

# Single Photon Counting Module

## SPCM-AQR Series



### Description

The SPCM-AQR is a self-contained module which detects single photons of light over the wavelength range from 400 nm to 1060 nm... a range and sensitivity which often outperforms photomultiplier tubes.

The SPCM-AQR-IX utilizes a unique silicon avalanche photodiode which has a circular active area whose peak photon detection efficiency over a 180  $\mu\text{m}$  diameter exceeds 65% at 650 nm. The photodiode is both thermoelectrically cooled and temperature controlled, ensuring stabilized performance despite changes in the ambient temperature. The SPCM-AQR module can count to speeds exceeding 10 million counts per second (Mc/s) for the SPCM-AQR-1X. There is a "dead time" of 50 ns between pulses.

The SPCM-AQR requires a +5 volt power supply. A TTL pulse of 2.5 volts (minimum) high in a 50  $\Omega$  load and 35 ns wide, is output at the rear BNC

connector as each photon is detected. To avoid a degradation of the module linearity and stability, the case temperature should be kept between 5 C and 40 C during operation.

### Saturation

The 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. Consequently, in certain applications, some tests should be performed by the operator to ensure that a low count rate is not caused by detector saturation.

Precautions should be taken to avoid any excessive light level that will damage the SPCM module.

### Applications

- LIDAR
- Photon Correlation Spectroscopy
- Astronomical Observation
- Optical Range Finding
- Adaptive Optics
- Ultra Sensitive Fluorescence
- Particle Sizing

### Features

- Peak Photon Detection Efficiency @ 650nm: 65% Typical
- Active Area: SPCM-AQR-IX: 175  $\mu\text{m}$
- User Friendly
- Gated Input
- Single +5v Supply



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**Fiber Connection Option**

**Ordering Guide 1**

The SPCM-AQR-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. Due to the wavelength dependence of the graded index coupling lens, the operating wavelength range must be specified; see Ordering Guide 2. The photon detection efficiency of connectorized modules is about 95% of that quoted for standard modules.

**Fiber Shielding**

When used with optical fibers, both the fiber itself and the connector shrouds must be completely opaque; if not stray light will increase the count rate. The SPCM-QCX pigtailed conform to this requirement; see Ordering Guide 2.

**Gating Function**

A gating function is provided with each module. It is useful when you are looking for a signal that occurs only in a small time frame 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 is disabled when a TTL low level is applied to the module gate input.*

**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 light emitted 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-AQR is reflected back on itself. If these photons return 35 ns after the initial event, they will be detected.

