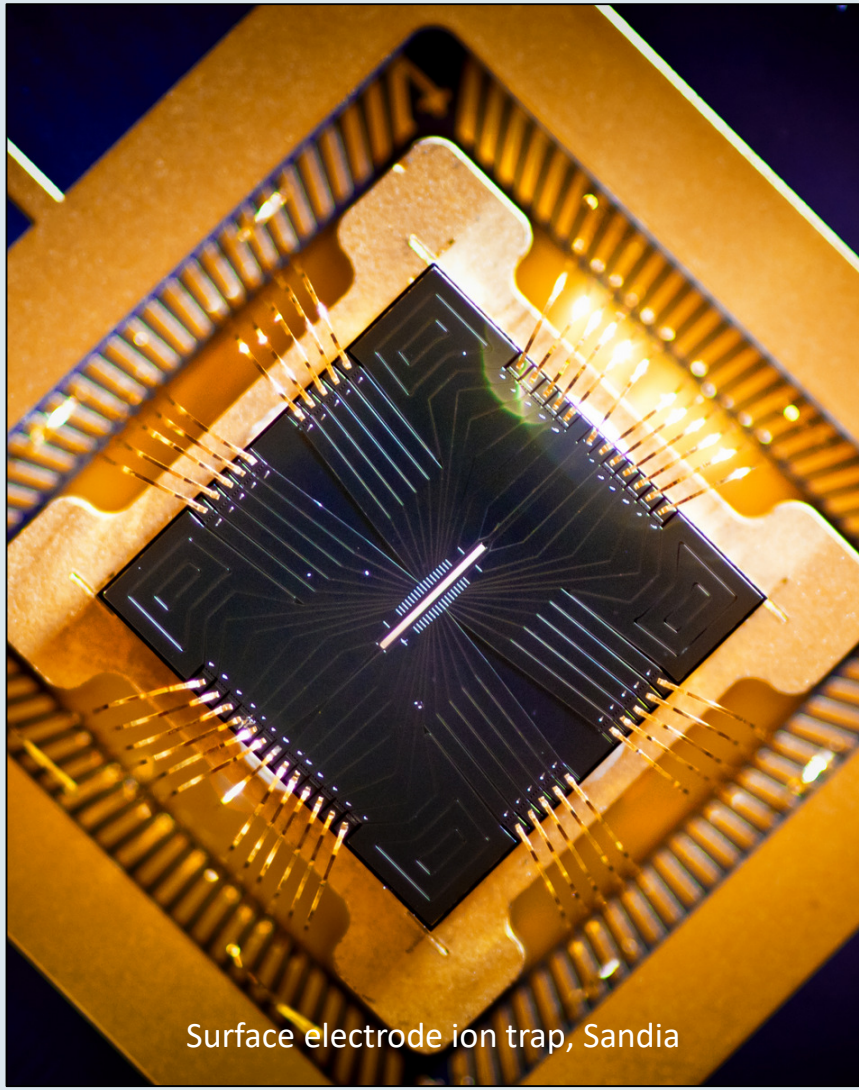
Trapped ion qubits

- Ion-based quantum computing frameworks have long coherence times and high gate/readout fidelities.
- Slow gates and readout



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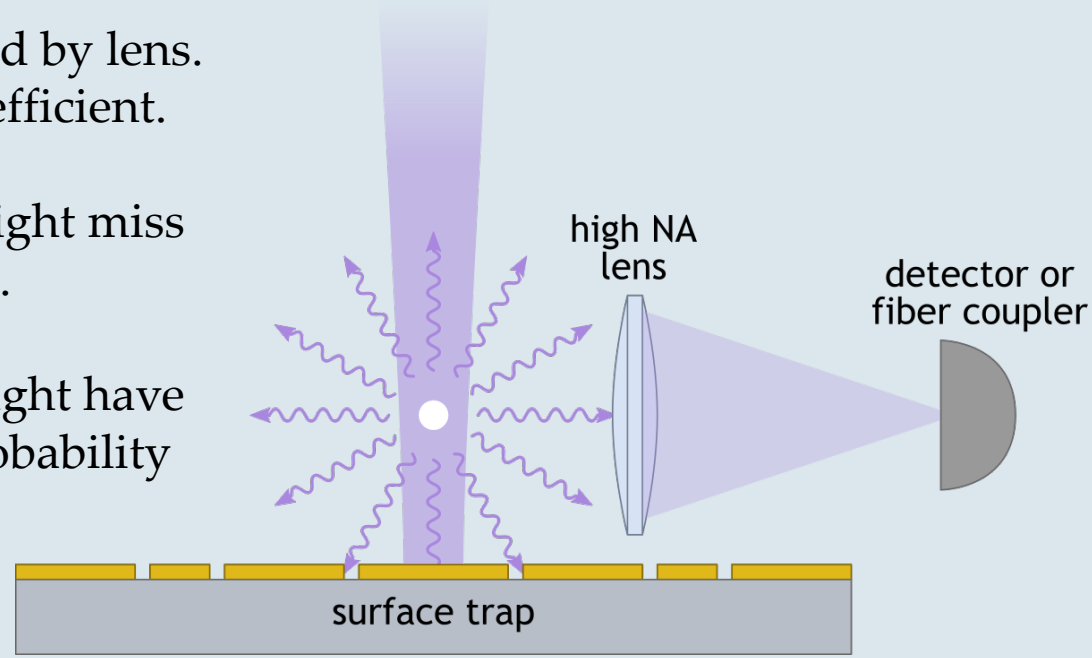
EPICS
(Extreme-Performance Ion trap-Cavity System)

- Measurement time: how long do you have to wait before declaring the qubit in the bright/dark state?
- Only 10% of light collected by lens. Current PMTs are ~ 30% efficient.
- Short integration time: might miss photons from bright state.
- Long integration time: might have dark counts; non-zero probability of state switching.



