



EVERYTHING

IN A

NEW

LIGHT

## Single Photon Counting Module SPCM-AQR Series

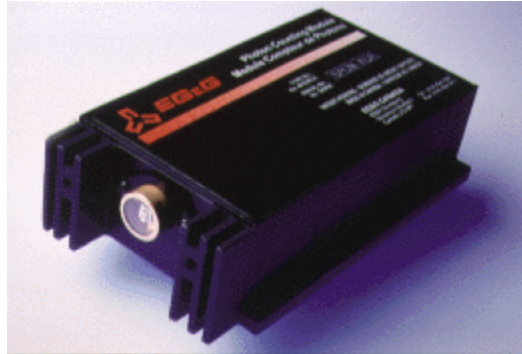
### Description

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-1X utilizes a unique silicon avalanche photodiode which has a circular active area whose peak photon detection efficiency over a 180 mm diameter exceeds 70% at 630 nm. If a bigger detection area is required, the SPCM-AQR-2X has a peak photon detection efficiency over a 475 mm diameter that exceeds 35% at 630 nm. The photodiode is both thermoelectrically cooled and temperature controlled, ensuring stabilized performance despite changes in the ambient temperature.

The SPCM-AQR module utilizes an improved "active quench" patent pending circuit which can count to speeds exceeding 10 million counts per second for the SPCM-AQR-1X and 7 million counts per second for the SPCM-AQR-2X. There is a "dead time" of 40 ns between pulses and single photon arrival can be measured with an accuracy of 300 ps FWHM.

The SPCM-AQR requires a +5 volt power supply (a mating cable is supplied with each module). A TTL pulse, 2.5 volts high in a 50  $\Omega$  load and 25 ns (SPCM-AQR-1X) or 65 ns (SPCM-AQR-2X) 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.



### Features

- Peak Photon Detection Efficiency @ 630 nm:  
SPCM-AQR-1X: 70% TYPICAL  
SPCM-AQR-2X: 35% TYPICAL
- Active Area:  
SPCM-AQR-1X:  $\geq 170$  mm  
SPCM-AQR-2X:  $\geq 425$  mm
- Timing Resolution of 300ps FWHM
- User Friendly

### Applications

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

## SATURATION

At higher incoming light levels, the count levels out and then decreases as light levels continue increasing. The count at which the output rate levels out 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 test should be performed by the operator to ensure that a low count rate is not caused by detector saturation.

Some precaution shall be taken to avoid any excessive light level that will damage the SPCM module.

## FIBER CONNECTOR OPTION - Ordering Guide 1

The SPCM-AQR-WX-FC has an “FC” fiber optic receptacle prealigned to the optical detector. Optical fibers with an FC connector on one end are available separately. 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 detector is **disabled** when a “**low**” level is applied to the module gate input; see specification table for threshold level.

## TIMING RESOLUTION

If the typical 300 ps FWHM (SPCM-AQR-1X) timing resolution is inadequate, then a custom selection is currently available for a better timing resolution. Call the factory for details.

