Operating Instructions

S900
Single Photon Photomultiplier Detection System

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Edinburgh Instruments Ltd., 2 Bain Square, Kirkton Campus, Livingston, EH54 7DQ. UK
T: +44 (0)1506 425300 - F: +44 (0)1506 425320 - E: eai.service@edinst.com - W: www.edinst.com

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1. Introduction

The S900 is a photomultiplier detection system specifically designed to operate in the single photon counting mode. General components of the photomultiplier detection system are:

- a side window photomultiplier
- the photomultiplier socked and the voltage-divider circuit
- the photomultiplier housing
- a mechanical / optical coupling flange to the monochromator

There are two standard versions of the S900, one version containing a blue sensitive photomultiplier covering a spectral range up to about 670nm (S900-B) and another version containing a red sensitive photomultiplier with a sensitivity in a spectral range up to about 870nm (S900-R). The red sensitive version is generally operated with a cooled housing at -20°C to -30°C . It therefore comprises the following items in addition to the list given above:

- a cooled photomultiplier housing
- a cooler power supply.

Warning

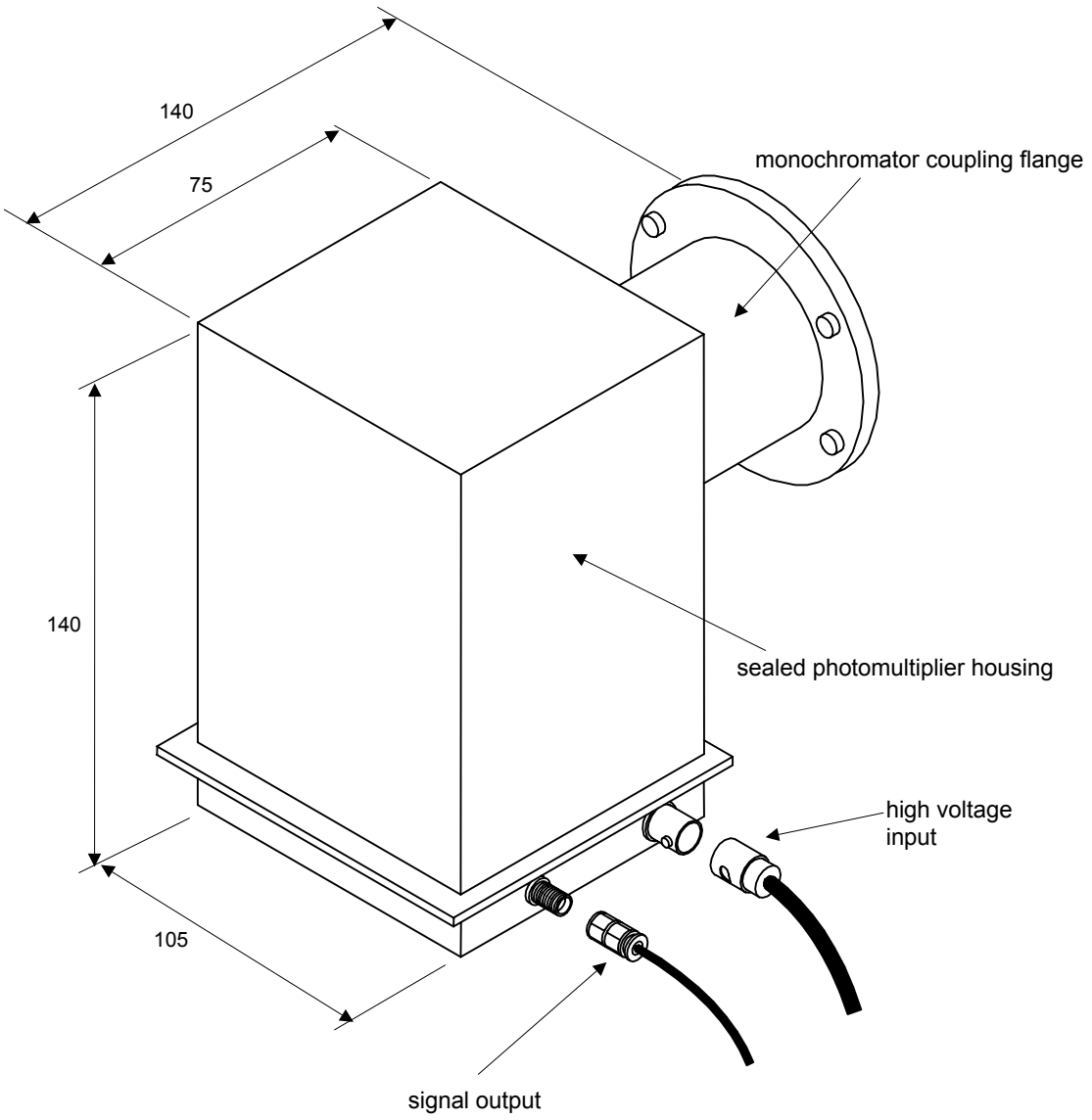
The photomultiplier detectors are operated at voltages exceeding 1000Vdc.
Improper use of the S900 can cause serious personal injury!