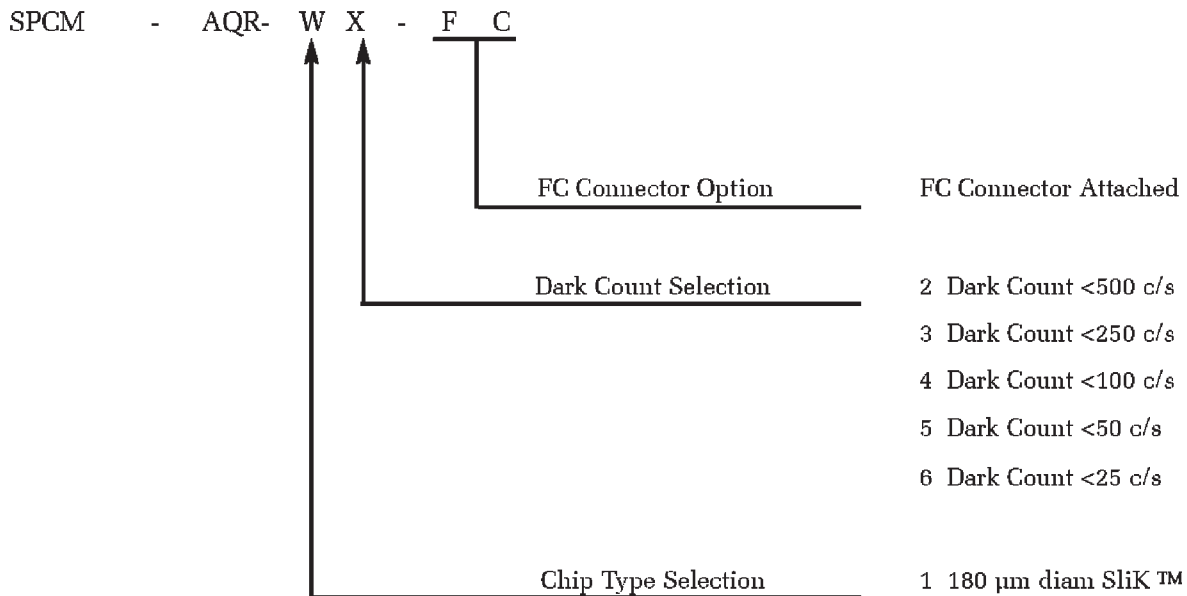
**Safety**

The SPCM-AQR contains a high voltage power supply. All internal settings are pre-set; *there are no user adjustments.* Units which appear defective or have suffered mechanical damage should not be used because of possible electrical shorting of the high voltage power supply.

**Warranty**

A standard twelve month warranty following shipment applies. Any warranty is null and void if the module case has been opened.

**Table 1. Ordering Guide Diagram 1**



\* SliK is a trademark of PerkinElmer Inc.

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**Table 2. Ordering Guide Diagram 2**

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					

**Table 3. Specifications SPCM-AQR-WX @ 22° C, all models, unless otherwise indicated**

Parameter	Minimum	Typical	Maximum	Units
Supply current		0.5	1.9	Amps
Supply voltage: (1)	4.75	5.0	5.25	V
PerkinElmer power cable total resistance		0.2		Ω
Case operating temperature (1.3)	5		40	°C
Active area (diameter) @ minimum Pd	170	175		μm
Photon detection efficiency (Pd) @				
400 nm	2	5		%
650 nm	50	65		%
830 nm	35	45		%
1060 nm	1	2		%

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Table 4. Specifications SPCM-AQR-WX @ 22° C, all models, unless otherwise indicated

Parameter	Minimum	Typical	Maximum	Units
Pd variation at constant case temperature (2h @ 25° C)		± 1	± 3	%
Pd variation 5° C to 40° C case temperature		± 4	± 10	%
Dark Count (4,5,6) =				
SPCM-AQR-12		—	500	Counts/Second
SPCM-AQR-13		—	250	Counts/Second
SPCM-AQR-14		—	100	Counts/Second
SPCM-AQR-15		—	50	Counts/Second
SPCM-AQR-16		—	25	Counts/Second
Average dark count variation at constant case temperature (6 hrs @ 25° C) for (4,5,6);				
SPCM-AQR-12 & 13			± 10	%
SPCM-AQR-14 & 15 & 16			± 1	o
Average dark count variation at 5° C to 40° C case temperature for (4,5,6);				
SPCM-AQR-12 & 13			± 20	%
SPCM-AQR-14 & 15 & 16			± 2	o
Single Photon Timing Resolution		Contact factory for availability		
Dead Time (Count rates below 5 Mc/s)		50	60	ns

## Single Photon Counting Module - SPCM-AQR Series

Table 5. Specifications SPCM-AQR-WX @ 22° C, all models, unless otherwise indicated - continued

Parameter	Minimum	Typical	Maximum	Units
Output count rate before saturation	10	15		Mc/s
Linearity correction factor: (7)				
@ 200 kc/s		1.01		
@ 1 Mc/s		1.08	1.15	
@ 5 Mc/s		1.40	1.67	
Afterpulsing probability		0.5		%
Settling time following power up (1% stability) @ 1 meg counts/sec and 25° C		15	30	S
Threshold setting required on counter for digital output pulse (terminate in 50 Ohms)	0.75	1.0	2.0	V
Output pulse width		35		ns
Gating turn on/off: (50Ω output)				
Disable = TTL Low		2	4	ns
Enable = TTL High		45	55	ns
Gating Threshold Voltage: (@ V <sub>supply</sub> = 5V)				
Low level (sink current >90mA)		0	0.4	V
High level (sink current >30mA)		3.5	5.25	V

