High-efficiency superconducting single-photon detectors

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Applications:

- Exo-planet detection: Low light level sensing, low dark counts
- Asteroid Detection: Imaging, IR sensitivity
- LIDAR: Time-of-flight
- Spectroscopy: Calorimetric Measurements
- Quantum Information: High Efficiency
SUPERCONDUCTING DETECTORS

- Extremely low to no dark counts
- Very high detection efficiency

- Transition Edge Sensors (TESs)
  - Photon-number resolving
  - Shown Sensitivity: 400 nm – 2500 nm*

- Superconducting Nanowire Single Photon Detectors (SNSPDs)
  - Fast Gaussian response, extremely low jitter
  - Shown Sensitivity: 300 nm – 7000 nm
Bias Current
substrate
WSi
80 nm
5 nm

sensitivity 300 nm – 7000 nm
SUPERCONDUCTING NANOWIRE SINGLE PHOTON DETECTOR (SNSPD)
SUPERCONDUCTING NANOWIRE SINGLE PHOTON DETECTOR (SNSPD)

Bias Current

Incident Photon

substrate

Hot spot (R > 0)

WSi

5 nm

80 nm

Voltage (mV)

0

-100

-200

-300

0 2 4 6 8 10

Time (ns)

27th August 2014

Thomas Gerrits

20th June 2018
SUPERCONDUCTING NANOWIRE SINGLE PHOTON DETECTOR (SNSPD)
SNSPD EFFICIENCY
AND TIMING JITTER PERFORMANCE

Marsili et al, Nat. Photon 7, 210 (2013)
OVERVIEW

- Superconducting Nanowire Single Photon Detectors
- Compressive Imaging using SNSPDs
- Transition Edge Sensors
- Single photon detector calibration efforts at NIST
TIME-OF-FLIGHT MEASUREMENTS

Direct measurement of the scene. However, long integration times required

SINGLE PIXEL CAMERA
(VIA COMPRESSIVE IMAGING)

System receives a series of measurements with changing known sampling patterns
Compressive Imaging requires less measurements (M) compared to Raster Scanning, typically less than 10 percent.
SUB-NANOSECOND, TIME-RESOLVED IMAGING

100 ps pulsed laser spectral profile

SUB-NANOSECOND, TIME-RESOLVED IMAGING


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OVERVIEW

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TRANSITION EDGE SENSOR

Energy deposition

Thermometer Absorber, C

Weak thermal link, g

Thermal sink (50 mK)

Counts

Pulse height

Signal (V)

time (µs)

R

T

Rn
LARGE PHOTON NUMBER COUNTING


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TES SPECTROMETER AND WGM RESONATORS

**ELECTRICAL SUBSTITUTION TES**

Electrical substitution of up to 5 pW of optical power.
OVERVIEW

- Superconducting Nanowire Single Photon Detectors
- Compressive Imaging using SNSPDs
- Transition Edge Sensors
- Single photon detector calibration efforts at NIST
Beamsplitter calibration method

Free-space and fiber coupled at 850 nm and 1533 nm
## RESULTS

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<tr>
<th>detector</th>
<th>Laser</th>
<th>Fiber-coupled</th>
<th>Wavelength (nm)</th>
<th>Measurements</th>
<th>DE at $10^5$ cps</th>
<th>rel. standard type A unc.</th>
<th>rel. expanded combined unc.</th>
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DEDICATED REFERENCE SUPERCONDUCTING
NANOWIRE SINGLE PHOTON DETECTOR SYSTEM

Reference Manual for NIST
Cryostat/SNSPD

By: Natalie Majica-Schwahn
CONCLUSIONS

- Transition Edge Sensors are energy-resolving detectors with timing (spatial) resolution of ~100 ns (~30 m) and no dark counts
- Superconducting nanowire single photon detectors provide exquisite timing resolution, low dark count rate and high efficiency
- Imaging of sparse scenes with a single detector – potential for 3D, hyper- and multispectral imaging
- Calibration service establishment efforts underway at NIST for customers – free-space, fiber-coupled, afterpulsing, dark counts, blocking loss, etc