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Photomultiplier Tubes

Advantages:

- Easy to use
- Large active area (~ 1 cm^2)
- Can be fast (~ 50 ps jitter)

Disadvantages:

- Low quantum efficiency (~30%)
- Large volume
- Dark count rates ~ 50 Hz
  (6 Hz w/ filter)

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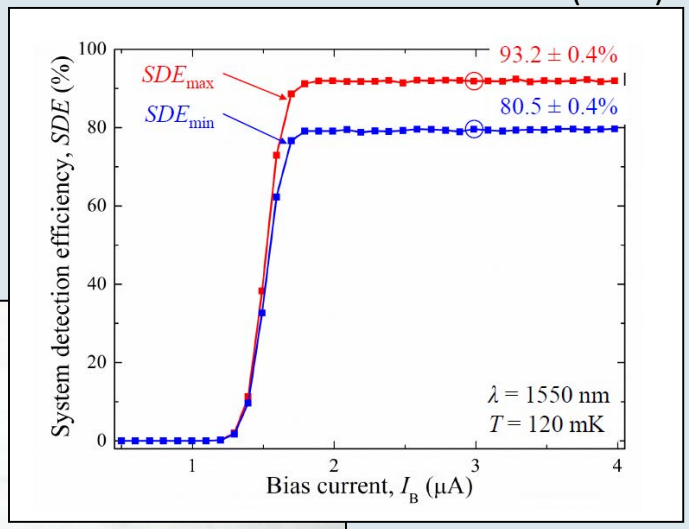
SNSPDs

Marsili et al. (2013)

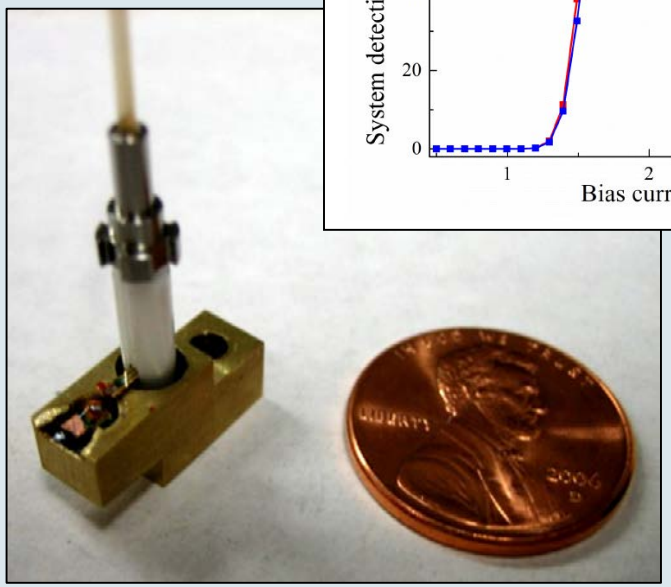


Advantages:

- High detection efficiencies possible (>90%)
- Low jitter (< 100 ps)

Disadvantages:

- Requires low temperatures
- Smaller active area (fiber-coupled)
- Largely uncharacterized below 400 nm



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Why MoSi?

	WSi	MoSi	NbN	MgB2
Bulk Tc	5 K	7 K	16 K	40 K
Compatible w/ optical stack?	Yes	Yes	Somewhat	Not yet
Jitter	~ 150 ps	~ 75 ps	~ 50 ps	~ 50 ps

Three goals: High efficiency, high operating temperature, low dark counts

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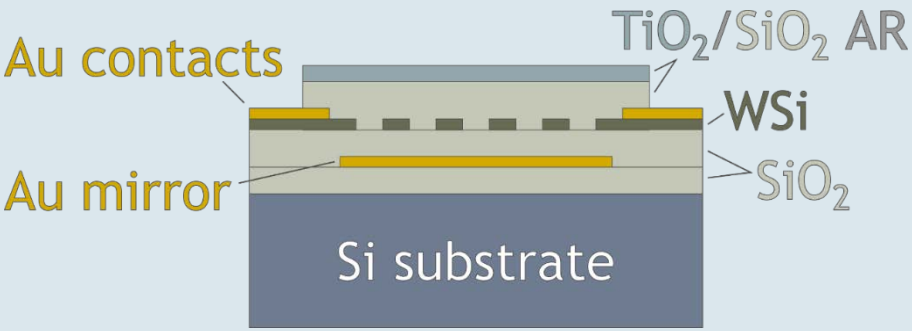
Changes from NIR WSi devices



- WSi devices have a gold back mirror and a TiO2/SiO2 AR coating to make an optical cavity stack.

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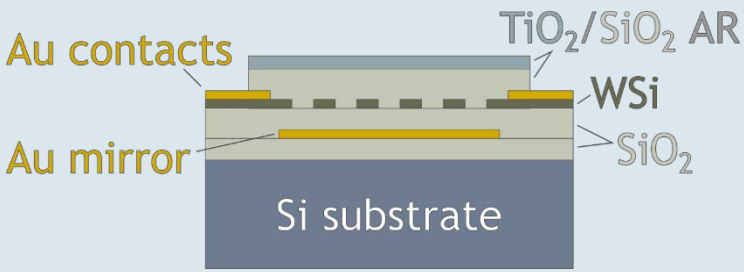
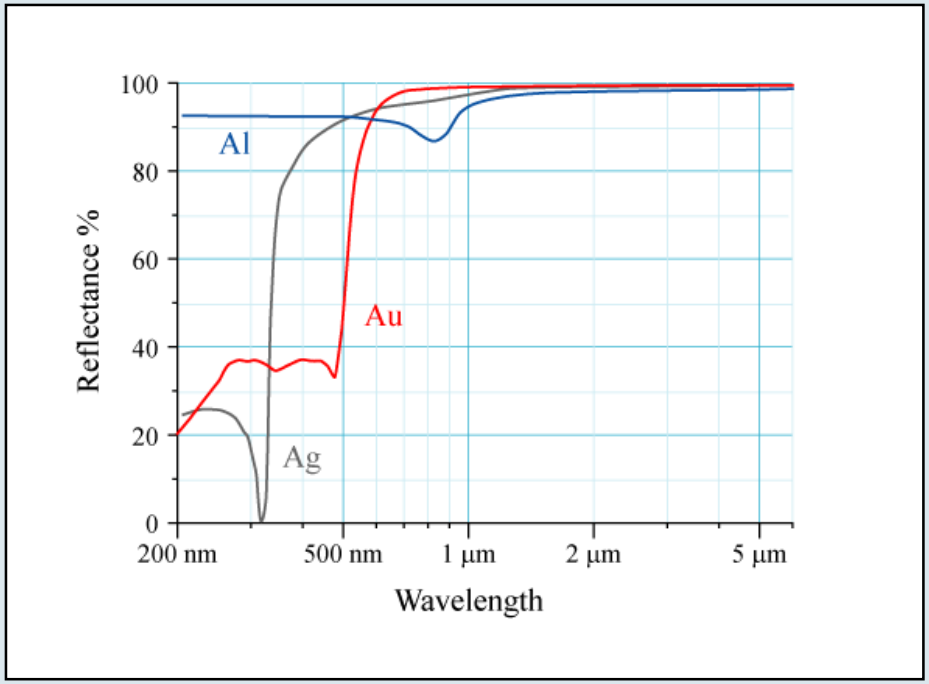
Changes from NIR WSi devices





- WSi devices have a gold back mirror and a TiO2/SiO2 AR coating to make an optical cavity stack.
- Gold is not a good reflector below 400 nm.