Table 6. Absolute Maximum Ratings

Supply Voltage (1)	5.5V
Mean Count Rate	5 Mc/s (Above this point, dead time will increase due to diode self-heating)
Peak Light Intensity	10 <sup>4</sup> photons per pulse and pulse width less than 1 ns.
Case Temperature (3)	50° C Storage, 40° C operating

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1. Connection to incorrect voltage or reverse voltage may destroy the module. The warranty is invalid where such damage occurs.
2. These modules are not qualified for shock or vibration other than normal instrumentation environments.
3. The module dissipates a mean power of 2.5W, and a maximum power of 6.5W at high count rate and 40° 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 40° C.
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 that 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 which depends on 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 outside PerkinElmer's control. Warranty claims will not be entertained against bi-stability alone. 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 counts. 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 below:

**Table 7. Equation**

$$ACTUALCOUNTRATE_{Photons} = \frac{(OUTPUT_{ModuleCountRate} \times CORRECTIONFACTOR @ the Module CountRate) - DARK COUNT Module}{PHOTON DETECTION EFFICIENCY Module}$$

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

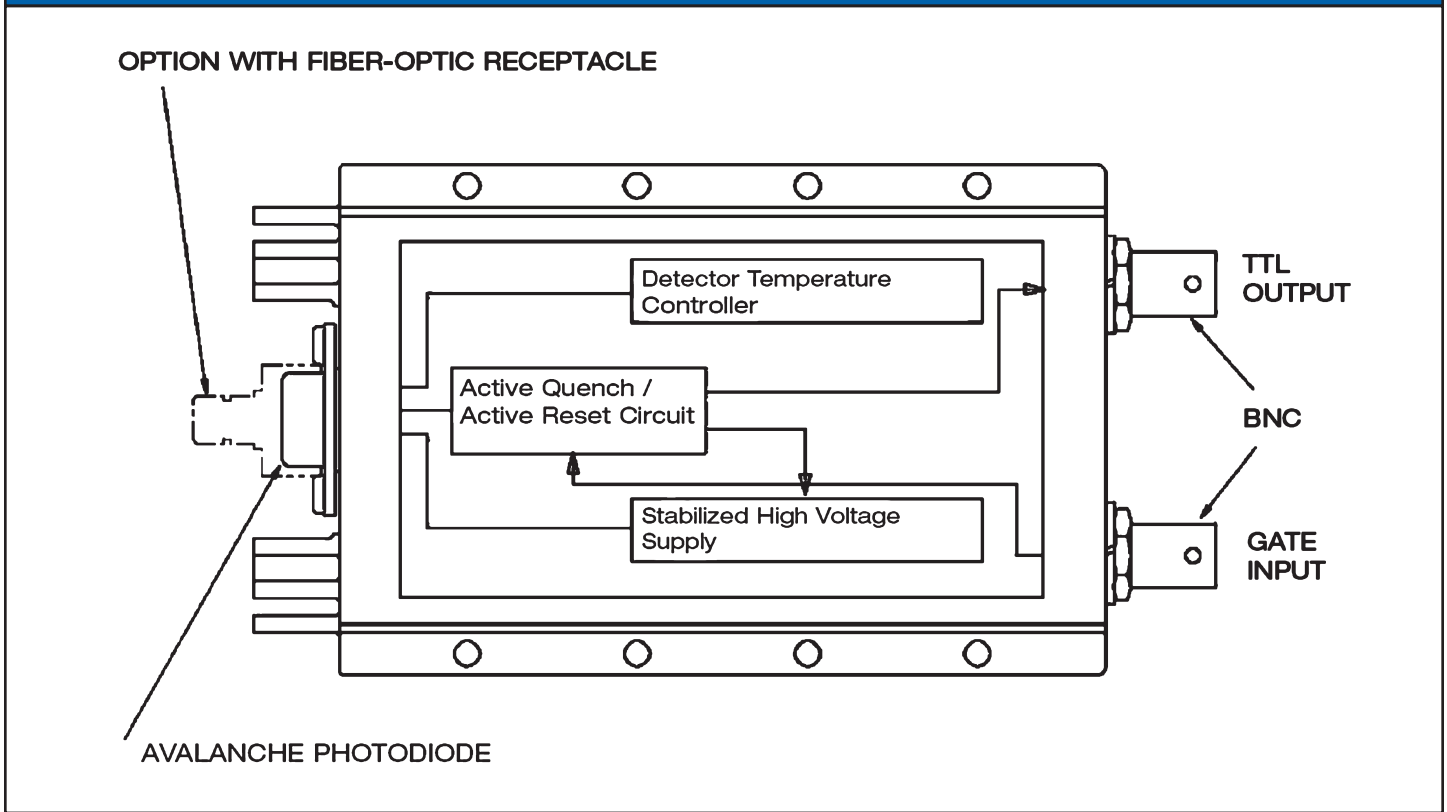
The deviation from an ideal linear system is another way of looking at the saturation effect. The following equations show how to calculate this departure from the linearity:

$$LINEARITY = \frac{OUTPUT_{ModuleCountRate}}{(PHOTONS_{Actual Count Rate} \times PHOTON DETECTION EFFICIENCY Module) + DARK COUNT Module} - 1$$

$$= \frac{1}{Correction Factor} - 1$$

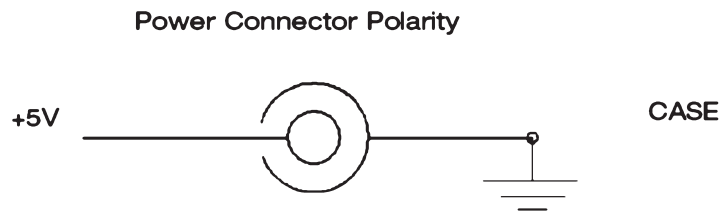
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**Figure 1. Block Diagram of Module**



**Figure 2. Electrical Connections**

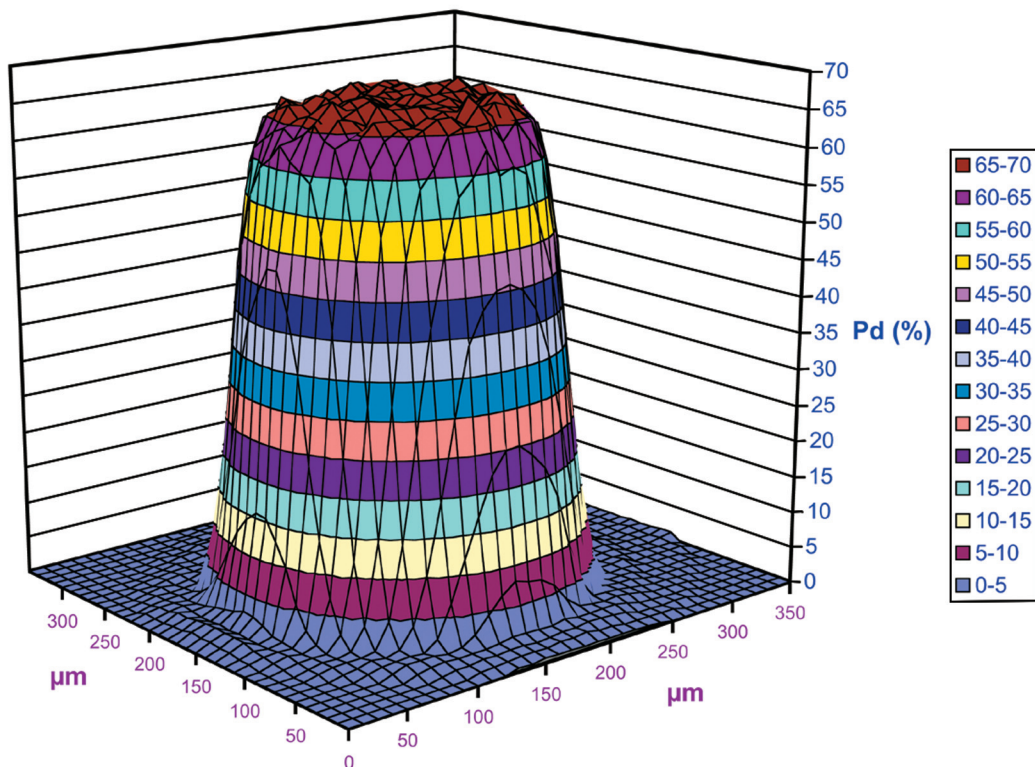
The digital output pulse,  $\geq 2.5V$ , should be terminated with a  $50 \Omega$  load to avoid distortion and ringing. A 1.0V triggering level is recommended. The gate input impedance is  $50 \Omega$  and is connected through an internal pull-up resistor to the +5V supply.  $\Omega$  lo