## 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 time exceed the SPCM-AQR dead time, they will be detected.

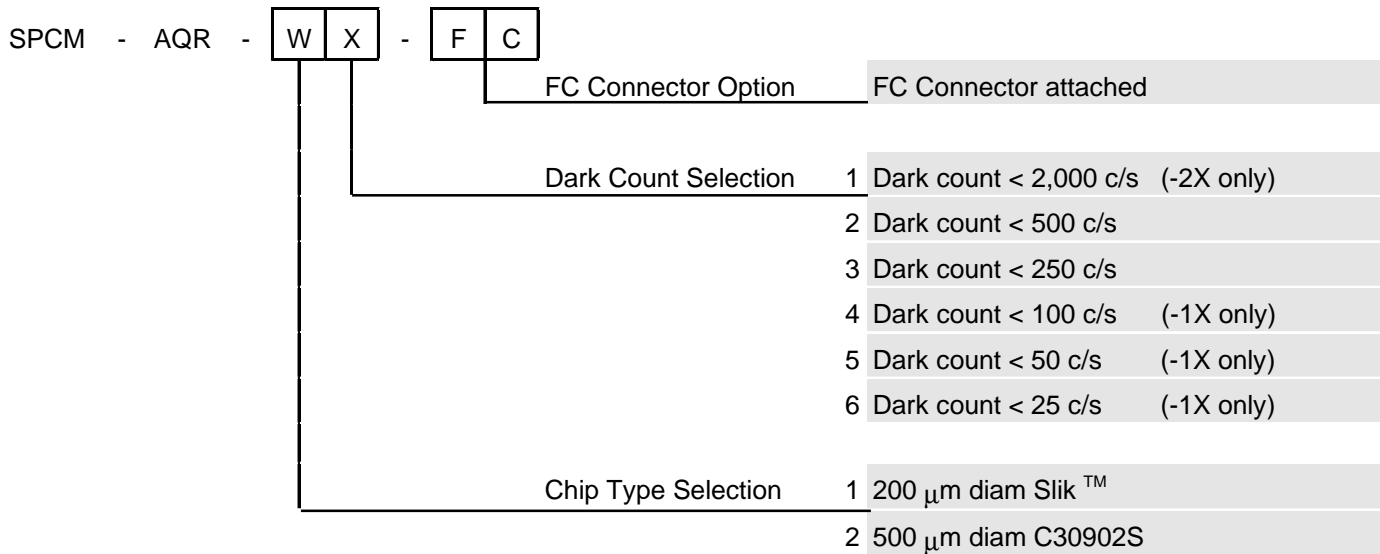
## SAFETY

The SPCM-AQR contains a high voltage power supply. All internal settings are preset; 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.

## ORDERING GUIDE 1:



## ORDERING GUIDE 2:

Standard fiber pigtail options. Standard length is  $1.0 \pm 0.1$  meters.  
Standard pigtail is FC terminated at one end, bare fiber at free end.

| PART NUMBER | FIBER TYPE                                | FIBER MANUFACTURER | DIAMETER           |                   |        | NUMERICAL APERTURE |
|-------------|---|--------------------|--------------------|-------------------|--------|--------------------|
|             |   |                    | CORE               | CLADDING          | OUTER  |                    |
| SPCM-QC4    | Multimode                                 | Canstar            | 62.5 $\mu\text{m}$ | 125 $\mu\text{m}$ | 2.5 mm | 0.27               |
| SPCM-QC6    | Multimode                                 | Canstar            | 100 $\mu\text{m}$  | 140 $\mu\text{m}$ | 2.5 mm | 0.29               |
| SPCM-QC8    | As SPCM-QC6 but 905 SMA on free end       |                    |                    |                   |        |                    |
| SPCM-QC9    | As SPCM-QC-6 but FC connector on free end |                    |                    |                   |        |                    |