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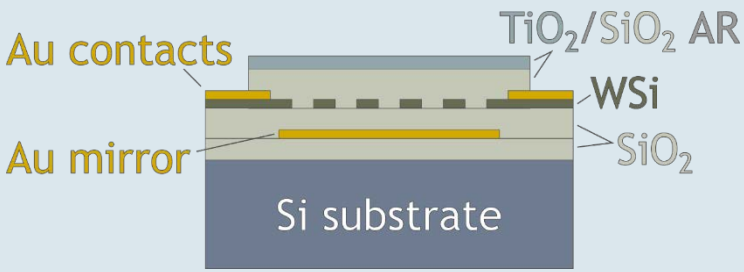
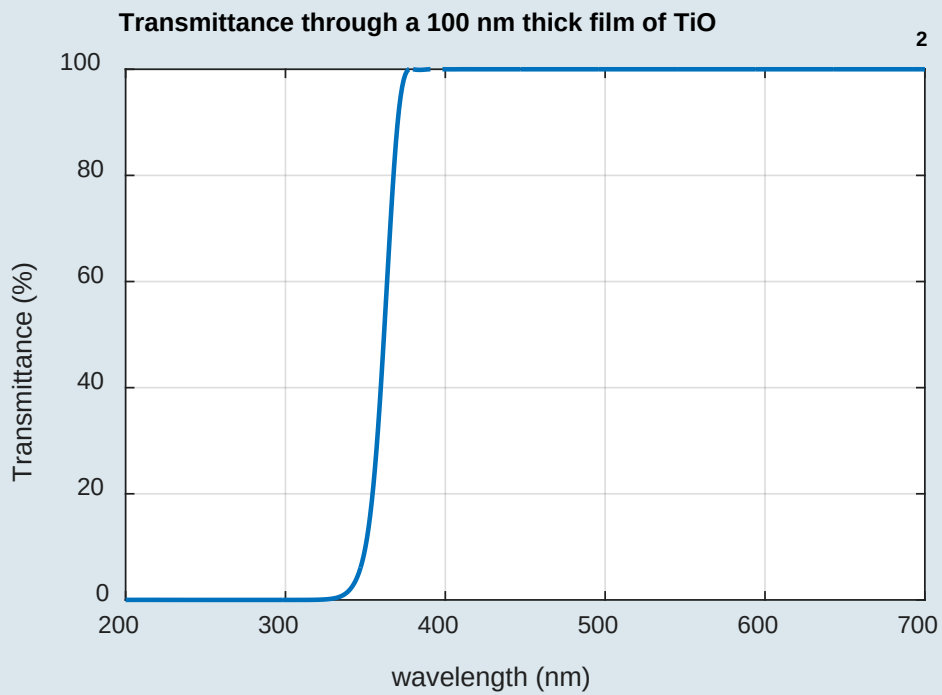
Changes from NIR WSi devices





- WSi devices have a gold back mirror and a TiO2/SiO2 AR coating to make an optical cavity stack.
- Gold is not a good reflector below 400 nm.
- TiO2 does not have good transmission below 400 nm.

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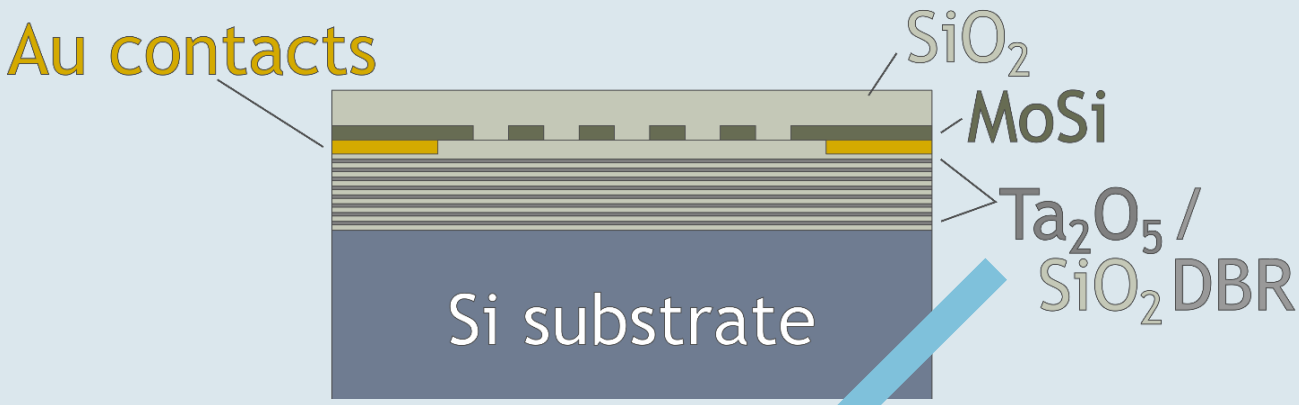
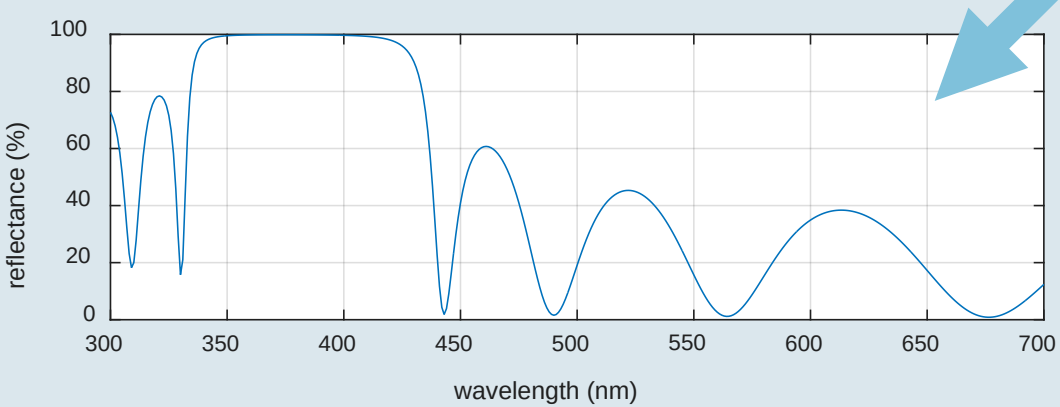
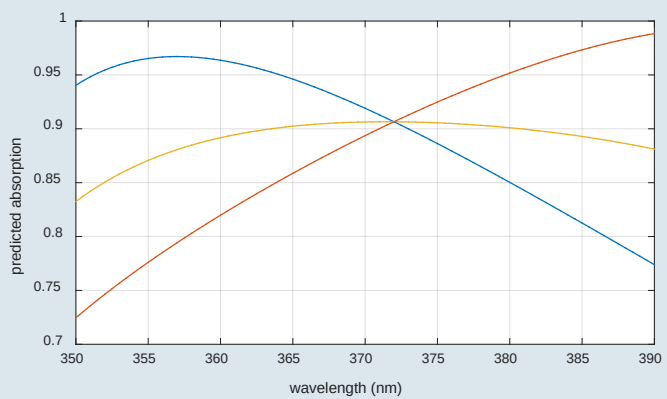
Changes from NIR WSi devices







