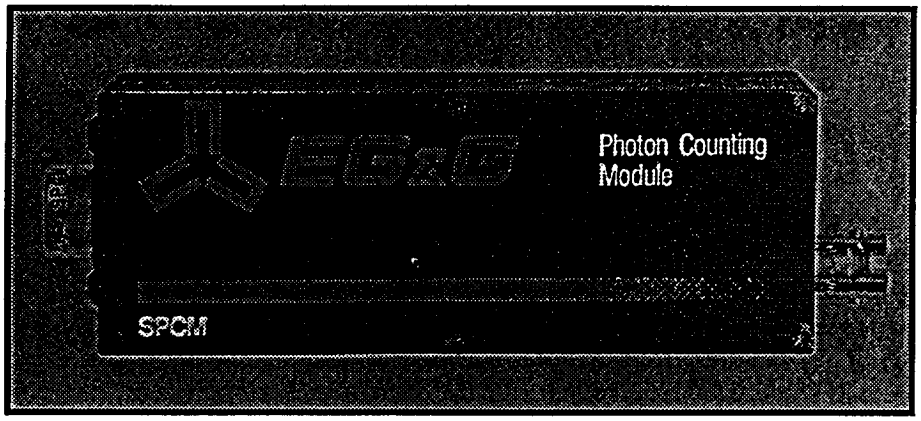
Single Photon Counting Module

SPCM-AQ Series



Features:

- Peak Photon Detection Efficiency @ 700nm:
  SPCM-AQ-1XY: 70% Typical
  SPCM-AQ-2XY: 35% Typical
- Active Diameter:
  SPCM-AQ-1XY: ≥ 180µm
  SPCM-AQ-2XY: ≥ 475µm
- Timing Resolution of 300ps FWHM
- User Friendly

Applications:

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

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

The SPCM-AQ-1XY utilizes a unique silicon avalanche photodiode which has a circular active area. The peak photon detection efficiency over a 180µm diameter exceeds 70% at 700nm. If a larger detection area is required, the SPCM-AQ-2XY has a peak photon detection efficiency over a 475µm diameter that exceeds 35% at 630 nm. The photodiode is both thermoelectrically cooled and temperature controlled, ensuring stable performance despite changes in the ambient temperature.

The SPCM-AQ-1XY module utilizes a patented "active quench" circuit which can count to speeds exceeding 10 million counts per second. The SPCM-AQ-2XY can acheive 7 million counts per second. There is a "dead time" of 30ns between pulses and single photon arrival can be measured with an accuracy of 300ps FWHM.

The SPCM-AQ requires a +5 volt power supply (a mating cable is supplied with each module). A TTL pulse, 2 volts high in a 50Ω load and 9ns (SPCM-AQ-1XY) or 40ns (SPCM-AQ-2XY) 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 10°C and 35°C during operation.

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Specifications: *SPCM-AQ-WXY @ 22°C, all models, unless otherwise indicated.*

