

# 導波路集積型SNSPD

## DENA Detector Series

Superconducting single-photon detector

### Standalone devices

- One-button operation
- Highly parallelized
- High efficiency
- Ultra fast single-photon detection

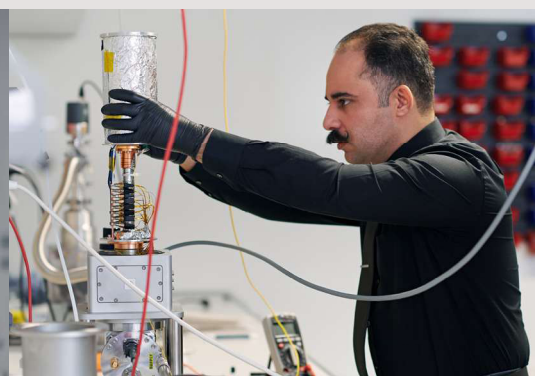
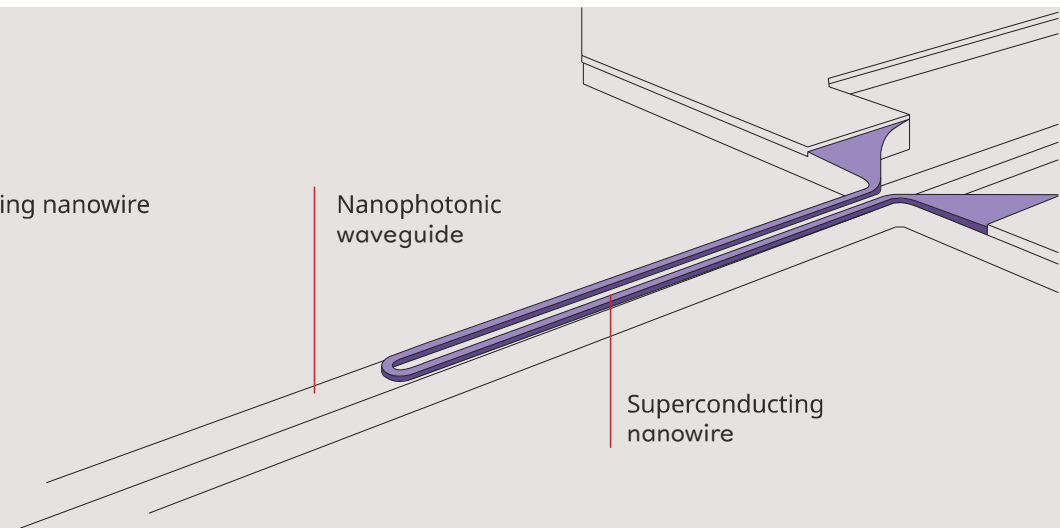
### Photonic integrated circuits

- Compact photonic functionalities
- In-house fabrication
- Customized individuality



### WI-SNSPD

Waveguide-integrated superconducting nanowire single-photon detector



## Housing system key features

Cryostat operation temperature	2.5–3 K, fully automatized solution, closed-cycle cryostat
Cooldown time	3 h
Number of channels	Variable (2–64+)
Optical fiber access	Via FC or LC
Electrical readout	Via SMA
Compatibility	- Standard 19" Rack Format including compressor - Desktop Format with external compressor
Dimensions	- Rack Format: 78x43.5x72 cm - Desktop Format: 58x38x60 cm (excluding external compressor)
Power consumption	- During cooldown: 1.5 kW - During operation: 1.3 kW

## Detector specifications

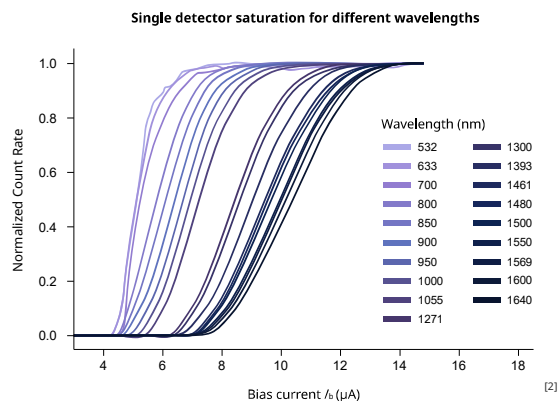
Specification	Pixel Photonics (current product)	Lab Demonstrator (max.)
Wavelength spectrum	Visible to IR spectrum	UV, visible to IR spectrum
System detection efficiency (SDE)	> 80 %	98 %
Dark count rate (DCR)	< 100 Hz	< 0.5 Hz
Timing uncertainty (Jitter)	< 35 ps	10 ps
Max. count rate (MCR)	> 200 MHz	> 1000 MHz
Polarisation dependency	Insensitive (+/- 0.17 dB)	
Recovery time (FWHM)	< 10 ns	0.5 ns
Multi-mode fiber option	Current development 50 $\mu\text{m}$ (>100 $\mu\text{m}$ in future) Funded by the Agentur für Sprunginnovation SPRIN-D	

## Upgradable

Unlatching hardware implementation	Automatic detector reset upon "latching" with nanosecond-level response time, significantly faster than software-based solutions
Experimental QKD receiver channels	On-chip QKD receiver, optimized for 1550 nm wavelength, ideal for QKD time-based protocols, including time-bin with decoy state, differential phase shift, and coherent one-way [1]  [1] Beutel, Fabian, et al. npj Quantum Information 7.1 (2021): 1–8.

