SPCM-AQRH
Single Photon Counting Module

Key Features
- Peak PDE: > 70% @ 700 nm
- 180 µm active area
- > 35 Mcps dynamic range
- Gated output
- Single +5 V supply
- RoHS-compliant
- Low after pulse probability
- High uniformity over large active area
- Unmatched linearity

Applications
- LIDAR
- Quantum Cryptography
- Photon correlation spectroscopy
- Astronomical observation
- Optical range finding
- Adaptive optics
- Ultra-sensitive fluorescence
- Particle sizing

Excelitas Technologies' newly improved SPCM-AQRH Single Photon Counting Module detects single photons over the wavelength range of 400 nm to 1060 nm with performance parameters superior to other solid state or vacuum-tube based photon counters.

The SPCM-AQRH uses a unique silicon avalanche photodiode (SliK™) with a circular active area, achieving a peak photon detection efficiency greater than 70% at 700 nm over a 180 µm diameter with unmatched uniformity over the full active area. A TTL level pulse is generated for each photon detected and the signal is available at the BNC connector at the rear of the module. The signal should be terminated into 50 Ω.

The photodiode is both thermoelectrically cooled and temperature controlled, ensuring stabilized performance despite ambient temperature changes. Temperature of operation has been increased and the module (case temperature) will function between 5˚C and 70˚C.

Recent electronic circuit improvements have reduced the minimum dead time to 20 ns, thereby increasing linearity and improving the dynamic range of the module. Timing resolution of the module was also improved significantly. The SPCM-AQRH has internal protection circuitry that protects the avalanche photodiode and the modules electronics from damage due to accidental overload from exposure to ambient lighting.

Excelitas' series of photon counting modules are designed and built to be fully compliant with the European Union's RoHS Directive 2011/65/EU.

Table 1. Specifications of SPCM-AQRH-1X, @ 22 ºC, all models, unless otherwise indicated

Parameter	Min	Typ	Max	Unit
Supply voltage [1]	4.75	5.0	5.25	V
Supply current		0.4	1.2	A
Power cable total resistance		0.1	0.2	Ω
Case operating temperature [1, 3]	5		70	°C
Active area (diameter) at minimum PDE	170	180		µm
Photon detection efficiency (PDE) (without FC adaptor)[10, 11] at: 400 nm 650 nm 830 nm 1060 nm	 2 50 35 1	 5 65 45 2		 % % % %
Dark Count [4, 5, 6] SPCM-AQRH-10 SPCM-AQRH-11 SPCM-AQRH-12 SPCM-AQRH-13 SPCM-AQRH-14 SPCM-AQRH-15 SPCM-AQRH-16			1500 1000 500 250 100 50 25	Counts / second
Average dark count variation at constant case temperature (6 hrs. at 25 °C) [4, 5, 6] SPCM-AQRH-10, 11, 12, 13 SPCM-AQRH-14, 15, 16			 ± 10 ± 1	 % σ
Variation of average dark count rate at 5°C to 70°C case temperature for [4, 5, 6] SPCM-AQRH-10, 11, 12, 13 SPCM-AQRH-14, 15, 16			 ± 20 ± 2	 % σ
Single photon timing resolution (at 825 nm)[12] Contact factory for optimized timing below 350 ps and at other wavelengths		350		ps
Dead time (count rate below 5M/c) Other values can be factory set		20	40	ns
Output count rate before saturation[8]	12	40		Mc/s
Linearity correction factor [7] at 200 Kc/s 1 Mc/s 5 Mc/s 10 Mc/s 20 Mc/s 25 Mc/s		1 1.02 1.16 1.40 2.35 3.32		
Afterpulsing probability[13]		0.5		%
Setting time following power up (1% stability) at 1 Mc/s and 25°C		15	20	s

Parameter	Min	Typ	Max	Unit
Threshold setting required on counter for digital output pulse (terminate in 50 Ω)		1.0		V
Output pulse width [(9)] Other values can be factory set		8		ns
Output pulse amplitude TTL HIGH TTL LOW	1.5 -0.1	2	5.25 0.8	V V
Gating turn on/off (50Ω output) Disable = TTL low (<0.8 V) Enable = TTL high (>2.0 V)		 40 60	 45 65	ns
Gating threshold voltage (at V supply = 5 V) Low level (sink current >90 mA) High level (sink current >30 mA)	 0 2.0		 0.4 5.25	V

Refer to Operating Instructions below for noted items

Operating Instructions

1. Connection to incorrect voltage or reverse voltage may damage or destroy the module. The warranty is invalid in case such damage occurs. The center contact of the barrel type power connector (corresponds to the white stripe on the wire) is +5V.

2. These modules are not qualified for shock or vibration other than normal instrumentation environments.

3. The module dissipates a mean power of 2.0 W and a maximum power of 6W at high count rate and 70°C. Adequate heat sinking must be provided by clamping the module to a suitable heat sink via the holes in the module base. For the specification performance, the module case temperature must not exceed 70°C. See Figure 8 for stability of probability of detection vs. temperature.

4. Bi-stability of the dark count: On a small percentage of delivered modules, bi-stability of the dark count has been observed. Research indicates this bi-stability is probably due to transitions at a single impurity site between a low energy and a high energy state.