Parameter	MIN	TYP	MAX	UNITS
Supply voltage: 1.6A max., 0.7A typ. [1,2] @ the module connector @ the EG&G power cable wires end	 4.75 4.90	 5.0 5.1	 5.25 5.30	V
Case operating temperature [1,4]	10		35	°C
Active area (diameter) @ minimum Pd	-1XY - 2XY 170 425	-1XY -2XY 180 475		µm
Photon detection efficiency (P_d) @ λ = 400nm λ = 630nm λ = 830nm λ =1060nm	-1XY -2XY 2.0 1.0 50 30 40 20 1.0 0.5	-1XY -2XY 5.0 1.5 70 35 50 25 2.0 1.0		%
P_d variation at constant case temperature (2h @ 25°C)		±3	±5	%
P_d variation, 10°C to 35°C case temperature (2h @ 25°C)		±5	±10	%
Dark count [5] SPCM-AQ-W1Y SPCM-AQ-W2Y SPCM-AQ-W3Y SPCM-AQ-14Y SPCM-AQ-15Y SPCM-AQ-16Y		1,000 250 150 50 – –	2,000 500 250 100 50 25	Counts/s
Average dark count variation at constant case temperature (2hrs @ 25°C) for [6,7]: SPCM-AQ-W1Y & -W2Y & -W3Y SPCM-AQ-W4Y & -15Y & -16Y			 ±10% ±1 σ	
Average dark count variation 10° to 35°C case temperature for [6,7]: SPCM-AQ-W1Y & -W2Y & -W3Y SPCM-AQ-W4Y & -15Y & -16Y			 ±20% ±2 σ	
Dead time (Count rates below 5Mc/s)		-1XY - 2XY 30 70	-1XY -2XY 50 100	ns
Output count rate before saturation [1]	-1XY - 2XY 10 7	-1XY -2XY 15 10		Mc/s
Linearity correction factor: [8] @ 200kc/s @ 1Mc/s @ 5Mc/s		-1XY - 2XY 1.01 1.02 1.05 1.11 1.33 1.82	-1XY -2XY 1.67 2.5	
Afterpulsing probability		-1XY - 2XY 0.2 1.0	-1XY -2XY 0.75 4.0	%
Single photon timing resolution (-XY only):		300		ps FWHM
Settling time following power up (1% stability) @ 1 Mcounts/sec and 25°C		13	15	s
Threshhold setting required for digital output pulse (Terminate in 50 ohms)	0.5	1.0	1.5	V
Pulse Width (Terminated in 50 Ohms)		-1XY -2XY 9 40		ns FWHM
Gating Turn On/Off: On=TTL High (3V<VOn<5.5V<10mA) Off=TTL Low (0V<VOff<0.3V)		 100 50		ns

Notes:

1. Absolute Maximum ratings:

Supply Voltage	5.3V
Mean Count Rate	5Mc/s (Above this point, dead time will increase due to diode self-heating).
Peak Count Rate	10Mc/s for brief periods. See note 5 below for SPCM-151 and SPCM-161 modules.
Case Temperature	50°C Storage, 35°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 3.5W, and a maximum power of 8W at high count rates and 35°C. Adequate heatsinking must be provided by clamping the module to a suitable heatsink via the 1/4"-20 blind nuts in the module base. For the specified performance, the module case temperature must not exceed 35°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 390c/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. Also, the SPCM-151 and the SPCM-161 have a maximum count rate of 5Mc/s.

6. EG&G performs an 6 hour screen on temperature stability which includes dark count; this test also screens for bistability and multistability. Longer term bistability would not be detected by this test because this phenomenon is related to fundamental semiconductor physics and is outside EG&G's control. Warranty claims will only be entertained if the high level of the dark count exceeds the "max" level in the specification.

7. In the dark, the module generates random counts that follow a "Poission" distribution. In a Poissonnian process the standard deviation (σ) 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.

8. The actual photon rate could be calculated using the following equation:

$$\text{Actual Count Rate}_{\text{Photons}} = \frac{(\text{Output}_{\text{Module Count Rate}} \times \text{Correction Factor @ the Module Count Rate}) - \text{Dark Count}_{\text{Module}}}{\text{Photon Detection Efficiency}_{\text{Module}}}$$

The theorical value of the correction Factor follows this equation:

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

Where: τ_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:

$$\text{Linearity} = \frac{\text{Output}_{\text{Module Count Rate}}}{(\text{Photons}_{\text{Actual Count Rate}} \times \text{Photon Detection Efficiency}_{\text{Module}}) + \text{Dark Count}_{\text{Module}}} - 1$$

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

Ordering Guide 1

SPCM - AQ - W X Y - F Z

FC Connector Option	C	FC Connector Attached	
Module Option	1	Standard	
	2	Gated Option	
Dark Count Selection	1	Dark count < 2,000c/s	-2XY only
	2	Dark count < 500c/s	
	3	Dark count < 250c/s	
	4	Dark count < 100c/s	-1XY only
	5	Dark count < 50c/s	-1XY only
	6	Dark count < 25c/s	-1XY only
Chip Type Selection	1	200µm diam. Slik™	
	2	500µm diam. C30902S	

Ordering Guide 2

Standard fiber pigtail options. Standard length is 1.0 ± 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	62.5µm	125µm	2.5mm	0.27
SPCM-QC6	multimode	Canstar	100µm	140µm	2.5mm	0.29
SPCM-QC8		As SPCM-QC6 but 905 SMA on free end				
SPCM-QC8		As SPCM-QC6 but FC connector on free end				

Fiber Connector Option
Ordering Guide 1

The SPCM-AQ-WXY-FZ 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 1.* The photon detection efficiency of connectorized modules is about 90% 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 pigtails conform to this requirement, see *Ordering Guide 2.*

Gating Option
Ordering Guide 1

The gating option 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 module may be gated by applying a TTL "high" level to the module PIN 4.