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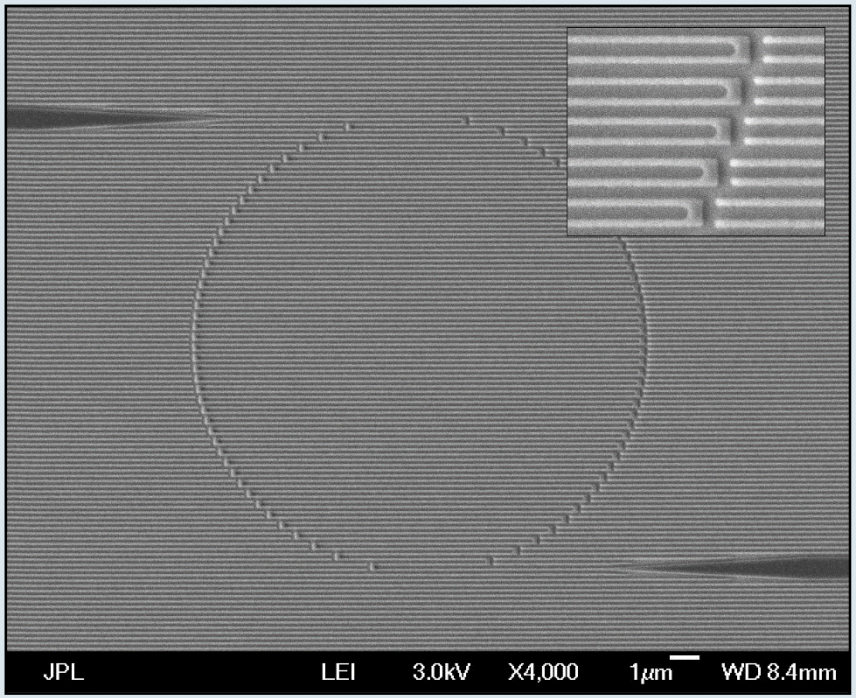
Device geometry

Considerations:

- **Thicker films / wider wires**: higher operating temperatures, lower dark counts, faster, smaller plateau, more likely to latch

- **Smaller pitch**: higher efficiency, less likely to latch, avoids diffraction effects, slower, susceptible to current crowding, more likely to have fabrication difficulties

Tried thicknesses ranging from 9 to 15 nm, wire widths from 60 nm to 160 nm, pitches from 150 nm to 400 nm, and active area diameters between 15 um and 18 um.



Wire width = 70 nm. Wire pitch = 175 nm. ~ 15,000 sq
Active area diameter = 15 um.

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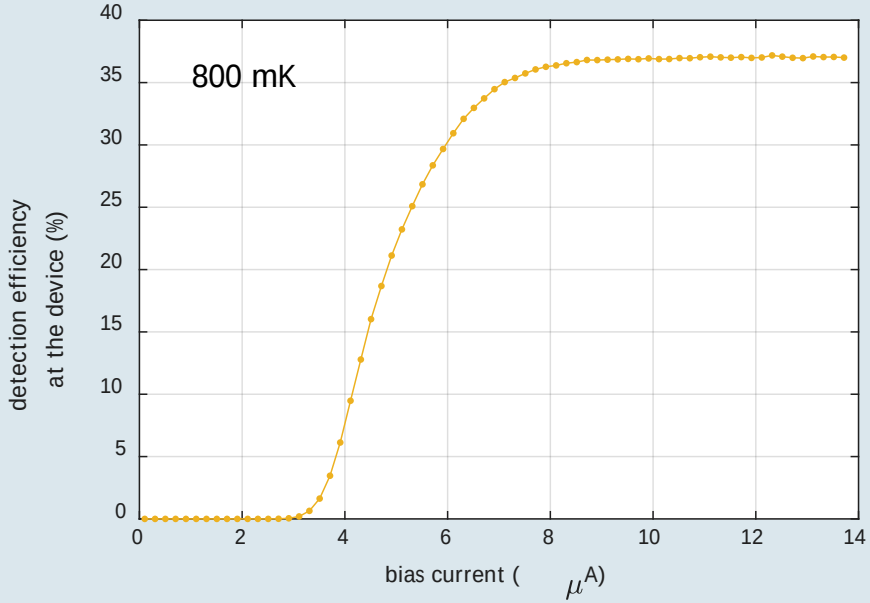
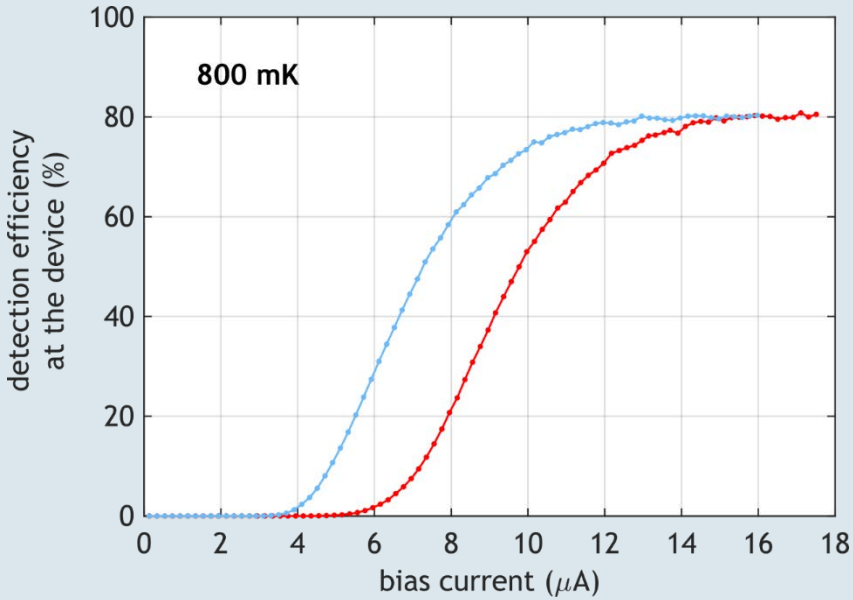
Efficiency