## Highest efficiencies over a broad spectrum

Our unique WI-SNSPD design eliminates the need for an optical cavity at specific wavelengths, allowing a single detector to operate effectively across a broad spectrum.



[2] Wolff, Martin A., et al. Applied Physics Letters 118.15 (2021): 154004.

# Pixel Photonics

## **PICs** (photonic integrated circuits)

The idea behind integrated photonics is to minimize optical components like, e.g., waveguides, phase shifters, sources, or detectors on monolithic chips, similar to electrical integrated circuits minimizing electrical components. Utilizing this minimization alongside with CMOS-compatible fabrication processes increases scalability, stability and reproducibility while decreasing size, enabling the production of complex, densely packed devices.

## **Cryostat**

A cryostat is a device for maintaining low cryogenic temperatures (down to K) that allow superconducting states of materials to be realized and harnessed.

## **SNSPDs** (superconducting nanowire single photon detectors)

SNSPDs are sensitive to very low amounts of light down to the single-photon level in a broad frequency spectrum. They consist of current-fed superconducting nanowires and offer high intrinsic quantum efficiencies, high count rates and ultra-high timing precision. They are a key technology for applications in quantum optics and optical quantum technologies.

## **SDE** (system detection efficiency)

The system detection efficiency is defined as the ratio between the amount of light measured (power) and the amount of light entering the optical fiber. The system detection efficiency is therefore composed of the individual efficiencies of all involved components such as the fiber, the fiber-to-chip interface, the photonic integrated circuit, the superconducting detector material's absorption and internal quantum efficiency (IQE) of the detector element.

## **IDE** (internal detection efficiency)

The internal detection efficiency is defined as the ratio between the amount of light measured (power) and the amount of light entering the photonic circuit. Here, the internal detection efficiency is composed of the photonic integrated circuits' transmission losses and the superconducting detector material's absorption and IQE.

## **Dead time – maximum count rate**

The dead time denotes the period after the detection of a photon, during which no further detection is possible since the detector is recovering into the superconducting state. This limits the maximum count rate.

## Jitter (timing uncertainty)

Jitter is a measure of the variation in latency, or more precisely, the variation in the time between the absorption event and the registered readout event. Three sources contribute to jitter: First-ly, the measurement setup, including readout electronics, optical fibers, photodetectors, etc. Secondly, the electronic noise. And finally, the intrinsic jitter of the detector. It is usually quantified with an r.m.s. (root mean square) value.

## Dark count rate

The dark count rate is the average registered count rate without light incidence. It determines the minimum count rate at which actual photons dominate the signal, defining the signal-to-noise ratio.

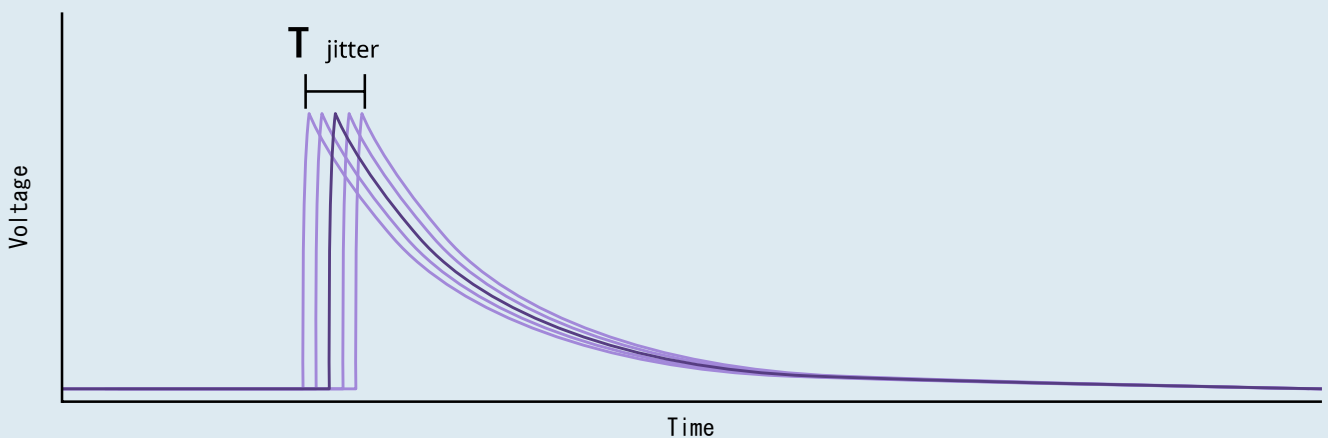
## Latching

Latching describes a condition where the detector fails to recover to its superconducting state after detecting a photon. As a result, it remains in a non-superconducting state and is unable to detect further photons. This necessitates a manual or automatic reset of the detector.

## DLW (direct laser writing)

Direct laser writing harnesses multiphoton lithography. Here, two photons are utilized to polymerize the resist. Due to the smaller cross-section of two-photon absorption, it is possible to focus the laser in small voxels, which allows manufacturing of out-of-plane structures.

Timing jitter of readout signal



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