Figure 1:
Typical Photon detection Efficiency vs Wavelength

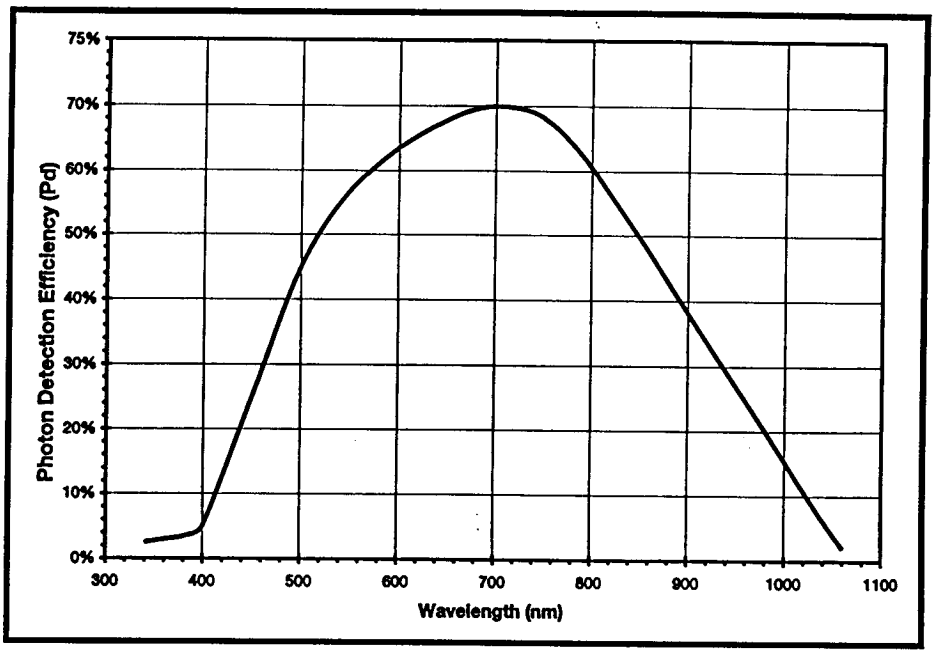
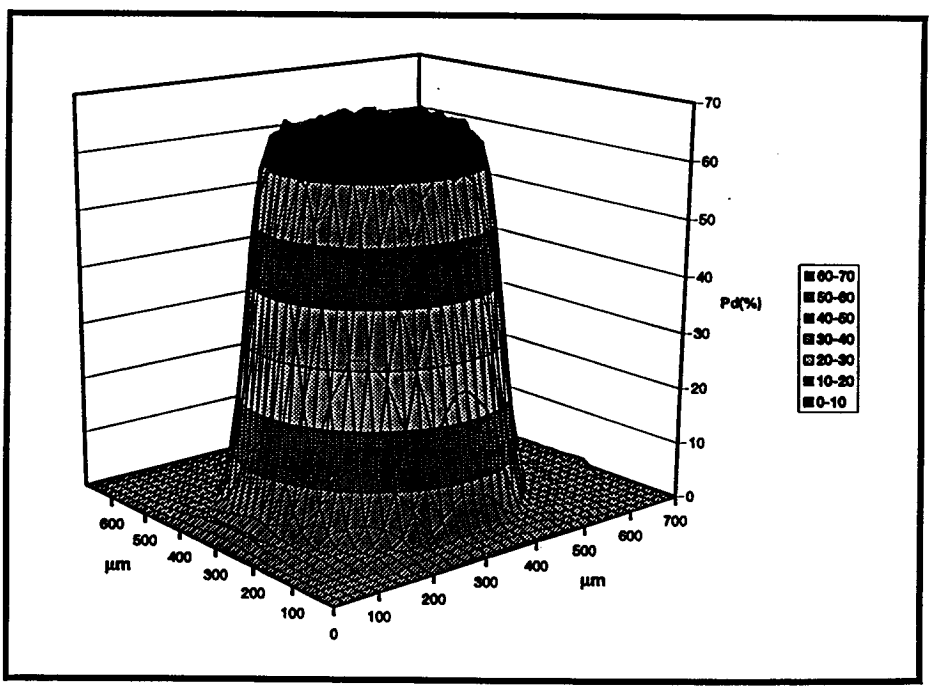


Figure 2:
Typical SPCM-AQ-1XY Photon Detection scan @ 650nm



Saturation

At higher incoming light levels, the count decreases. 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.