The phenomenon is seen as an abrupt change in the dark count rate, e.g., 350 to 390 c/s., and the dark count switches between the two states at a rate dependent upon the detector temperature. Multilevel switching has also been observed, where more than one impurity site is switching.

5. Long-term bi-stability is related to fundamental semiconductor physics and is beyond Excelitas' control. Warranty claims will not be considered against bi-stability alone.

Warranty claims will only be considered if the high level of the dark count exceeds the maximum level in the specification.

6. In the dark, the module generates random counts that follow a Poisson distribution. In a Poissonian process, the standard deviation is equal to the square root of the average count. In this specification the "dark count variation" refers to the stability of the average count of the module.

7. The actual photon rate could be calculated using the following equation, as indicated in Note #7 in the box below:

8. For typical dead time setting of 20 ns, typical maximum count rate is 40 Mc/s before saturation. If long output pulse width option is set (28 ns), typical maximum count rate is 30 Mc/s before saturation. If maximum dead time setting is used, about 62 ns, typical maximum count rate would be about 12 Mc/s. Note that using longer dead time will degrade linearity.

9. Output pulse width is set at the standard of 8 ns ± 2 ns at 1V. Optional output pulse width is 28 ns. If the application requires a 28 ns output pulse width, it should be requested at the time of quotation and order.

10. Fiber coupling. If needed, an FC fiber adaptor can be factory installed on the SPCM-AQRH module allowing optical fibers to be used. The FC adaptor is optimized for use at 550 nm and with a 100 um core multimode fiber. If other wavelengths or fiber sizes are needed, please contact the factory for availability.

11. The addition of an FC adaptor will cause a drop in the PDE of the module. The amount of the loss will depend on the wavelength and the diameter of the fiber used with the module. Typically, one can expect around a 5% loss with a 100 um core fibre at 650 nm.

12. Timing resolution is measured using a 10 um diameter light spot, at 825 nm, case temperature at 22 ºC. For timing resolution requirements of larger spot size measurement, or at different wavelength, please contact Excelitas.

13. After pulse is measured for the first 500 ns (excluding the first 75 ns) on the time line of the after pulse curve, with an average count rate of 100 kc/s ± 20 kc/s.

Note # 7: Actual photon rate calculation

$$ACTUAL\,COUNTRATE_{Photons} = \frac{(OUTPUT\ \ ModuleCountRate \times CORRECTIONFACTOR\ @\ the\ Module\ CountRate) - DARK\ COUNT\ Module}{PHOTON\ DETECTION\ EFFICIENCY\ Module}$$

The theoretical value, at low count rate, of the Correction Factor follows this equation:

$$Correction\ Factor = \frac{1}{1 - (t_d \times C_R)}$$

Where: t_d = Module Dead Time

C_R = Output Count Rate

The deviation from an ideal linear system is another way of looking at the saturation effect. The following equations show how to calculate this departure from the linearity:

$$LINEARITY = \left[\frac{OUTPUT\ ModuleCountRate}{(PHOTONS\ Actual\ Count\ Rate \times PHOTON\ DETECTION\ EFFICIENCY\ Module) + DARK\ COUNT\ Module}\right]^{-1}$$

$$= \left[\frac{1}{Correction\ Factor}\right]^{-1}$$

Table 2. Absolute Maximum Ratings

Supply voltage [1]	5.5 V
Maximum count rate	Maximum count rate can be sustained if case temperature is maintained within limit specified limits.
Peak light intensity	10^4 photons per pulse and pulse width < 1 ns
Case temperature [3]	-20°C/+70°C storage, +5°C /+70°C operating

Table 3. SPCM Ordering Guide

SPCM - AQRH - W X - FC

FC connector option
- FC connector attached

Dark count selection
- 0 – Dark count <1500 c/s
- 1 – Dark count <1000 c/s
- 2 – Dark count < 500 c/s
- 3 – Dark count < 250 c/s
- 4 – Dark count < 100 c/s
- 5 – Dark count < 50 c/s
- 6 – Dark count < 25 c/s

Chip type
- 1 – 175 um diameter SliK™

Table 4. Fiber Ordering Guide

Part Number	Fiber Type	Connector Type	Diameter			Numerical Aperature
			Core	Cladding	Outer	
SPCM-QC4	Multimode	FC / Bare	62.5 µm	125 µm	2.5 mm	0.27
SPCM-QC6	Multimode	FC / Bare	100 µm	140 µm	2.5 mm	0.29
SPCM-QC8	As SPCM-QC6 but 905 SMA on free end, 100 microns core fiber					
SPCM-QC9	As SPCM-QC6 but FC connector on free end, 100 microns core fiber					

