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# SPAD 23

A high-performance single-photon detector array

## DESCRIPTION

SPAD 23 is a detector array with 23 hexagonally packed single-photon avalanche diodes (SPADs) with best-in-class performance. It features both the capability of direct photon counting and photon time tagging to enable a wide range of single-photon applications.

## KEY BENEFITS

### Ideal point detector

SPAD 23 is the ideal solution for a confocal scanning setup. Each pixel can act as a virtual pinhole, increasing resolution and contrast.

### Wide detection spectra and low noise

Our single-photon detectors are fabricated in a state-of-the-art CMOS process and offer an ultra-low dark count rate of less than 100 cps. Microlenses enhance the detection with a peak detection efficiency of over 45%.

### High timing resolution

Real-time processing of photon events occurs in a field-programmable gate array. The detector can process up to 154 Mcps over the whole array. Time-to-digital converters per pixel enable a fine timing resolution down to 20 ps with at a maximum photon flux of 70 Mcps.

### Plug and Play

The system requires just a 5V power adapter and USB3 cable to run. For full flexibility, 4 additional control lines can be connected to the SMA connectors. The SM1 optical port, the M2.5 and the M4 screw mounting positions offer a flexible integration into an existing optical setup.

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## APPLICATIONS

### Confocal microscopy

SPAD arrays increase light collection and enable innovation in the field of confocal scanning microscopy. This innovation finally leads to a sharper and brighter image with functional information about the underlying molecular function, interactions and environment.

**Applications:**

Image scanning microscopy (ISM), quantum ISM (Q-ISM), fluorescence lifetime imaging (FLIM), fluorescence correlation spectroscopy (FCS), stimulated emission depletion microscopy (STED)

**Why SPAD arrays?**

- Achieve super-resolution with a standard confocal microscope
- Increase light collection
- Increase imaging speed
- Reduce background noise

### Quantum information

Temporal photon correlations and photon number resolving (PNR) enable probing of quantum properties of light. Our detector has an extremely low crosstalk and thus enables reliable measurements of second and third order photon correlations, as well as quantum random number generation for unbreakable encryption.

**Applications:**

Antibunching and coincidence correlation, quantum random number generation

**Why SPAD arrays?**

- Simplify setup with single-chip multi-channel detector
- Increase data rate with detector parallelization
- Photon number resolving (PNR) detection

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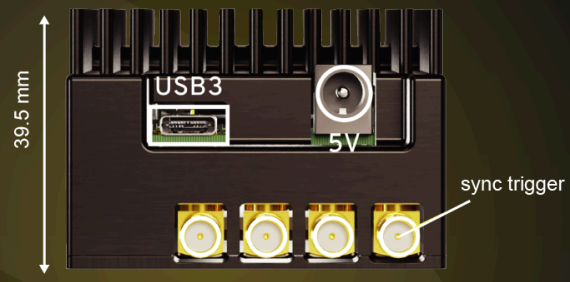
## OPERATING CONDITIONS & TECHNICAL SPECIFICATIONS

### RECOMMENDED OPERATING CONDITIONS

| SYMBOL | PARAMETER | MIN | MAX | UNIT |
|---|---|---|---|---|
| Operating voltages | | | | |
| $V_{ex}$ | SPAD excess bias | 4 | 9 | V |
| Environment | | | | |
| T | Temperature | -55 | 35 | °C |




### TYPICAL TECHNICAL SPECIFICATIONS

| PARAMETER | MIN | TYP | MAX |
|---|---|---|---|
| Peak detection probability @ 520 nm | 45% | 55% | - |
| Wavelength window with PDP > 35% | - | 440-660 nm | - |
| Fill factor | 70% | 80% | 100% |
| Median dark count rate | - | 50 cps | 100 cps |
| Number of pixels with DCR > 1 kcps | | 1 | 2 |
| Dead time | 25 ns | 50 ns | 75 ns |
| Timing jitter | - | 120 ps FWHM | 150 ps FWHM |
| Afterpulsing | - | 0.1% | - |
| Crosstalk | - | 0.14% | - |
| Maximum count rate per pixel | - | 6.7 Mcps | - |
| Time-tagging resolution | - | 20 ps | - |

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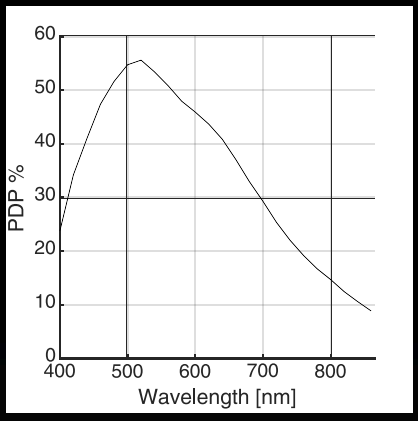
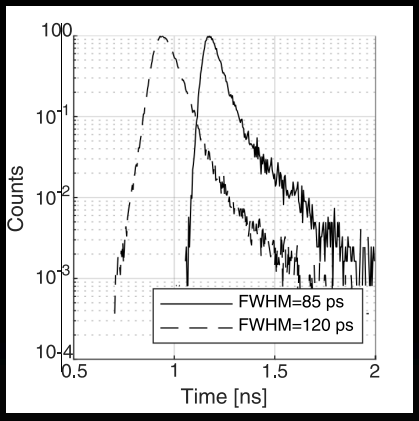
## PERFORMANCE CHARACTERISTICS




Photon detection probability.




Excellent timing jitter with a FWHM of <150 ps for wavelengths between 510 and 785 nm.

## SYSTEM INTEGRATION

A system overview is shown on the right. For operation, only two plugs are required, a 5 V power supply and a USB3 connection.

The software provides functionalities for photon-counting and time-tagging modes. It can be accessed through TCP/IP for easy integration into LabVIEW, MATLAB or Python.

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