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

| PARAMETER  | MIN              |                  | TYP                               |                   | MAX                       |                  | UNITS    |
|--|------------------|------------------|-----------------------------------|-------------------|---------------------------|------------------|----------|
| Supply voltage: 1.9A max., 0.5 A typ. <sup>(1,2)</sup> @ the module connector  | 4.75             |                  | 5.0                               |                   | 5.25                      |                  | V        |
| EG&G power cable total resistance  |                  |                  | 0.2                               |                   |                           |                  | Ω        |
| Case operating temperature <sup>(1,4)</sup>  | 5                |                  |                                   |                   | 40                        |                  | °C       |
| Active area (diameter) @ minimum P <sub>d</sub>  | <b>1X</b><br>170 | <b>2X</b><br>425 | <b>1X</b><br>180                  | <b>2X</b><br>475  |                           |                  | μm       |
| Photon detection efficiency (P <sub>d</sub> ) @ λ = 400nm  | <b>1X</b><br>2.0 | <b>2X</b><br>TBD | <b>1X</b><br>5.0                  | <b>2X</b><br>1.5  |                           |                  | %        |
| 630nm  | 55               | TBD              | 70                                | 35                |                           |                  |          |
| 830nm  | 40               |                  | 50                                | 25                |                           |                  |          |
| 1060nm   | 1.0              |                  | 2.0                               | 1.0               |                           |                  |          |
| P <sub>d</sub> variation at constant case temperature (2h @ 25 °C)   |                  |                  | ± 1                               |                   | ± 3                       |                  | %        |
| P <sub>d</sub> variation, 5 °C to 40 °C case temperature   |                  |                  | ± 4                               |                   | ± 10                      |                  | %        |
| Dark count <sup>(5)</sup>  |                  |                  |                                   |                   |                           |                  | Counts/s |
| SPCM-AQR-21  |                  |                  | 1,000                             |                   | 2,000                     |                  |          |
| SPCM-AQR-W2  |                  |                  | 250                               |                   | 500                       |                  |          |
| SPCM-AQR-W3  |                  |                  | 150                               |                   | 250                       |                  |          |
| SPCM-AQR-14  |                  |                  | 50                                |                   | 100                       |                  |          |
| SPCM-AQR-15  |                  |                  | -                                 |                   | 50                        |                  |          |
| SPCM-AQR-16  |                  |                  | -                                 |                   | 25                        |                  |          |
| Average dark count variation at constant case temperature (6 hrs @ 25 °C) for <sup>(5,6)</sup> :<br>SPCM-AQR-21 & -W2 & -W3<br>SPCM-AQR-14 & -15 & -16 |                  |                  |                                   |                   | ± 10%<br>± 1σ             |                  |          |
| Average dark count variation, 5 °C to 40 °C case temperature for <sup>(5,6)</sup> :<br>SPCM-AQR-21 & -W2 & -W3<br>SPCM-AQR-14 & -15 & -16              |                  |                  |                                   |                   | ± 20%<br>± 2σ             |                  |          |
| Single Photon Timing Resolution  |                  |                  | <b>1X</b><br>300                  | <b>2X</b><br>3000 |                           |                  | ps FWHM  |
| Dead time (Count rates below 5Mc/s)  |                  |                  | <b>1X</b><br>40                   | <b>2X</b><br>85   | <b>1X</b><br>50           | <b>2X</b><br>100 | ns       |
| Output count rate before saturation <sup>(1)</sup>   | <b>1X</b><br>10  | <b>2X</b><br>5   | <b>1X</b><br>15                   | <b>2X</b><br>10   |                           |                  | Mc/s     |
| Linearity correction factor: <sup>(7)</sup><br>@ 200 kc/s<br>@ 1 Mc/s<br>@ 5 Mc/s  |                  |                  | <b>1X</b><br>1.01<br>1.08<br>1.40 | <b>2X</b><br>TBD  | <b>1X</b><br>1.15<br>1.67 | <b>2X</b><br>TBD |          |
| Afterpulsing probability   |                  |                  | <b>1X</b><br>0.15                 | <b>2X</b><br>1.0  | <b>1X</b><br>0.30         | <b>2X</b><br>TBD | %        |
| Settling time following power up (1% stability) @ 1 Meg counts/sec and 25 °C   |                  |                  | 15                                |                   | 30                        |                  | s        |
| Threshold setting required for digital output pulse (terminate in 50 ohms)   | 0.75             |                  | 1.0                               |                   | 2.0                       |                  | V        |
| Pulse Width  |                  |                  | <b>1X</b><br>25                   | <b>2X</b><br>65   |                           |                  | ns       |
| Gating turn on/off: (50 Ω input)   |                  |                  |                                   |                   |                           |                  |          |
| Disable = TTL Low  |                  |                  | 2                                 |                   | 4                         |                  | ns       |
| Enable = TTL High  |                  |                  | 45                                |                   | 55                        |                  | ns       |
| Gate 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        |

Notes:

1. Absolute Maximum ratings:
 

|                  |   |
|------------------|---|
| Supply Voltage   | 5.5V  |
| Mean Count Rate  | 5 Mc/s (Above this point, dead time will increase due to diode self-heating). |
| Peak Count Rate  | The SPCM-AQR-15 and the SPCM-AQR-16 have a maximum count rate of 5 Mc/s       |
| Case Temperature | 50° C Storage, 40° C Operating  |
2. Connection to incorrect voltage or reverse voltage may destroy the module. The warranty is invalid where such damage occurs.
3. These modules are not qualified for shock or vibration other than normal instrumentation environments.
4. The module dissipates a mean power of 2.5W, and a maximum power of 10W at high count rate and 40°C. Adequate heatsinking must be provided by clamping the module to a suitable heatsink via the holes in the module base. For the specification performance, the module case temperature must not exceed 40°C.
5. Bistability of the dark count. On a small percentage of delivered modules, bistability of the dark count has been observed. Research indicates that this bistability is *probably* due to transitions at a single impurity site between a lower 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.
6. In the dark the module generates random counts that follow a "Poisson" distribution. In a Poissonian process the standard deviation ( $\sigma$ ) 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:

$$ACTUALCOUNT\ RATE_{Photons} = \frac{(OUTPUT\ Module\ Count\ Rate\ x\ CORRECTION\ FACTOR@the\ Module\ Count\ Rate) - DARK\ COUNT\ Module}{PHOTON\ DETECTION\ EFFICIENCY\ Module}$$