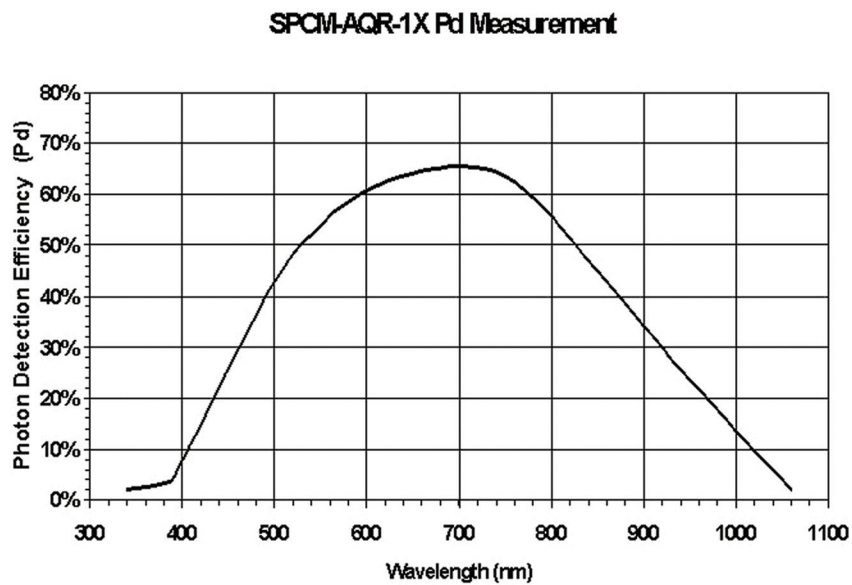
**CONNECTOR: BARREL TYPE**  
 I.D. = 2.5 mm (0.10")  
 O.D. 5.5 mm (0.22")  
 LENGTH = 12.0 mm (0.47")