Without dielectric mirror



With dielectric mirror



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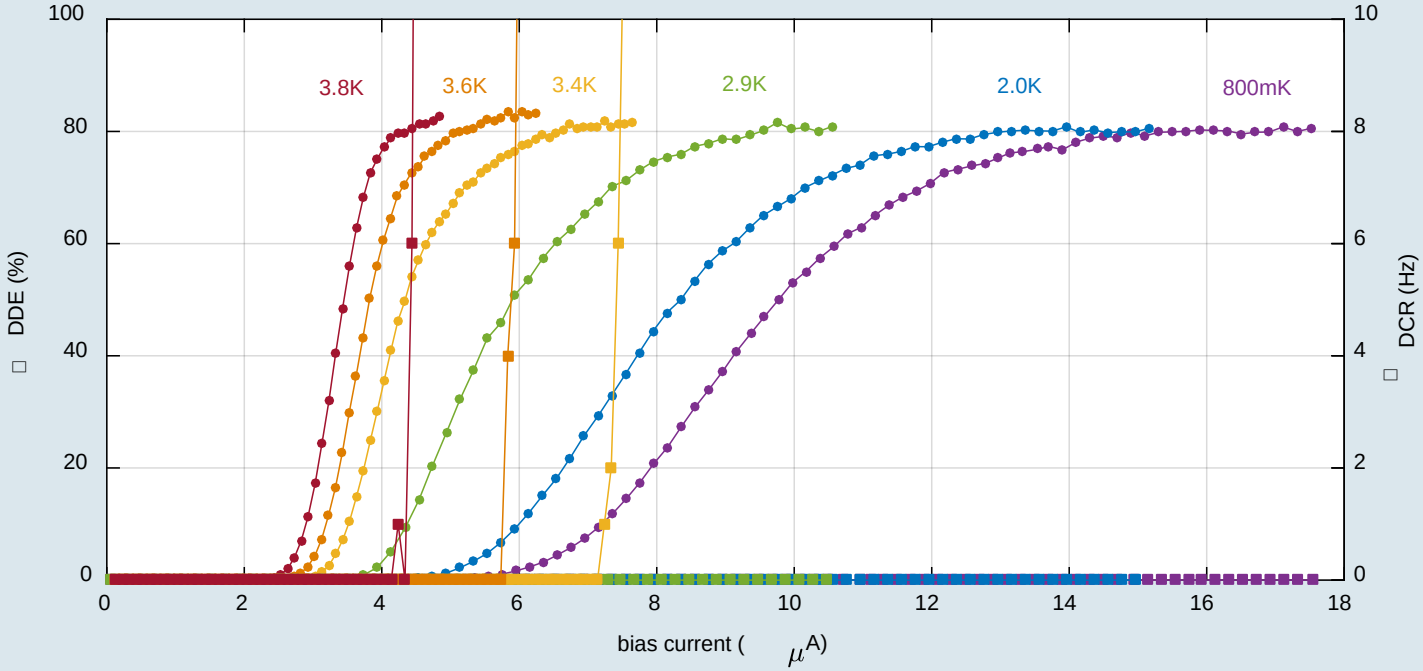
Temperature performance



Dark count rate increases at higher temperatures, limiting useable portion of plateau. At low temperatures, operational DCR < 100 mHz.

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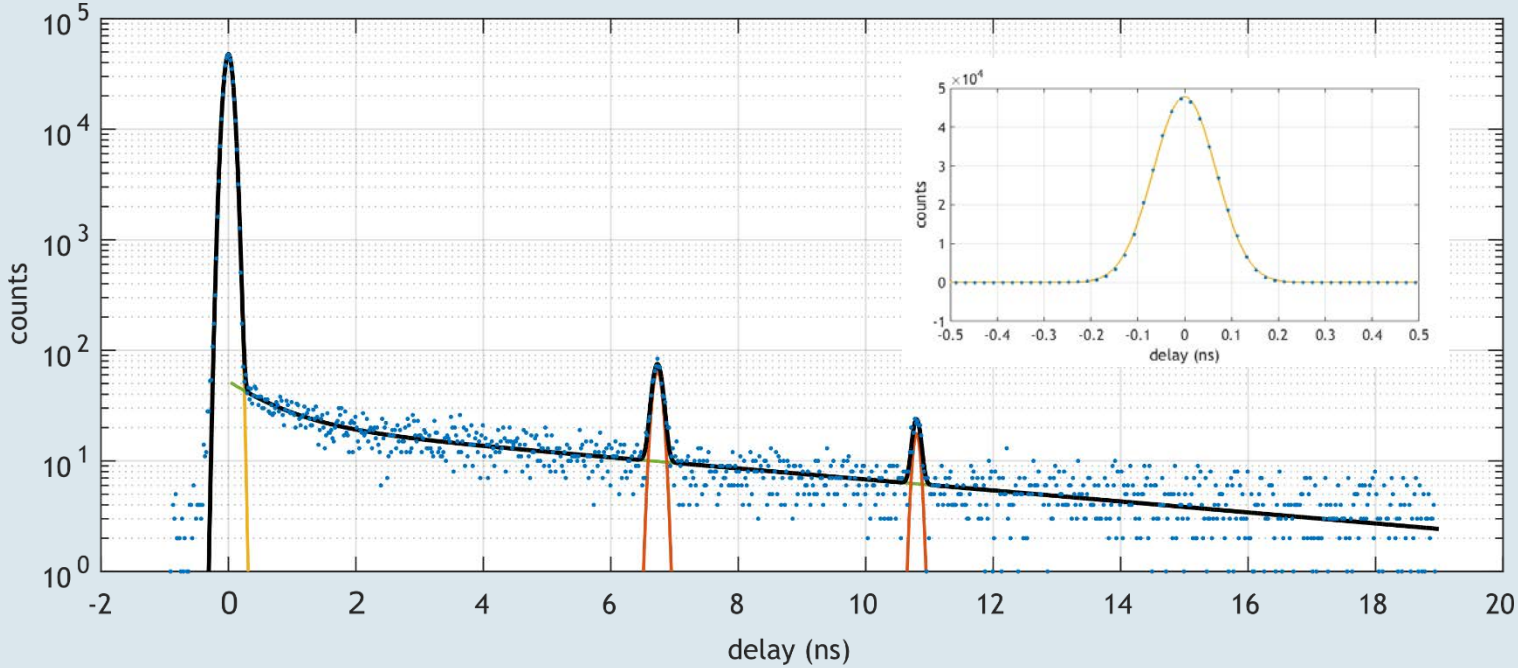
Timing / Fluorescence



Yellow: Gaussian fit to largest feature. Green: double exponential fit to background (excluding reflected pulses). Red: Gaussian fits to reflected pulses. Black: sum of all fits.
The exponential background contributes 2.5% of all counts, and the dominant component has a decay time of 8.7 ns. The reflected pulses contribute 0.2% of all counts.