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

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

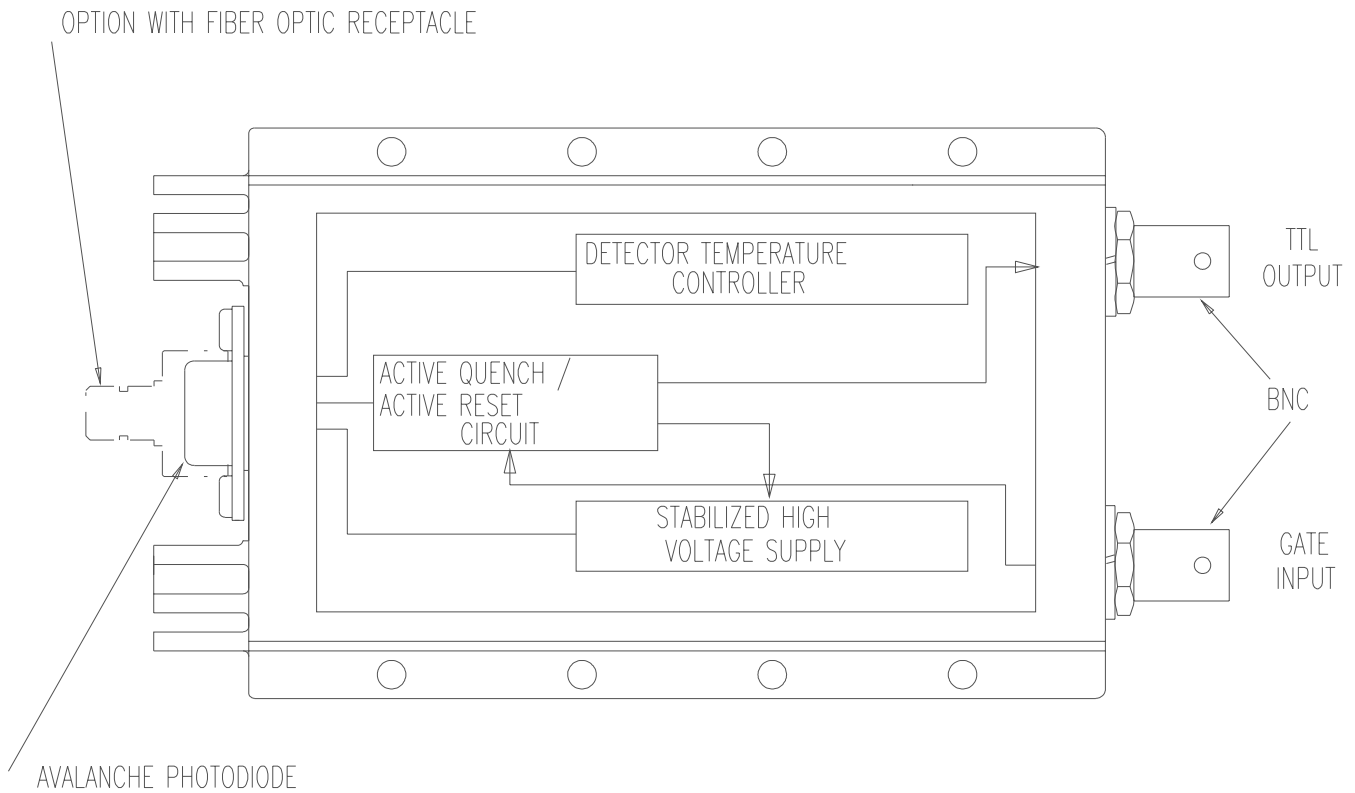
Where:  $\tau_D$  = Module Dead Time  
 $C_R$  = Output Count Rate

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

$$LINEARITY = \frac{OUTPUT\ Module\ Count\ Rate}{(PHOTONS\ Actual\ Count\ Rate\ x\ PHOTON\ DETECTION\ EFFICIENCY\ Module) + DARK\ COUNT\ Module} - 1$$

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

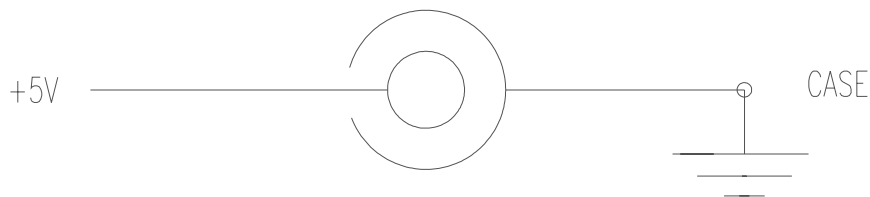
## Block Diagram of Module



VS-297R1

## Electrical Connections

### POWER CONNECTOR POLARITY



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 STRIPPED LEAD  
WIRE GAUGE = 22 AWG  
LENGTH = 1.8 m (72")