Some precaution shall be taken to avoid any damage of the SPCM module: First, do not expose the detector to room light when the module is being powered up. Secondly, do not power up the module when the detector is exposed to a photon rate above 1Mc/s.

Timing Resolution

If the 300ps FWHM (SPCM-AQ-1XY) timing resolution is inadequate, then the SPCM-PQ CD2027 is currently available with a lower timing resolution. Call the factory for details.

Light Emission During Photon Detectiion

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.

Figure 3:
Typical SPCM-AQ-2XY Photon Detection scan @ 650nm

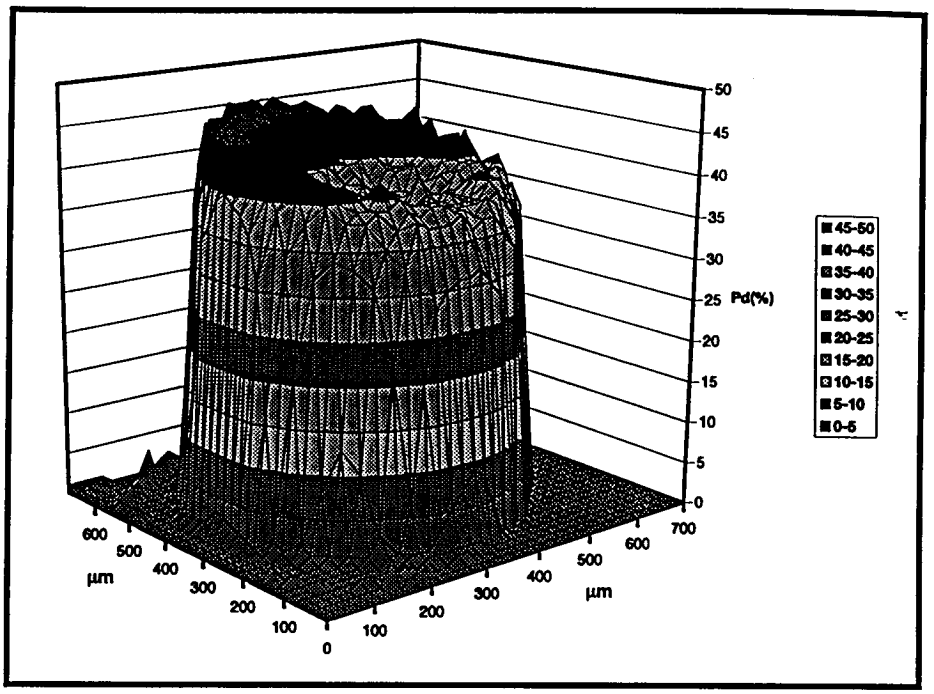
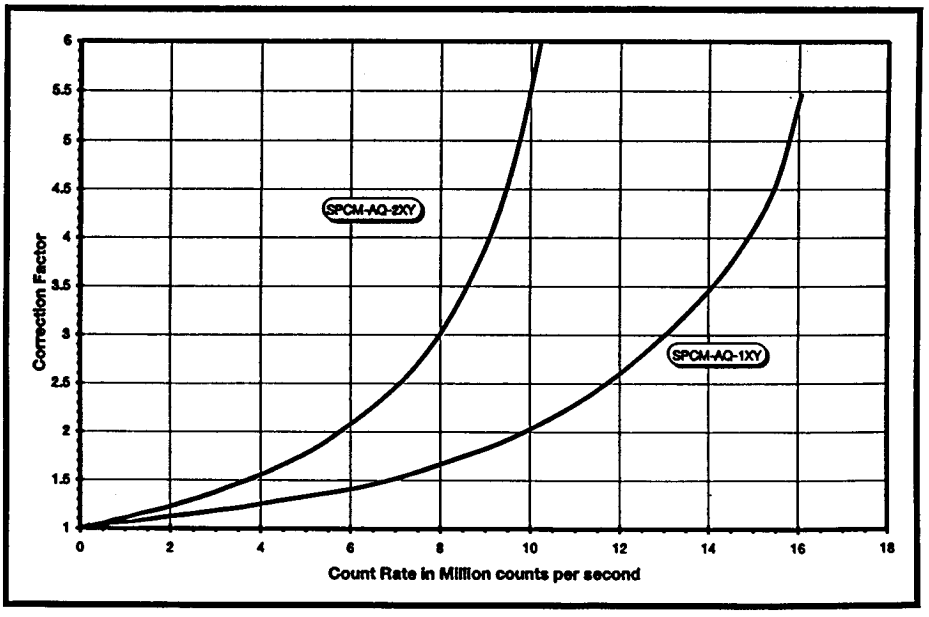