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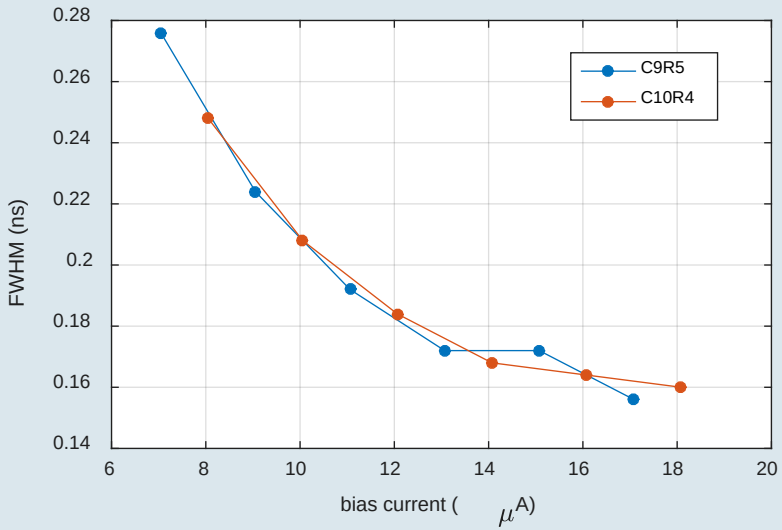
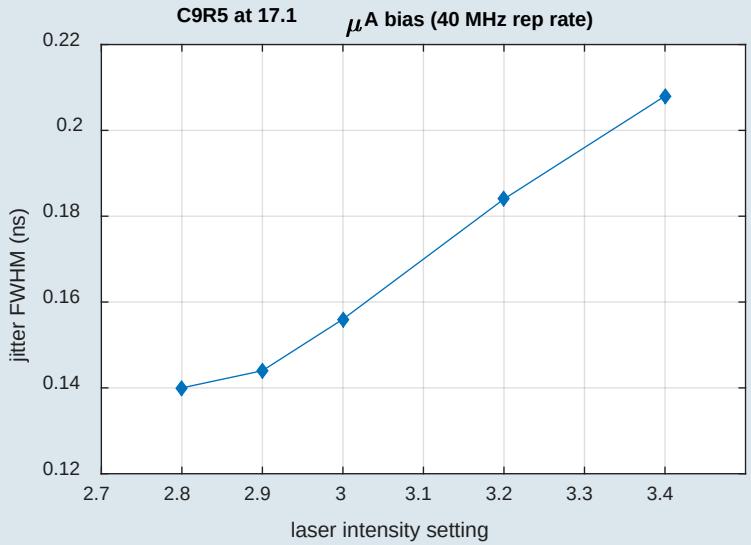
Jitter





Total jitter is > 140 ps and increases with decreasing bias current or increasing laser intensity. Jitter may be limited by bandwidth of multimode fiber – currently integrating single mode fiber for more accurate measurements.

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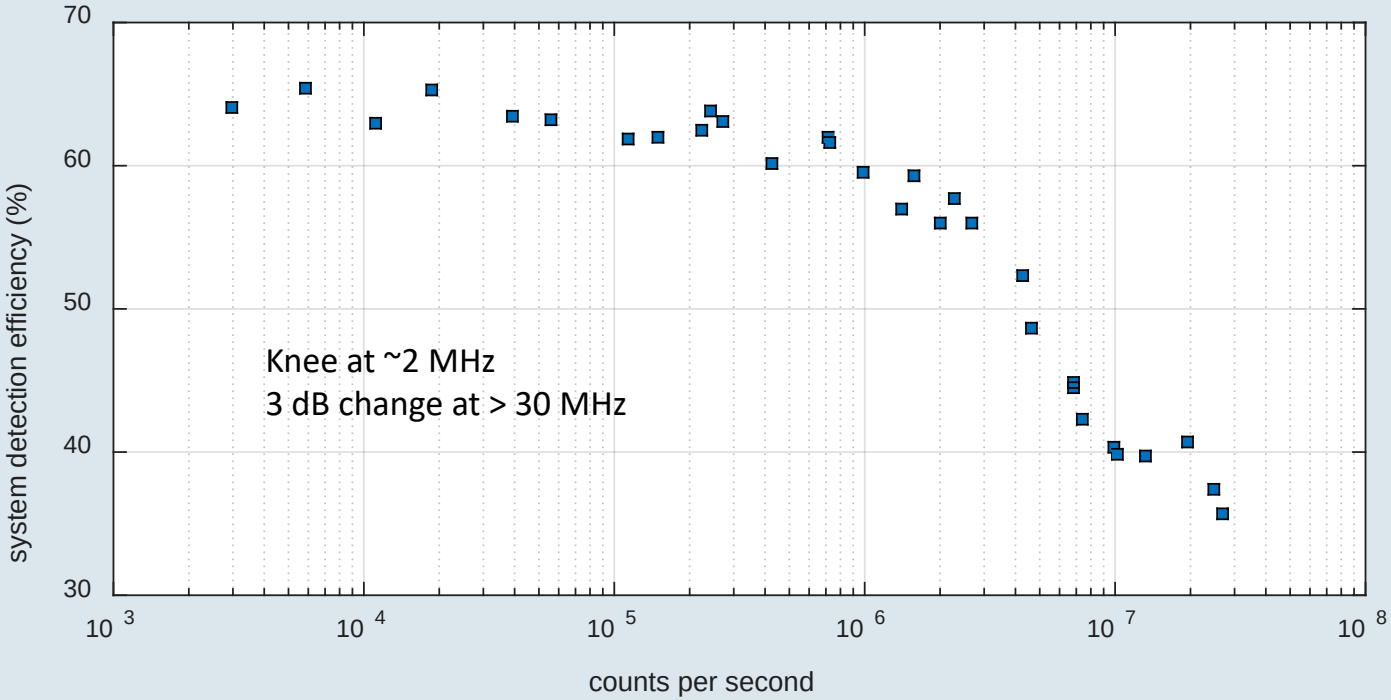
Maximum count rate