VS-298

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

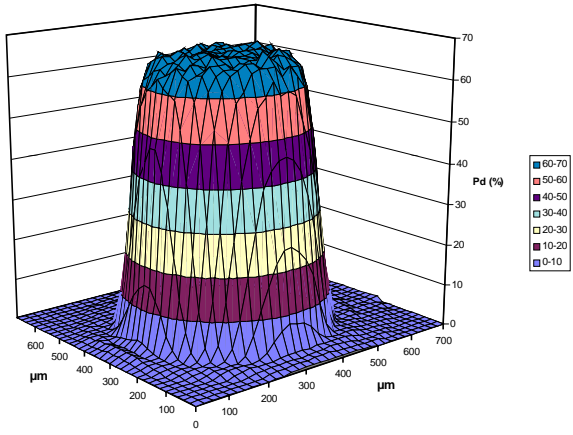


Fig. 1: SPCM-AQR-1X Photon Detection Scan @ 650nm

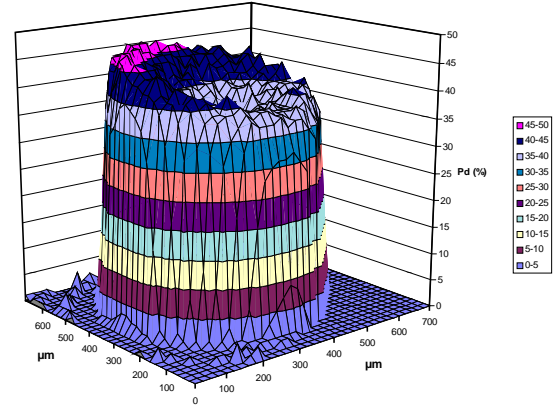


Fig. 2: SPCM-AQR-2X Photon Detection Scan @ 650nm

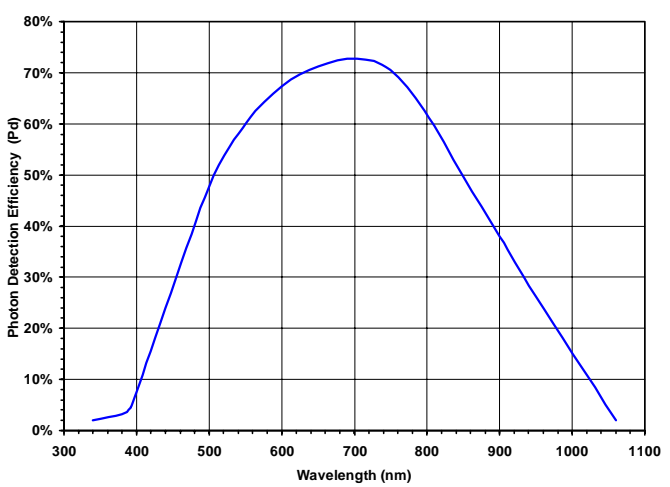


Fig. 3: SPCM-AQR-1X Photon Detection Efficiency vs Wavelength

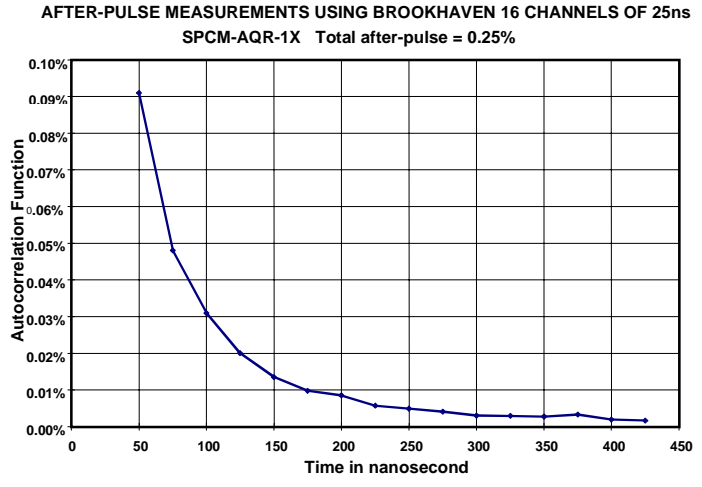


Fig. 4: SPCM-AQR-1X Typical After Pulse Probability

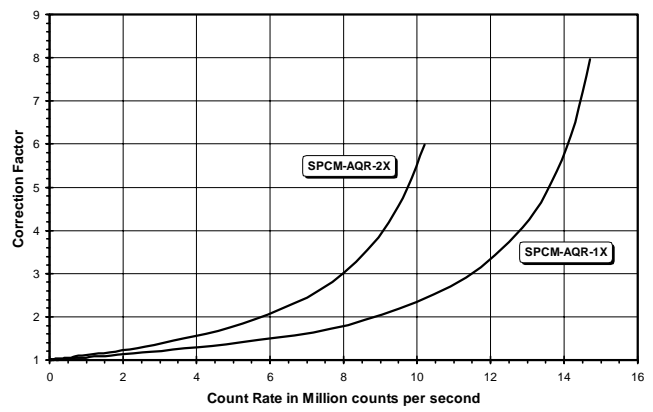


Fig. 5: Typical Correction Factor

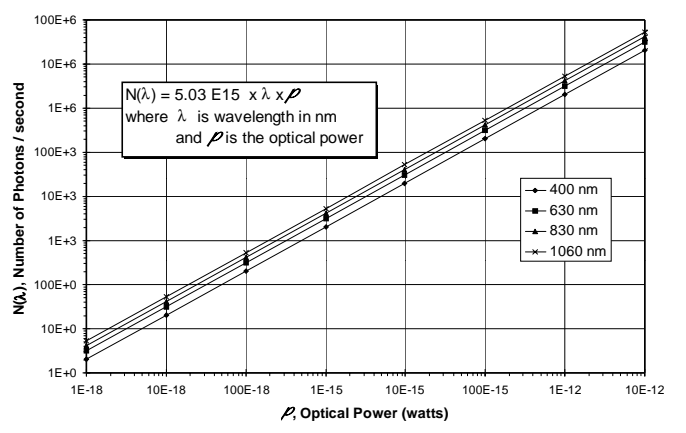
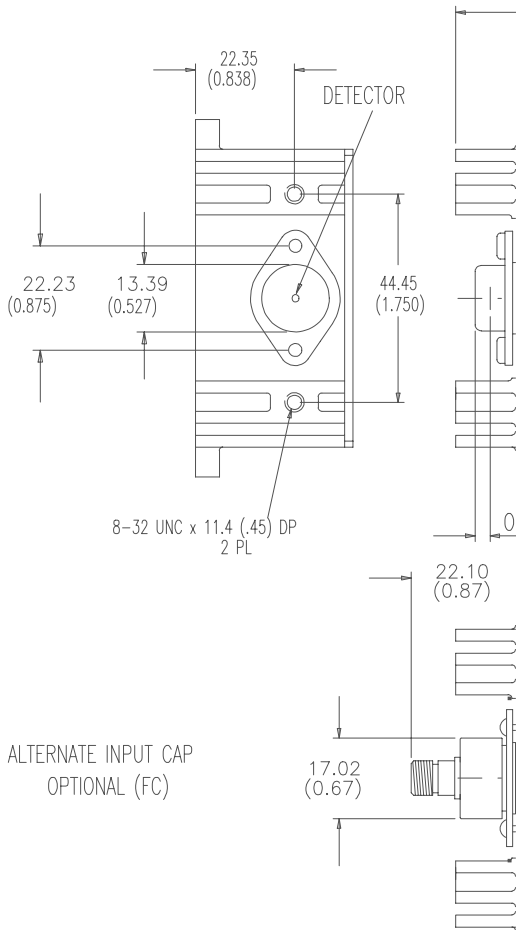


Fig. 6: Optical Power vs Number of Photons at Various Wavelengths

# Dimensional Outline



Dimensions in mm (inches). Do not warp the module walls during mounting since electronic components are attached to them. The rated case temperature is 5° to 40°C, so it is necessary to ensure good heatsinking or ventilation.

EG&G welcomes inquiries about special types. We would be pleased to discuss the requirements of your application and the feasibility of designing a type specifically suited to your needs.

**EG&G**® is a registered trademark of EG&G, Inc.



All values are nominal; specifications subject to change without notice.

EG&G  
 22001 Dumbrery Road  
 Vaudreuil, Quebec  
 J7V 8P7 Canada  
 1-800-775-OPTO (USA)  
 Tel: (450)-424-3300  
 Fax: (450)-424-3411