Figure 4:
Typical correction factor



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-AQ is reflected back on itself. If these photons return after more than 30ns after the initial event, then they will be detected.

Safety

The SPCM-AQ 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.

Figure 5:
Typical after pulse probability

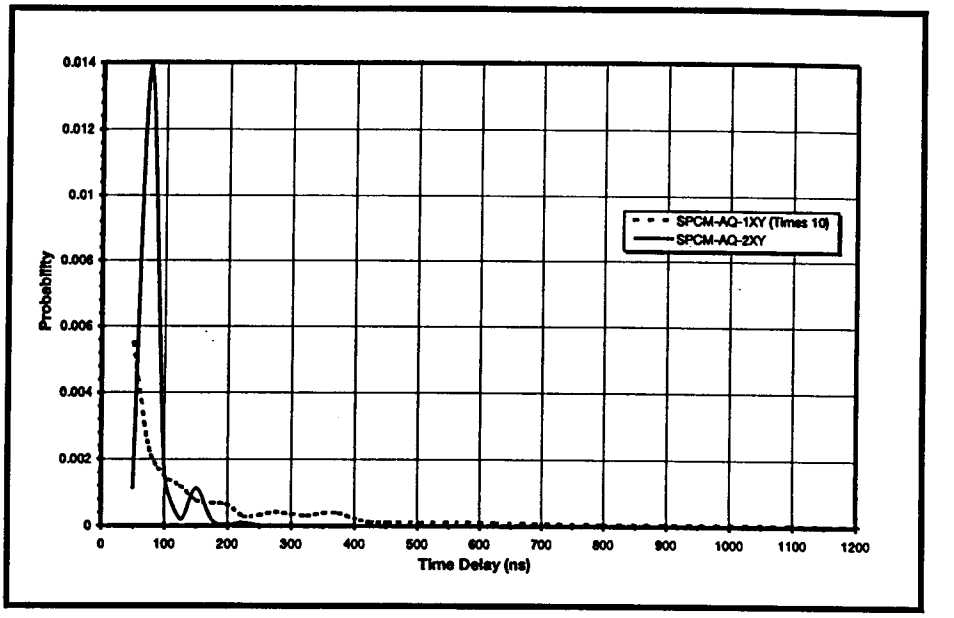
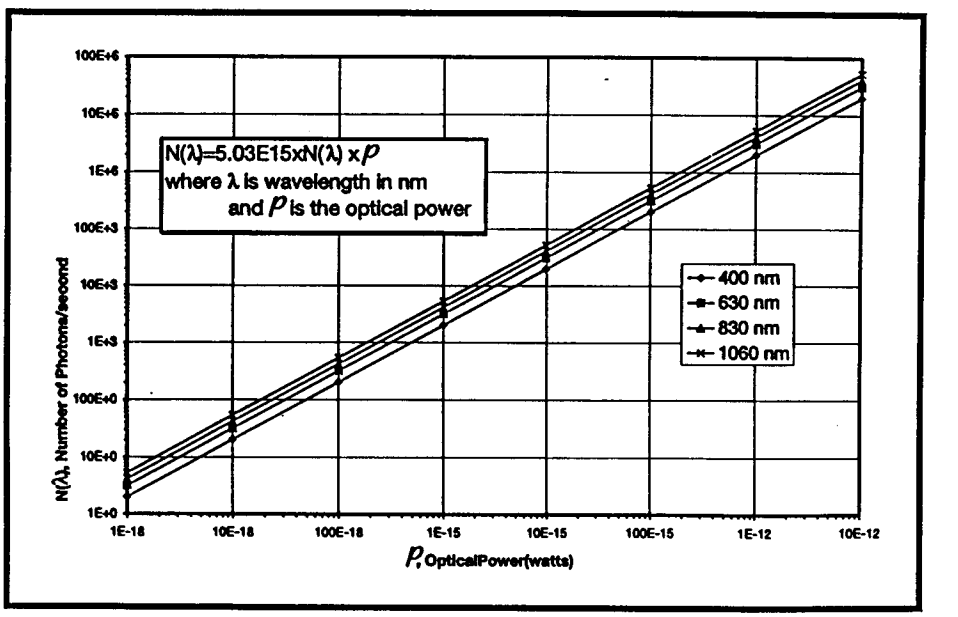