70nm x 12nm at 800 mK
Trigger fixed at 40 mV

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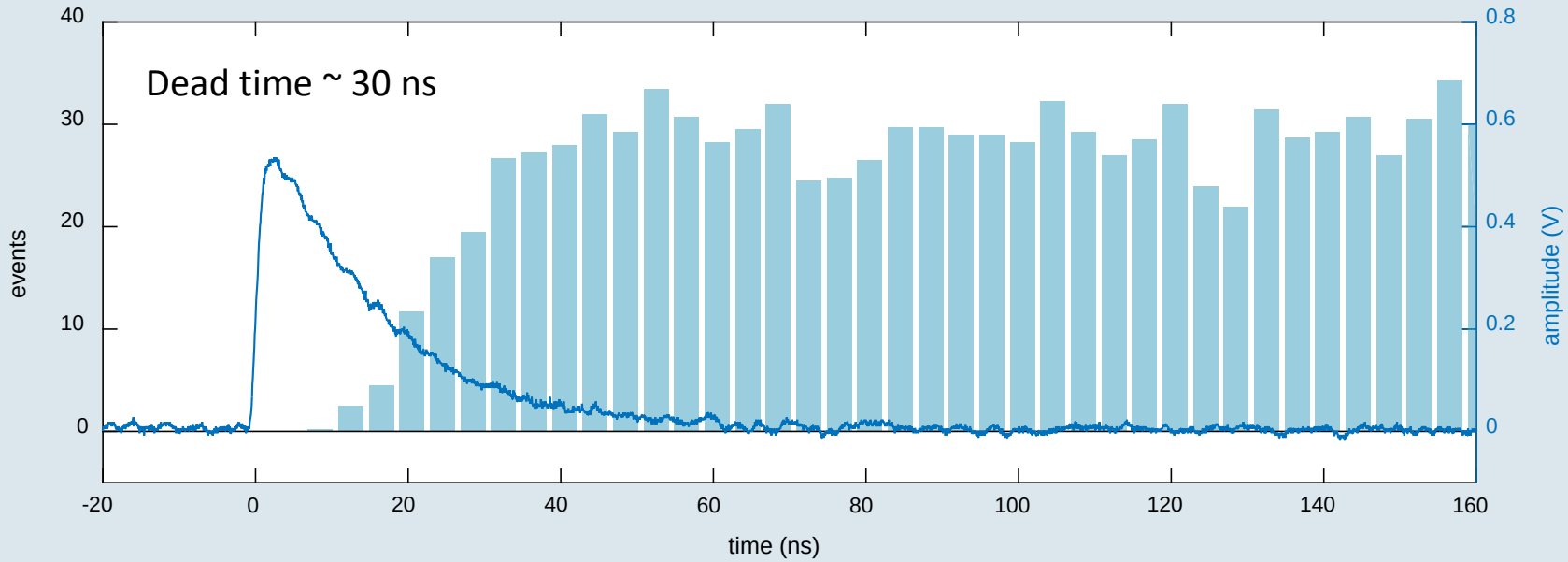
Maximum count rate



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Summary: UV MoSi SNSPDs

- 80% detector efficiency at 370 nm
- Dark count rates < 100 mHz in situ;
- Operating temperatures up to 3.6 K allow for use of compact cryocooler
- Promising timing properties

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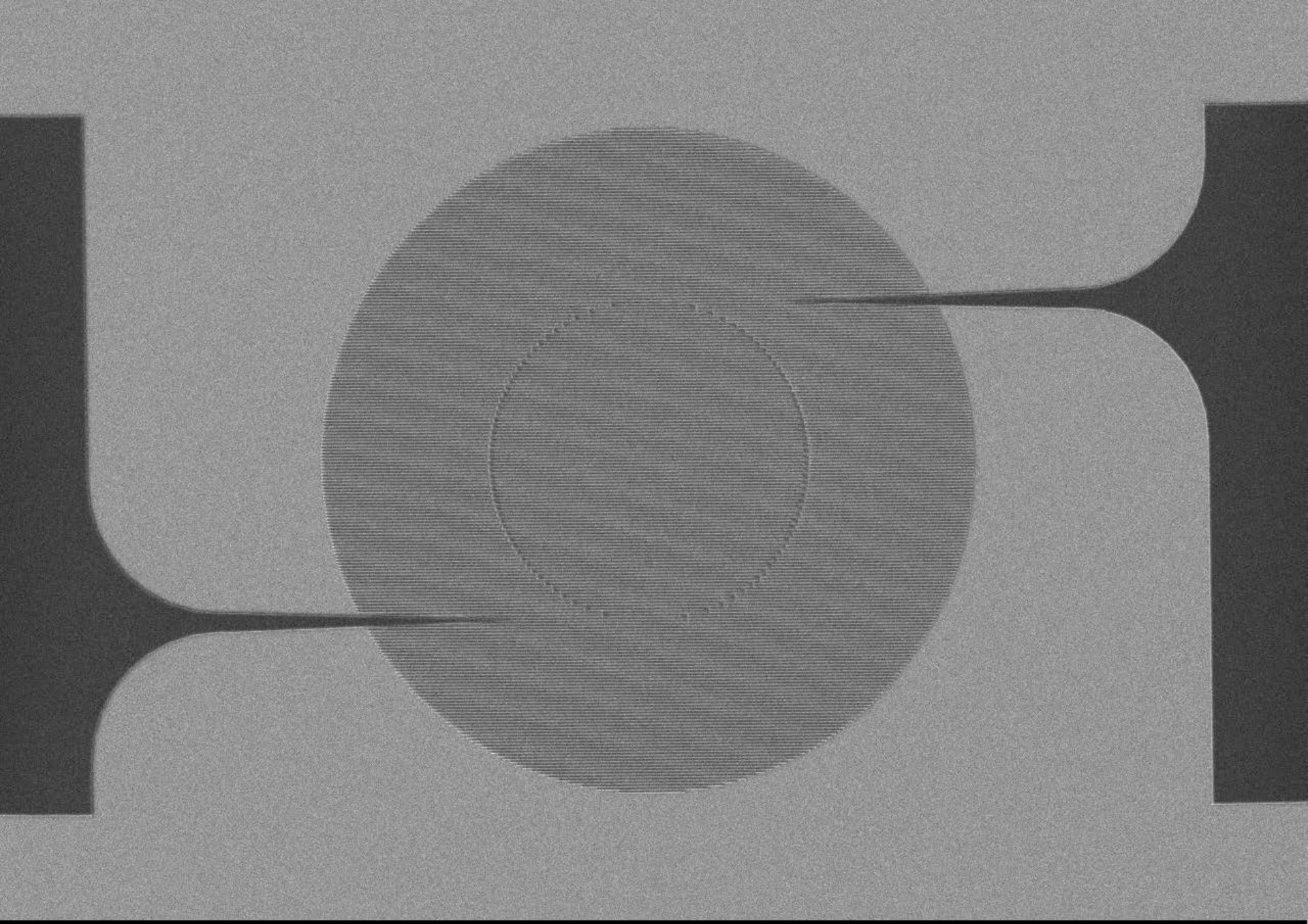
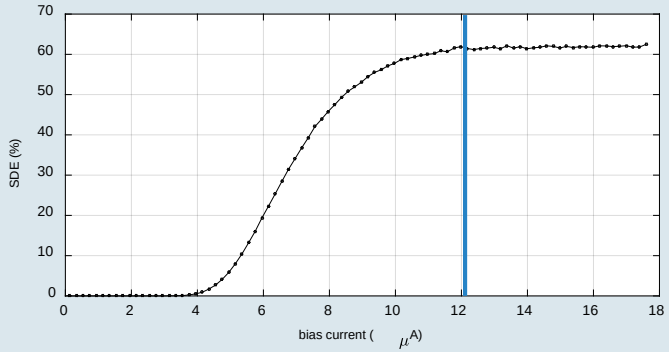
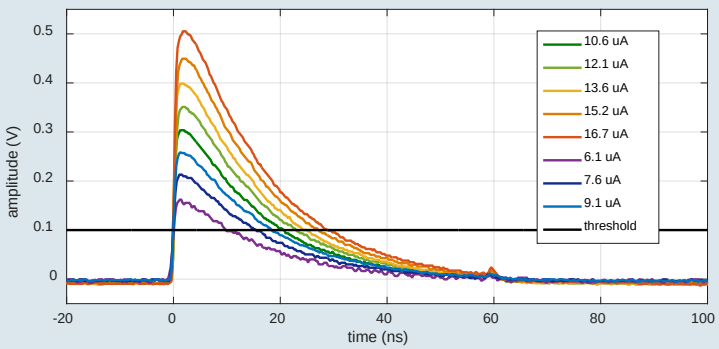
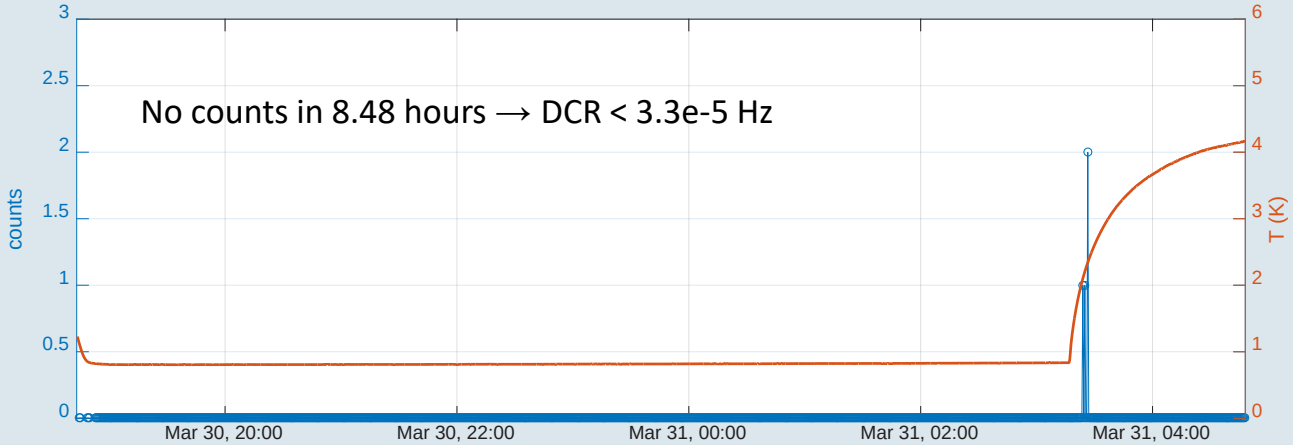