Figure 1. Module Block Diagram

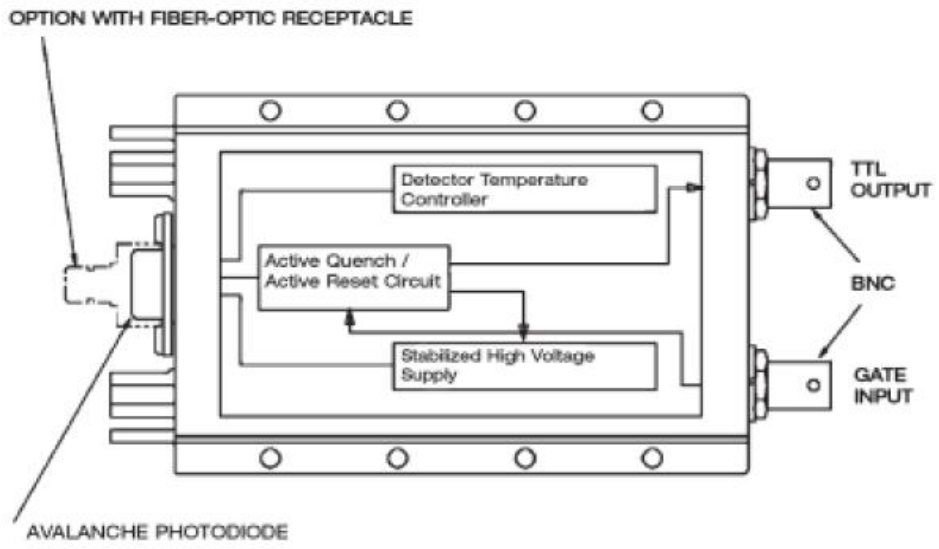


Figure 2. Electrical Connections

OUTPUT CONNECTOR

The digital OUTPUT pulse (BNC connector, TTL levels, >1.5 V) should be terminated into a 50 ohm load to avoid distortion and ringing. A 1.0 volt triggering level is recommended on counters and oscilloscopes to avoid triggering on noise. Note that TTL stands for Transistor Transistor Logic.

GATE CONNECTOR

The GATE input (BNC connector) impedance is 50 ohms and internally connected to the +5 volt supply through a 50 Ω pull-up resistor (standard module versions). It can be driven by standard TTL level signals. The gate drive must be capable of sinking 100 mA to gate the module off (5V/50 Ω). Operation: TTL high – module counts, TTL low – counting disabled.

POWER CONNECTOR

The +5V power connector is a standard barrel connector (2.5 mm I.D., 5.5 mm O.D.) with an 18 AWG cable. The center stripe corresponds to the center of the barrel and connects to the positive terminal of the 5 volt supply. Reversal of the wires may damage the module.