Figure 6:
Optical Power vs Number of Photons at Various wavelengths



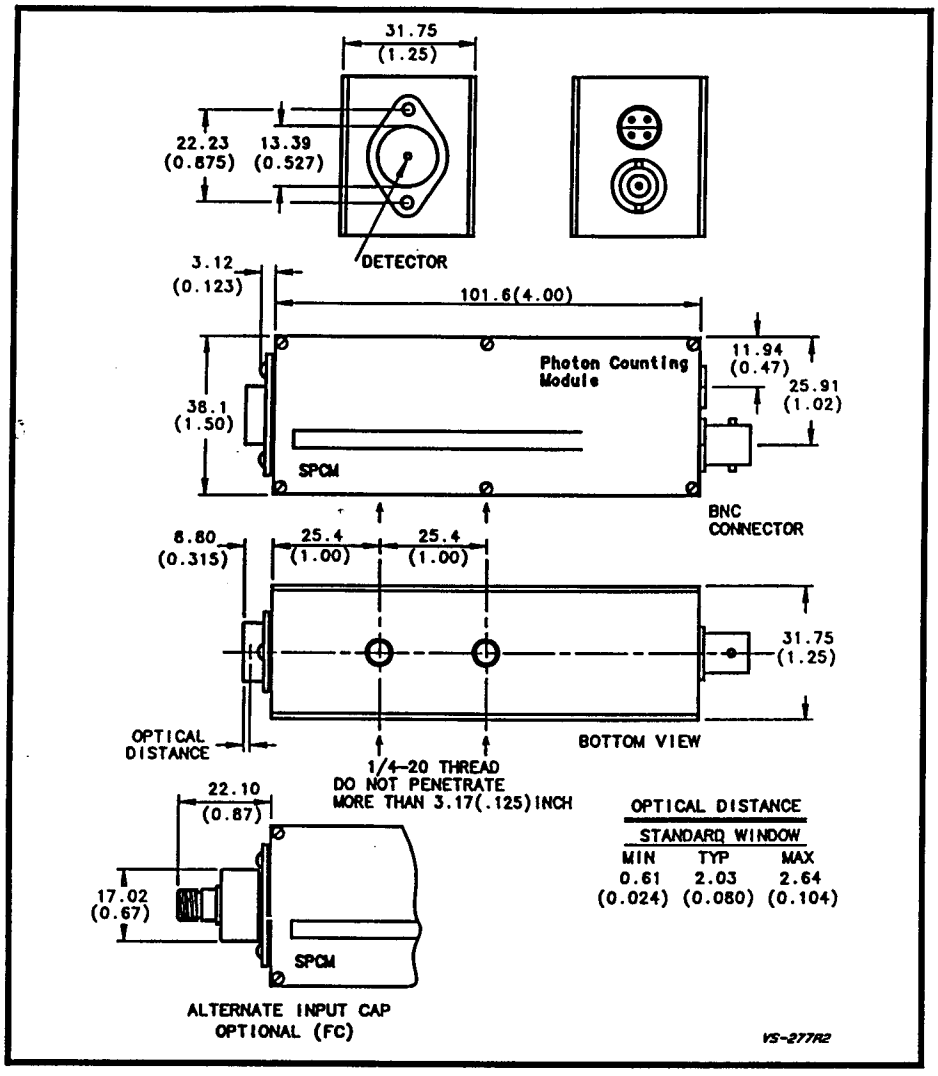


Figure 7:

Dimensions in mm (inches). Do not warp the module walls during mounting since electronic components are attached to them. The rated case temperature is 10°C to 35°C, so it is necessary to ensure good heatsinking and ventilation.