JPL
LEI
3.0kV
X1,600
10μm
WD 8.5mm

Intrinsic dark counts at low T







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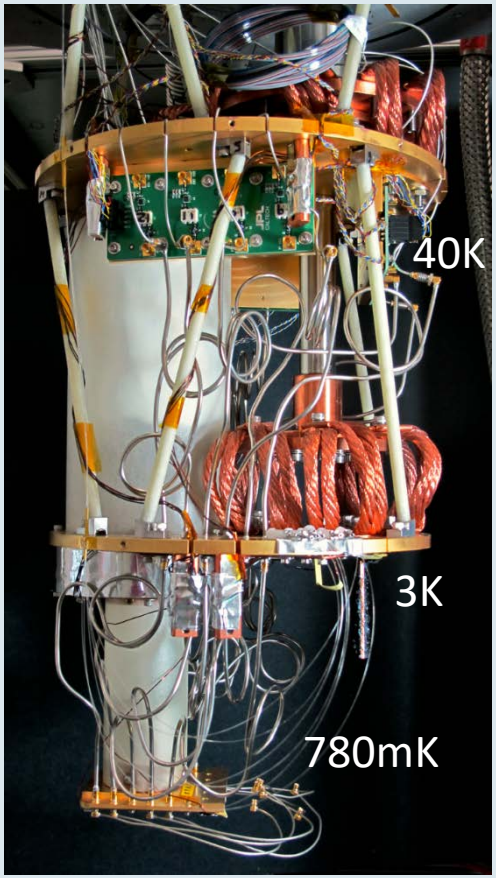
Cryostat

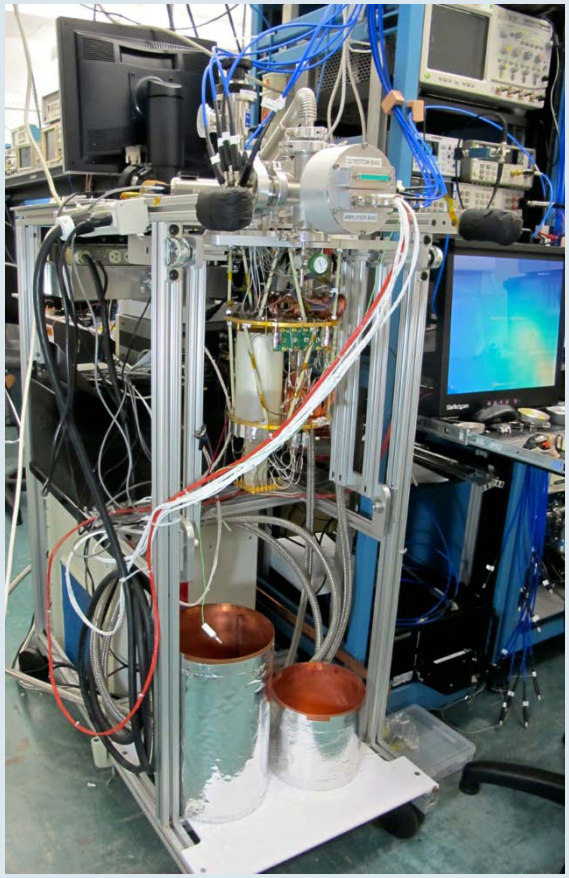


PhotonSpot prototype

~ 800 mK base temperature

6 UV fibers;
6 NIR fibers

12 RF lines



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