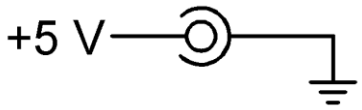


Figure 3. Typical SPCM-AQRH PDE Scan at 650 nm

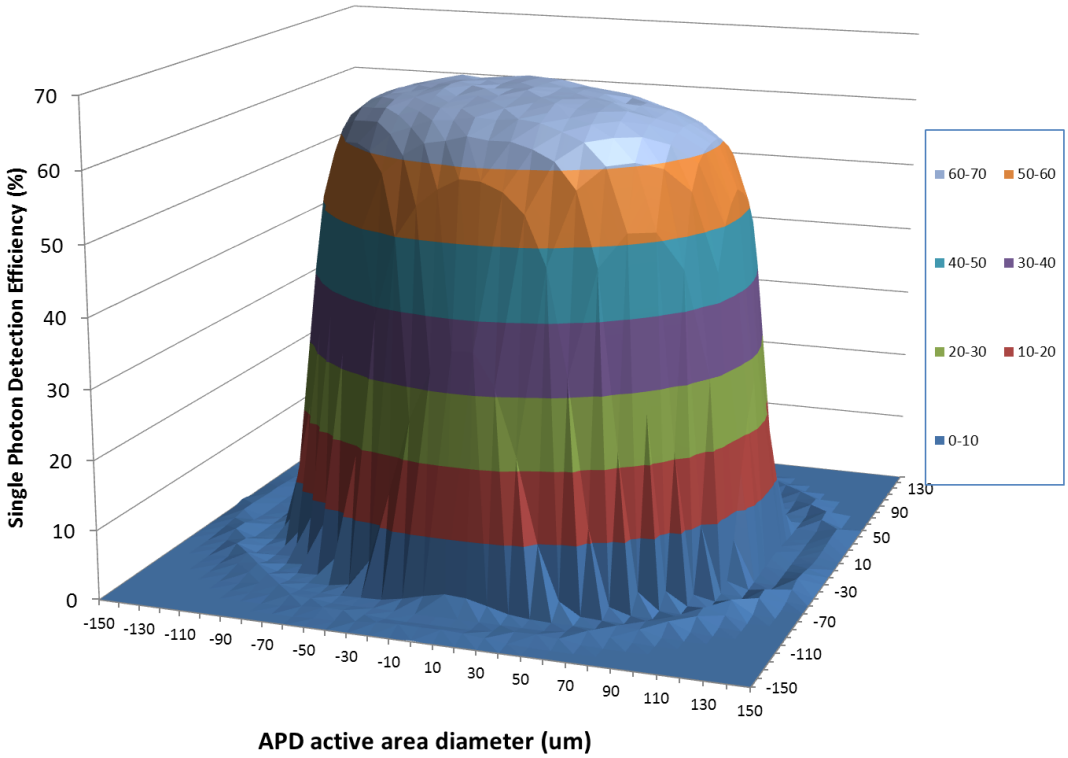


Figure 4. Typical Photon Detection Efficiency (PDE) vs. Wavelength

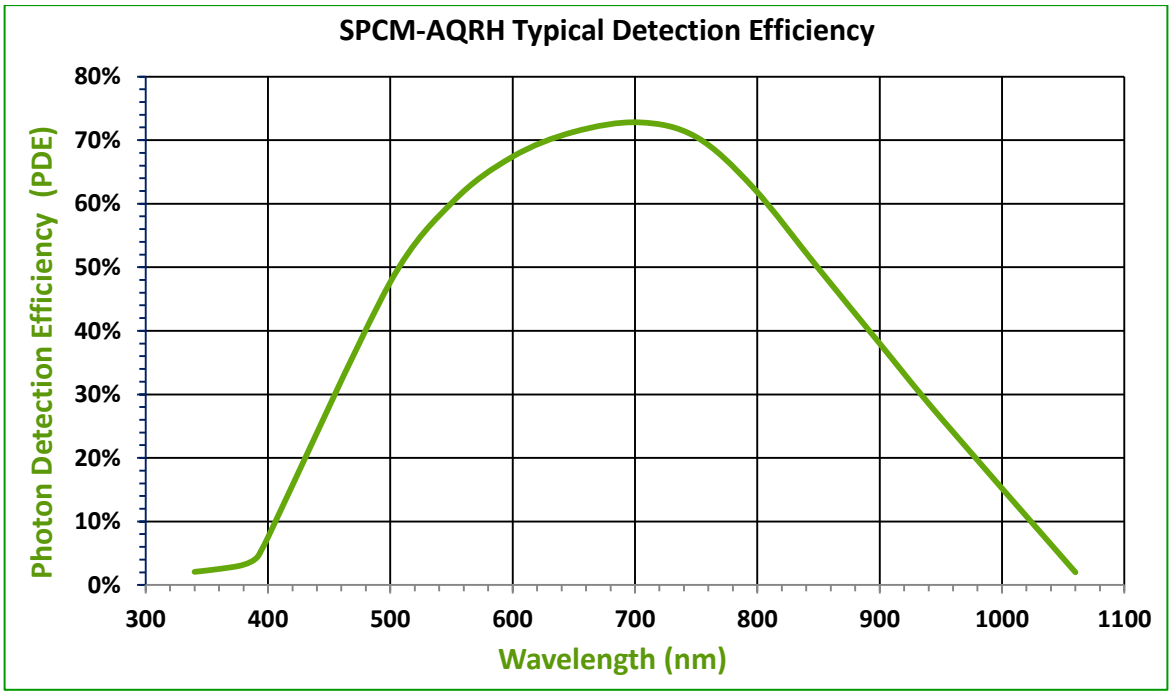


Figure 5. Photon detection probability (PD) uniformity vs. Light spot size

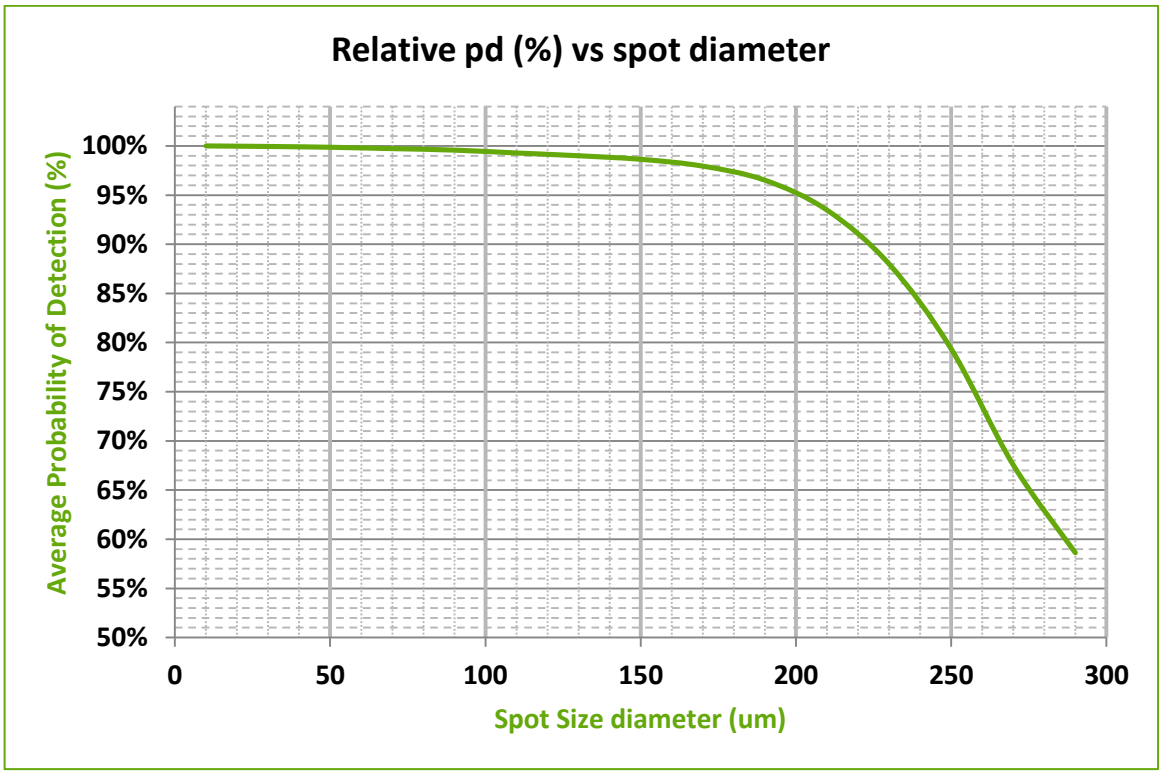


Figure 6. Probability of Detection Variation vs. Module case Temperature

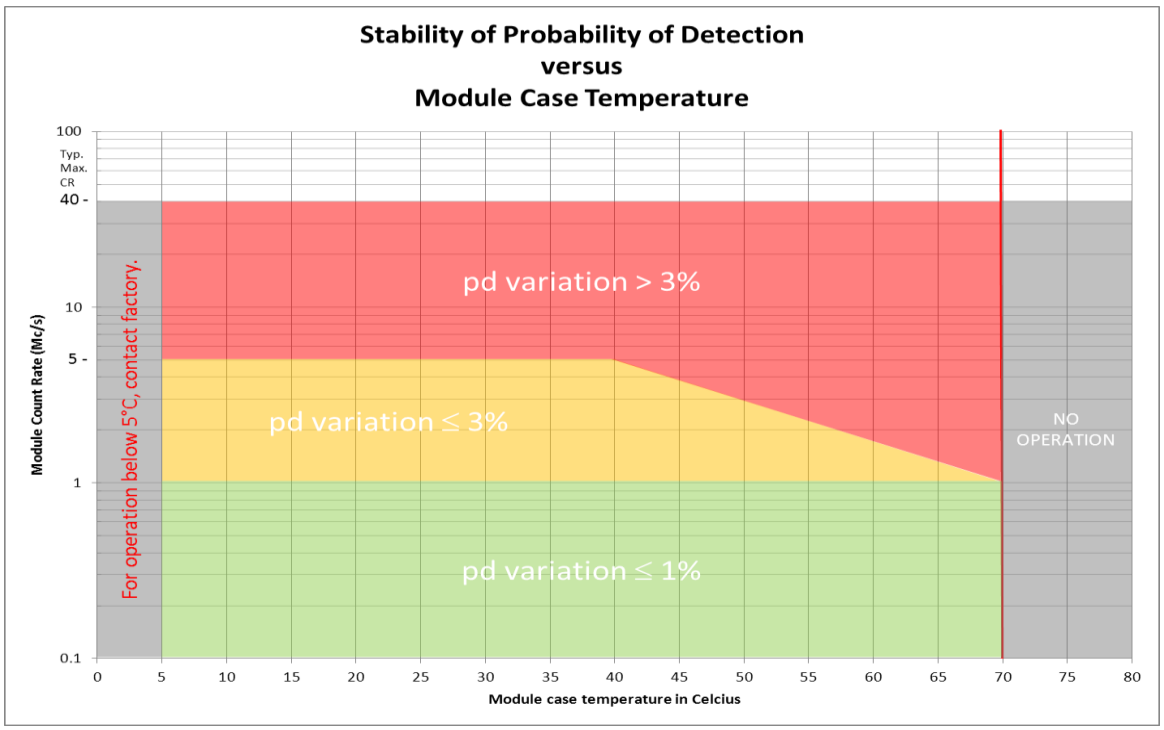


Figure 7. Typical Correction Factor

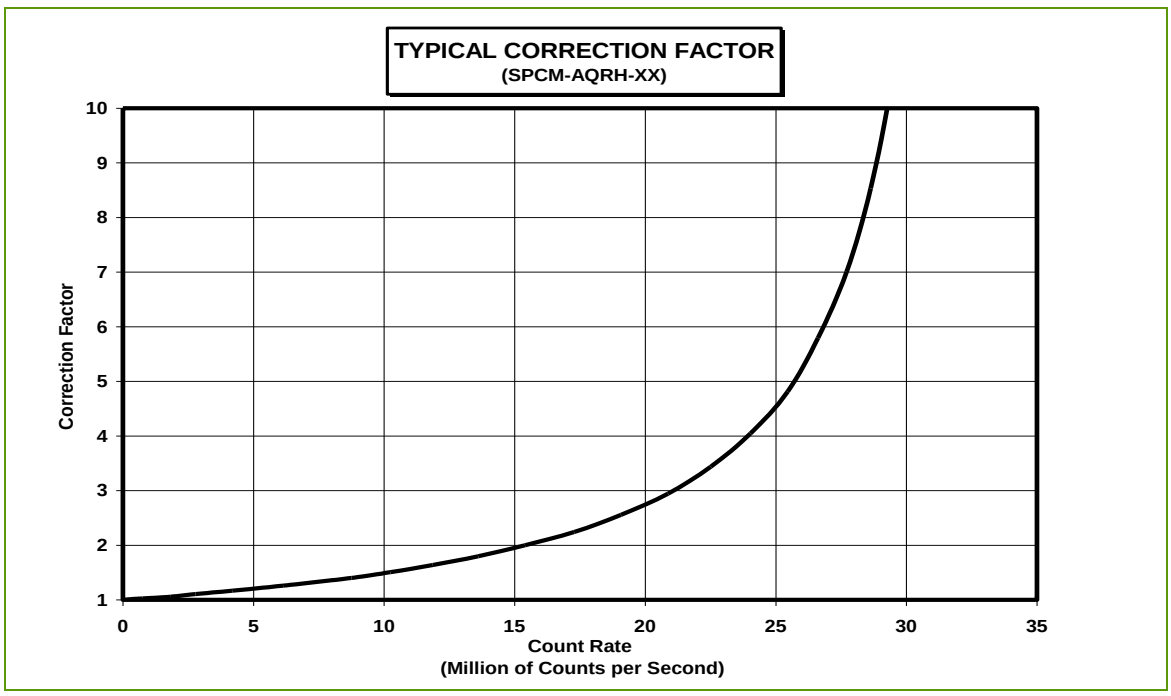


Figure 8. Count Rate Linearity

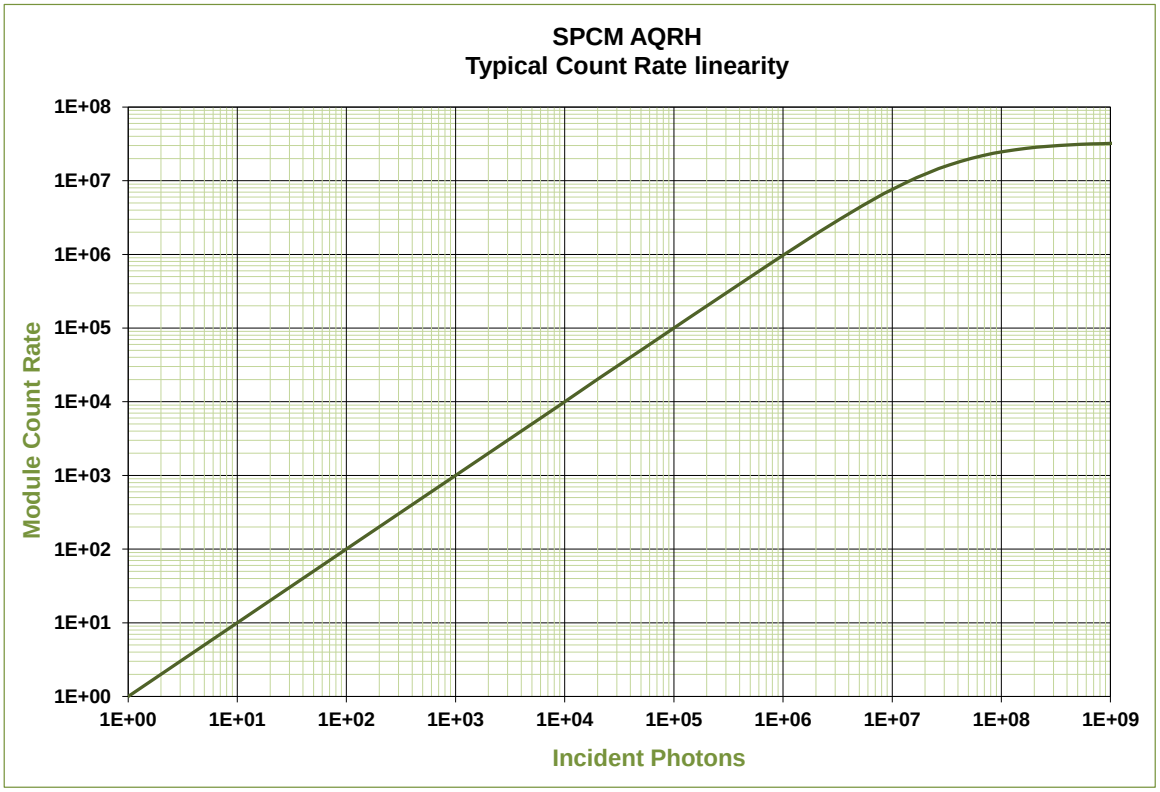


Figure 9. Optical Power vs. Number of Photons

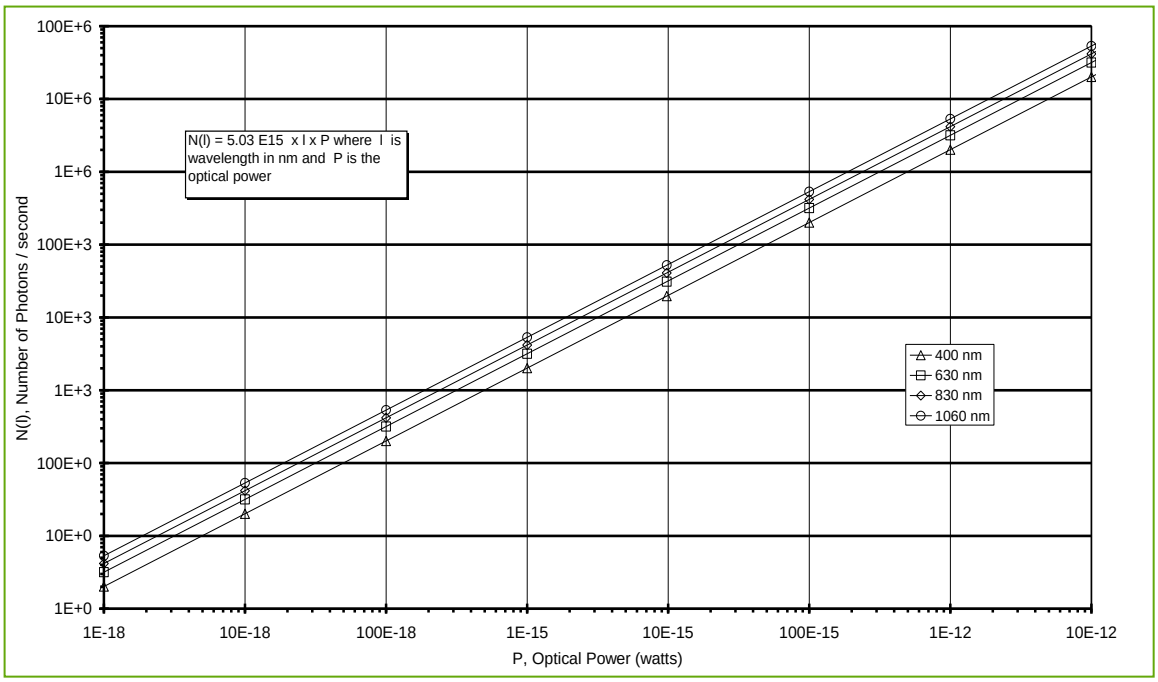
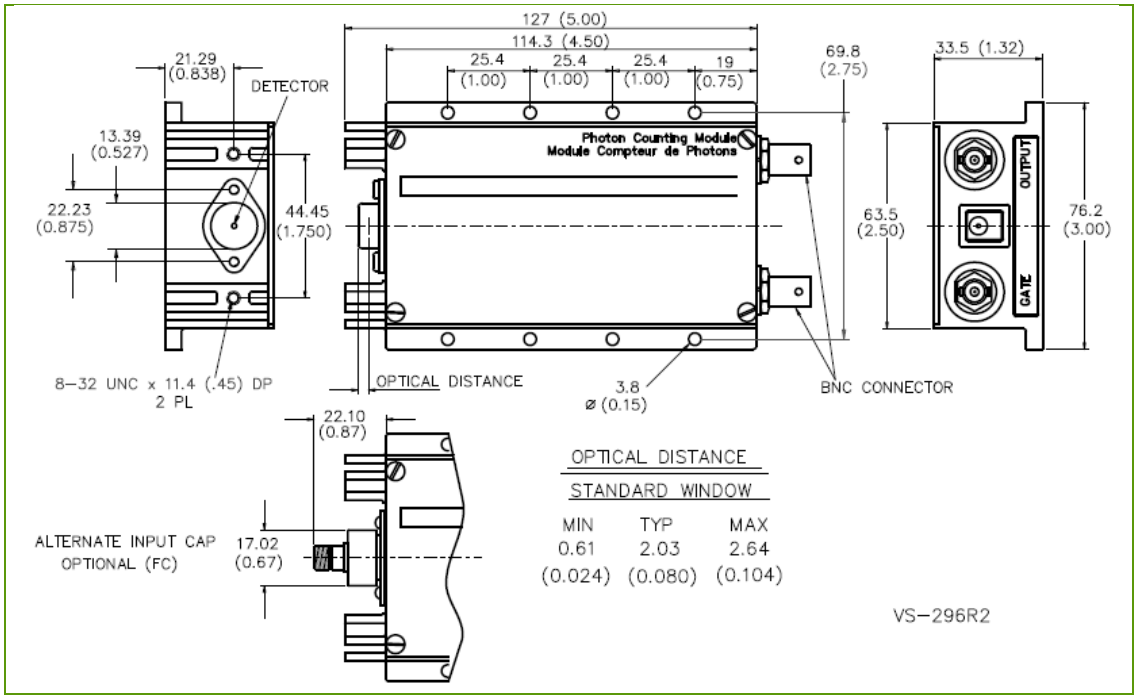