Never open the detector housing nor the high voltage power supply.
Plug and unplug the high voltage cable only when the instrument is switched off or the high voltage is turned down to zero.
Service the red sensitive photomultiplier only when the instrument is switched off and the high voltage cable is disconnected from the detector head.

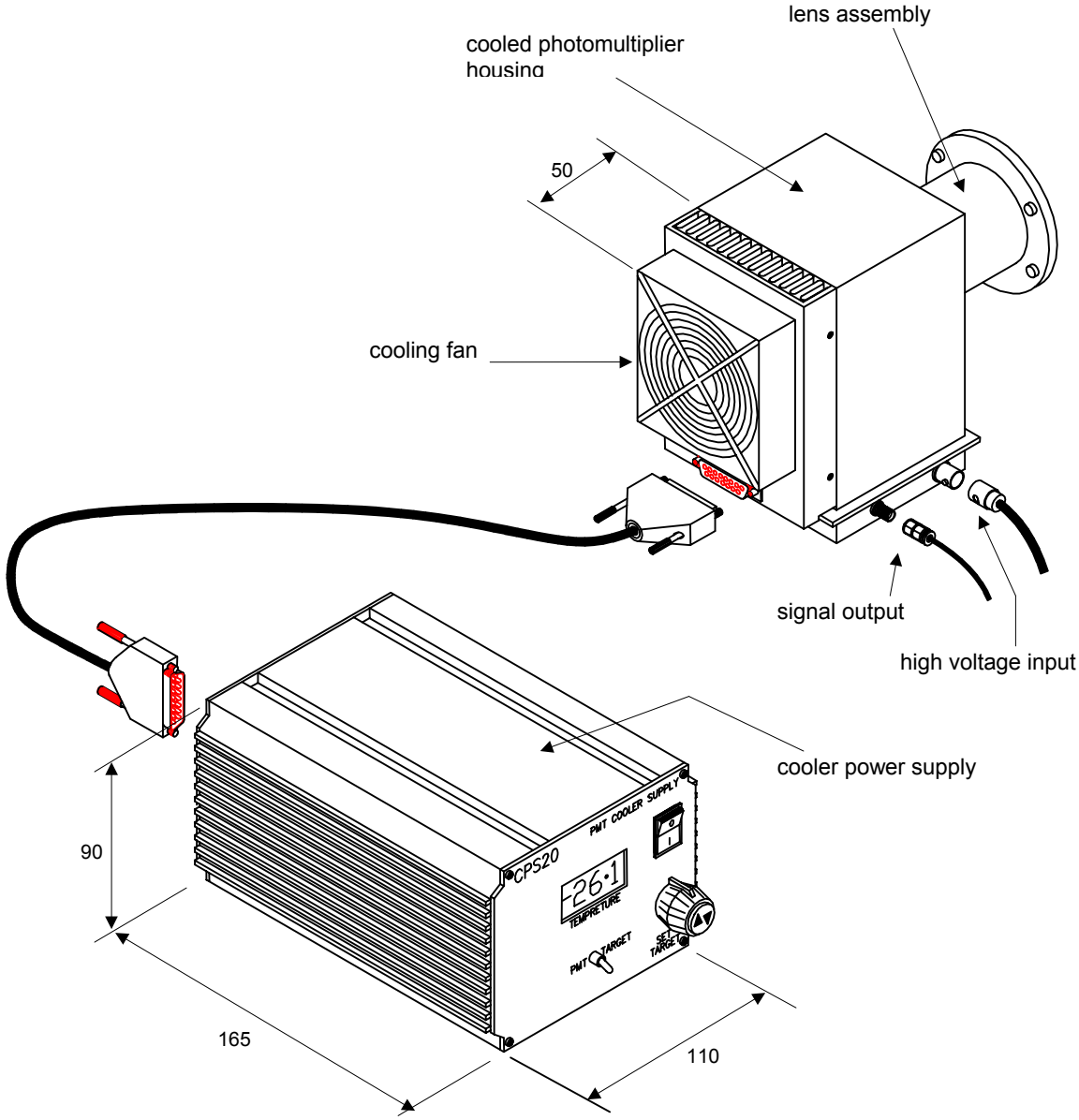
Warning

Photomultiplier detectors are extremely sensitive to light. Exposure of photomultipliers to ambient light levels when operated at bias voltages can cause damage to the detectors.