Figure 8: Block Diagram of Module

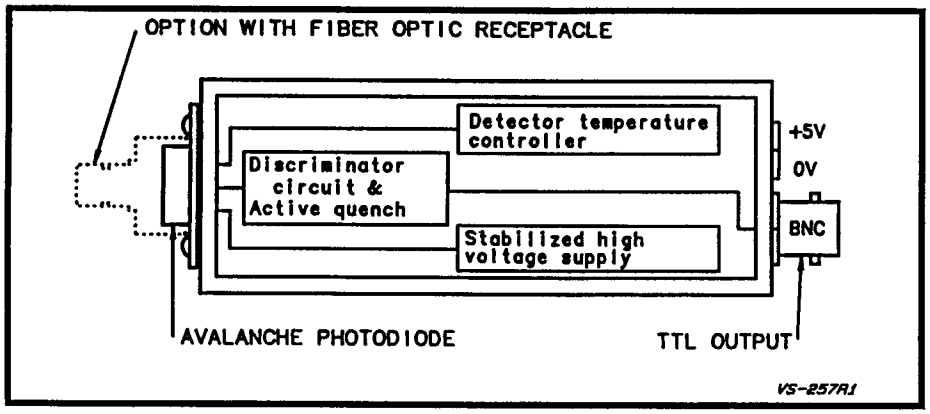
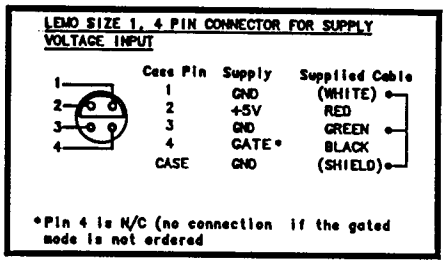


Figure 9: Electrical Connections



* *Pin 4 is N/C (no connection) if the gated mode is not ordered*
* *Wire colors in brackets are internally connected in the cable assembly*

This shield must be connected to the ground wire at the power supply end. This has been done in the 1 meter cable supplied. The digital output pulse, ≥ 2.0V, should be terminated with a 50Ω load to avoid distortion and ringing. A 1.0V triggering level is recommended.

EG&G CANADA

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SINGLE PHOTON COUNTING MODULE (04-22-97)

SPCM: High Timing Resolution Version

SPCM-200 CD2027

PARAMETER	SPECIFICATION
Probability of Detection (Pd)	> 60% @ 650nm typical
Background Count Rate	200 c/s max., ~80 c/s typ.
Saturation Count Rate	500 kc/s min., 700kc/s typ.
Timing Resolution, FWHM	230 psec typ., 400 psec max
Dead Time	~150 μsec
Output (analog signal) into 50Ω	-50 to -100 mV
Supply Voltages	±5V and +12V

Features:

- High timing resolution
- High probability of detection
- Low background count rate
- Temperature controlled
- User friendly

Applications:

- Photon correlation Spectroscopy
- Ultra-sensitive fluorescence
- High-precision LIDAR

Product Information

The SPCM-200 is a self-contained module which detects single photons over the wavelength range of 400nm to 1060nm.

The SPCM-200 CD 2027 utilizes a 180 μm diameter SliK® Silicon avalanche photodiode and a passive-quench circuit. The photodiode is mounted on a 2-stage thermo-electric cooler and is temperature controlled, ensuring stable performance despite changes in the ambient temperature.

In this SPCM version, the output signal is the direct, raw photodiode signal, which minimizes timing jitter and provides for pulse-to-pulse timing resolution on the order of 230 psec.

Also available are active-quench modules which have TTL outputs, lower background count rates and higher count-rate abilities. Please contact EG&G for details at (514) 424-3300.

Usage Notes

The output BNC is normally connected to a suitable amplifier (1 Ghz NIM module, Gain ~ 100) followed by a discriminator and then a TAC (Time-to-Amplitude Converter).

For best results, keep the signal focussed in the center of the active area.

- Use a very clean window and optics to avoid scattering
- Use a spot focussed to within ~30 μm
- Use a lens with minimal aberrations

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