Figure 10. Dimensional Outline



Saturation

The photon count decreases at higher incoming light levels. The count at which the output rate starts to decrease is called the saturation point. As an extreme example, if the module is exposed to intense light the count rate will fall to zero. While the module is protected against light overload, precautions should be taken to avoid any excessive light level that will damage the SPCM module. After an over exposure, the dark count of the module could increase temporarily for up to an hour. For faster recovery, it is recommended to power off the module and leave it in the dark for one to two minutes prior to restarting.

Fiber Connection Option

The SPCM-AQRH-WX-FC has an “FC” fiber-optic receptacle pre-aligned to the optical detector. Optical fibers with an FC connector on one end are available separately, (see Ordering Guide 2). The standard fiber lens is optimized for 550 nm. Though the fiber / GRIN in the standard module will function through the complete range of 400 nm to 1060 nm, due to the wavelength dependence of the graded index coupling lens, improvements to operating wavelengths other than 550 nm are special orders. The photon detection efficiency of connectorized modules is about 95% of that quoted for standard modules at 550 nm.

Fiber Shielding

When used with optical fibers, both the fiber itself and the connector shrouds must be completely opaque. Otherwise, stray light will increase the count rate. The SPCM-QCX pigtails conform to this requirement (see Ordering Guide 2).

Gating Function

A gating function is provided with each module – useful for viewing a signal that occurs only in a small timeframe window. Also, in some applications the background light flux is higher than the signal. In this case, the gating option could be used to improve the S/N ratio by opening a window only when the light signal is present. The output of the module and the active quench function are disabled when a TTL low level is applied to the module gate input. When a TTL high level is applied to

the module gate input, the output of the module and the active quench circuit are enabled again. Any photon detection that occurs less than 2 us before the module gate input changes can result in an output pulse. However, this output pulse has lost timing accuracy.