**CABLE: CENTER WHITE STRIPED LEAD**  
 WIRE GAUGE = 22 AWG  
 LENGTH = 1.8 M (72")

**Figure 3. Dectector Scan**

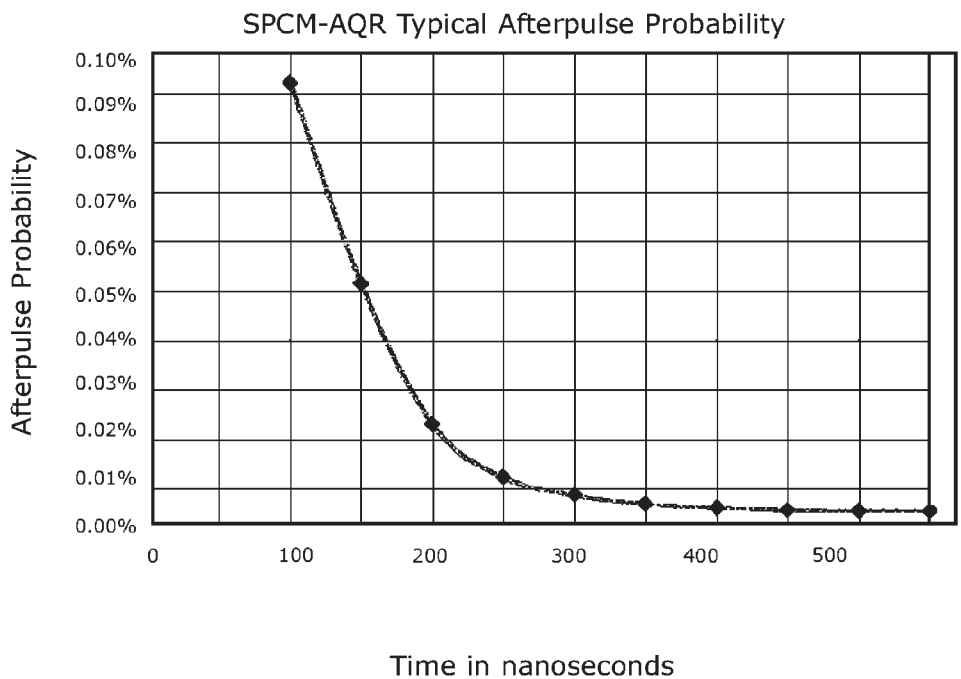


**Figure 4. Photon Detection Efficiency (pd) vs. Wavelength**

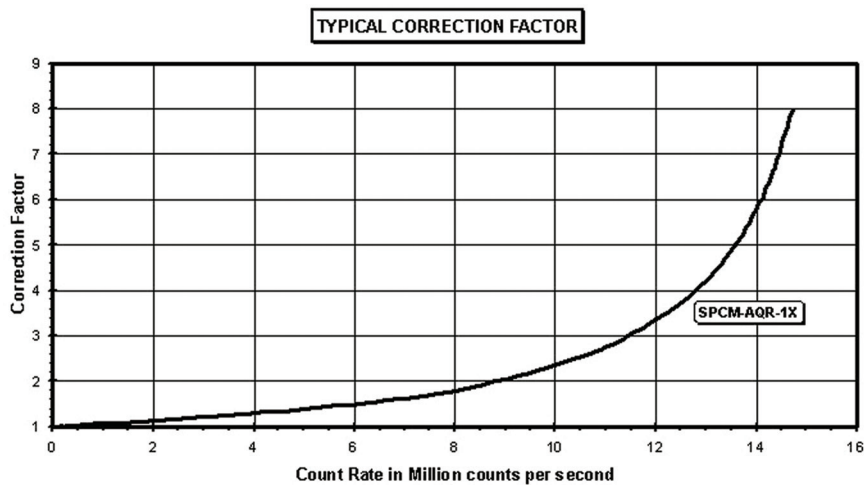




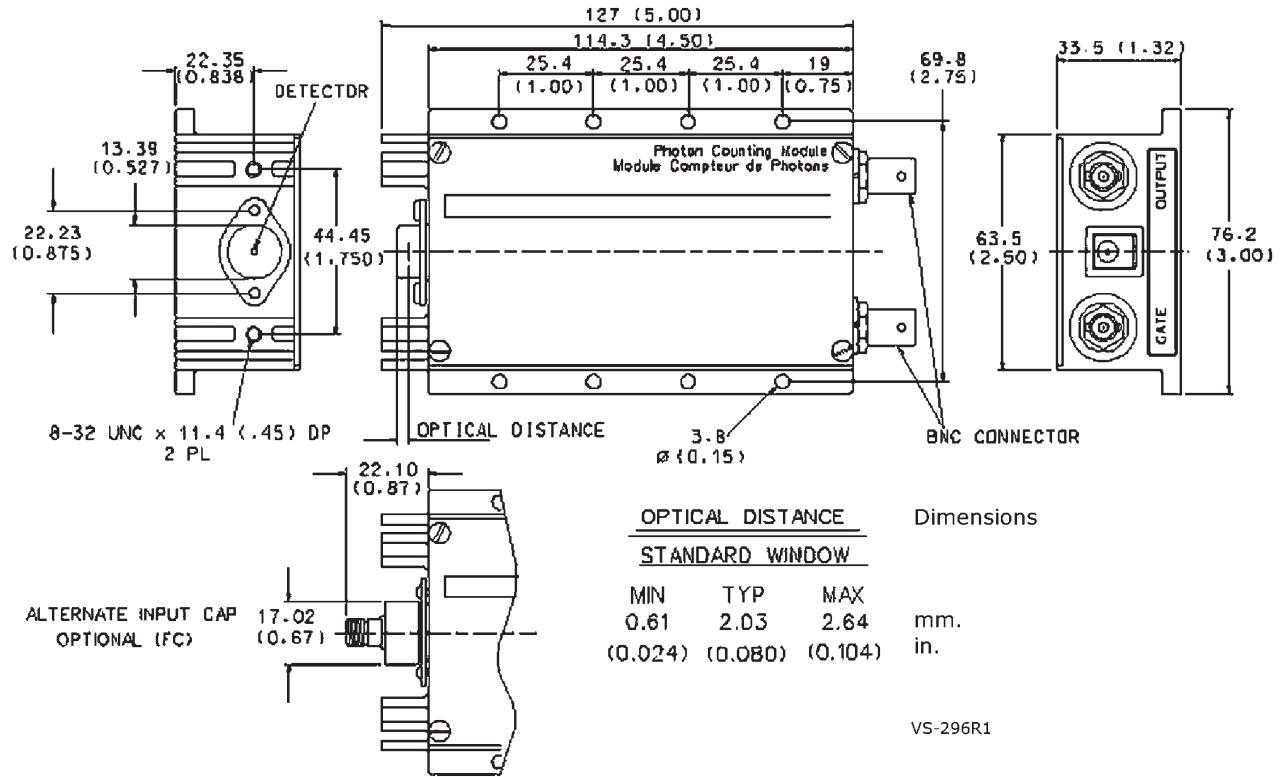
**Figure 5. Typical Afterpulse Probability**



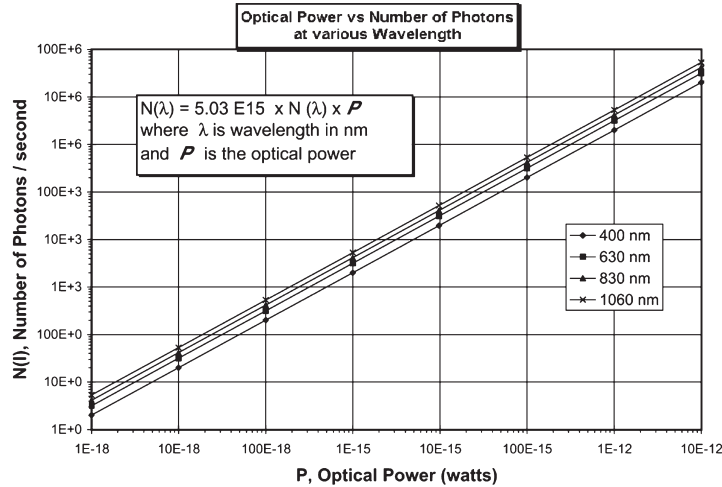
**Figure 6. Typical Correction Factor**



**Figure 7. Dimensional Outline**



**Figure 8. Optical Power vs. Number of Photons**



For more information e-mail us at [opto@perkinelmer.com](mailto:opto@perkinelmer.com) or visit our website at [www.perkinelmer.com/optoelectronics](http://www.perkinelmer.com/optoelectronics)  
 All values are nominal; specifications subject to change without notice.

North America:  
 PerkinElmer Optoelectronics  
 16800 Trans-Canada Highway  
 Kirkland, Quebec J7V 8P7 Canada  
 Toll Free: (877) 734-OPTO (6786)  
 Phone: +1-450-424-3300  
 Fax: +1-450-424-3411

Europe:  
 PerkinElmer Optoelectronics  
 Wenzel-Jaksch-Str. 31  
 D-65199 Wiesbaden, Germany  
 Phone: +49-611-492-430  
 Fax: +49-611-492-165

Asia:  
 PerkinElmer Optoelectronics  
 47 Ayer Rajah Crescent #06-12  
 Singapore 139947  
 Phone: +65-6770-4366  
 Fax: +65-6775-1008