Light Emission during Photon Detection

One peculiarity of silicon avalanche photodiodes is that as an incoming photon is detected, a small amount of light is emitted from the avalanche region. The emitted light has a broad spectral distribution. In most cases, this is not a problem. However, it can cause some confusion if another detector is monitoring light, or if the optical system is such that light emitted from the SPCM-AQRH is reflected back on itself. If these photons return 35 ns after the initial event, they will be detected.

Safety Warning

The SPCM-AQRH contains a **high voltage power supply.** Users may be injured if the case is opened. All internal settings are pre-set; there are no user adjustments.

Units that appear defective or have suffered mechanical damage should not be used because of possible electrical shorting of the high voltage power supply. Opening the case may damage sensitive components and expose the user to the risk of electrical shock. Please contact factory for repairs.

RoHS Compliance

This series of avalanche photodiode modules are designed and built to be fully compliant with the European Union Directive 2011/65/EU – Restriction of the use of certain Hazardous Substances in Electrical and Electronic equipment.

Warranty

A standard 12-month warranty following shipment applies. Any warranty is null and void if the module case has been opened. Warranty is null and void if the module input exceeds 5.5 V or the polarity of the +5 V supply is reversed.

EDS Warning

Modules should only be handled at an ESD-safe work station.

Individual Module Test Data

Each module is supplied with test data indicating the module's actual dark count, dead time, pulse width, photon detection efficiency @ 630 nm (550 nm for fiber-coupled versions), correction factor and linearity.

Declaration of Conformity

This product is eligible to bear the CSA mark with adjacent indicator 'C' and 'US'.

Products:

CLASS 8721 85 ELECTRICAL EQUIPMENT FOR LABORATORY USE – Certified to US standards
CLASS 8721 84 ELECTRICAL EQUIPMENT FOR LABORATORY USE – Certified to US standards
CLASS 8721 04 LABORATORY EQUIPMENT – Electrical
CLASS 8721 04 LABORATORY EQUIPMENT – Electrical

Single photon counting module SPCM-AQRH or SPCM-AQR model SPCM-AQRH-WX or SPCM-AQR-WX (where W = 1 and X = 2, 3, 4, 5, 6 not affecting safety certification), rated 5 Vdc, 1.2 A,

Single photon counting module SPCM-AQRH-WX-FC or SPCM-AQR-WX-FC model SPCM-AQRH-WX-FC or SPCM-AQR-WX-FC (where W = 1 and X = 2, 3, 4, 5, 6 not affecting safety certification), rated 5 Vdc, 1.2 A

Single photon counting module SPCM-CDXXXXY (where X = can be 0000 to 9999, Y could be a letter from A to Z, not affecting safety certification), rated 5 Vdc, 1.2 A

Altitude of Operation: 0 – 5000 Meters
Humidity of Operation: 15% - 95% relative humidity, non-condensing
Equipment class III, measurement category l, pollution degree 2

APPLICABLE REQUIREMENTS:

CAN/CSA-C22.2 No. 61010-1-04 – Safety requirements for electrical equipment for measurement, control, and laboratory use, part 1: General requirements (second edition) ANSI/UL std no. 61010-1 – Electrical equipment for measurement, control, and laboratory use; part 1: General requirements (second edition)

This product is eligible to bear the CE mark in accordance with:

EN 61326:1997 Electrical equipment for measurement, control and laboratory use
EN 61010-1:2001 Safety requirements for electrical equipment for measurement, control and laboratory use

This product has been tested as per the following standards:

- Emission CISPR 11
- IEC 61000-4-2 ESD
- IEC 61000-4-3 Radiated susceptibility
- IEC 61000-4-4 Burst
- IEC 61000-4-5 Surge
- IEC 61000-4-6 Conducted susceptibility
- IEC 61000-4-11 Voltage dips and interruptions

This equipment is intended for Indoor Use Only. There is no applicable maintenance manual. The data sheet is used also as an instruction manual.

About Excelitas Technologies

Excelitas Technologies is a global technology leader focused on delivering innovative, customized solutions to meet the detection, lighting, and other high-performance technology needs of OEM customers.

From analytical instrumentation to clinical diagnostics, medical, industrial, safety and security, and aerospace and defense applications, Excelitas Technologies is committed to enabling our customers' success in their end-markets. Excelitas Technologies has approximately 3,000 employees in North America, Europe and Asia, serving customers across the world.

Excelitas Technologies
22001 Dumberry Road
Vaudreuil-Dorion, Quebec
Canada J7V 8P7
Telephone: (+1) 450.424.3300
Toll-free: (+1) 800.775.6786
Fax: (+1) 450.424.3345
detection.na@excelitas.com

Excelitas Technologies GmbH & Co. KG
Wenzel-Jaksch-Str. 31
D-65199 Wiesbaden
Germany
Telephone: (+49) 611 492 430
Fax: (+49) 611 492 165
detection.europe@excelitas.com

Excelitas Technologies
1 Fusionopolis Walk #11-02,
Solaris South Tower
Singapore
138628
Telephone: (+65) 6775 2022
Fax: (+65) 6775 1008
detection.asia@excelitas.com

For a complete listing of our global offices, visit www.excelitas.com/Locations