Disconnect the mechanical assembly only from the monochromator when the detector is switched off, or when the high voltage is turned down and the optical shutter is closed.



blue sensitive photomultiplier detector assembly S900-B



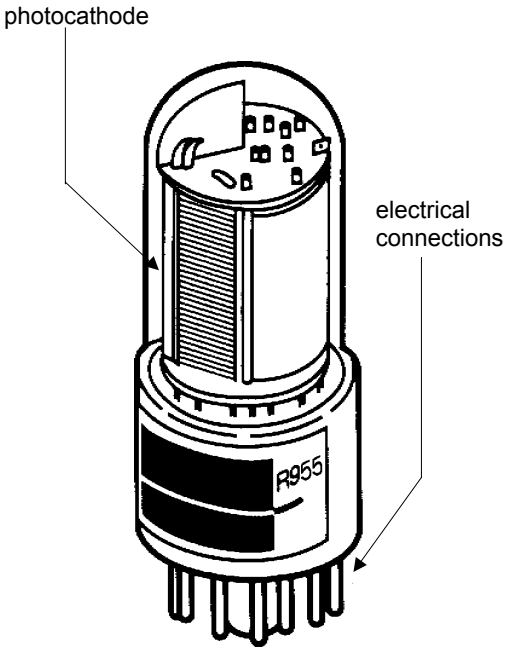
red sensitive photomultiplier detector assembly S900-R

1.1. Photomultiplier

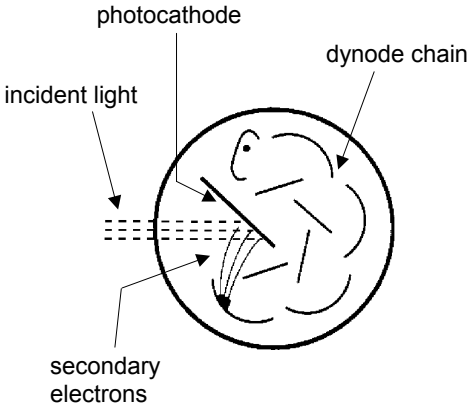
The photomultipliers used are Hamamatsu photomultipliers, specifically designed for single photon operation with very high amplification and very low dark noise level. They are photomultipliers of the side-on type, i.e. they receive the incident light through a side window (in contrast to the head-on type, which has the photosensitive area at the end of the photomultiplier tube).

Special features of the side-on photomultipliers are:

- opaque photocathode (reflection mode photocathode)
  ⇒ slightly enhanced sensitivity on the long wavelength side, in comparison to transmission mode photocathodes.
- rectangular photosensitive area
  ⇒ matches the image of a monochromator exit slit
- circular cage dynode chain
  ⇒ fast time response
  ⇒ compactness
- high amplification
  ⇒ direct signal processing of photon pulses



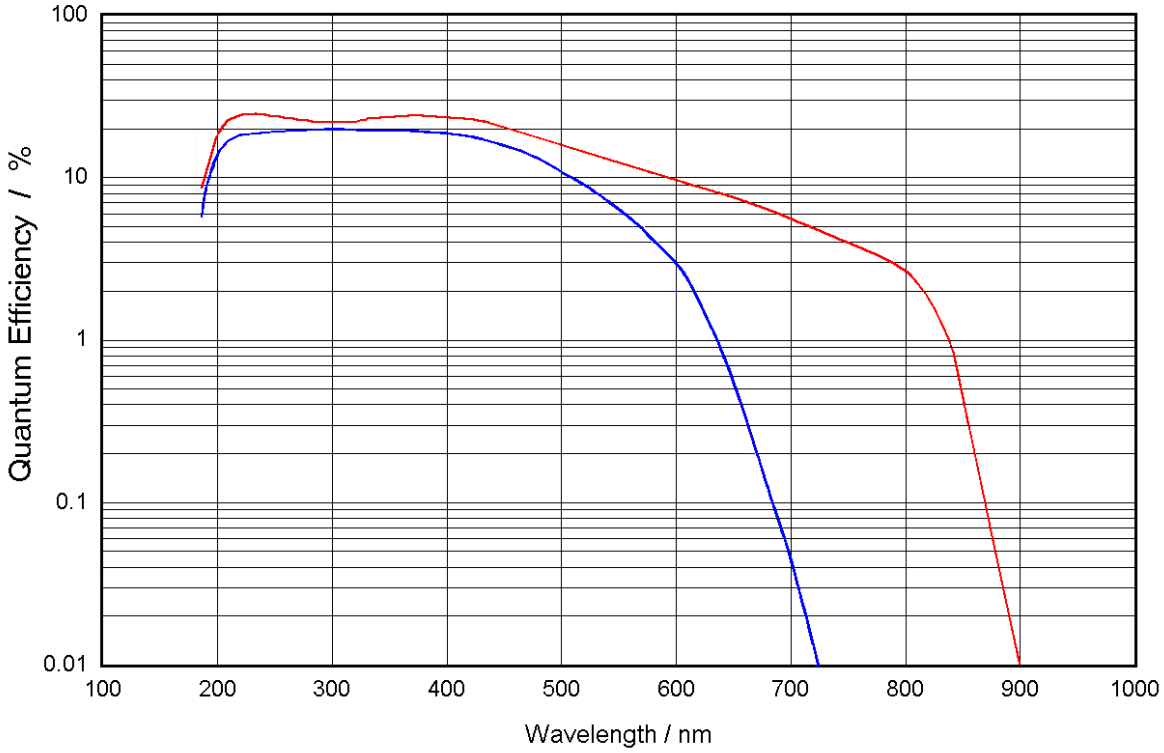
external appearance



photocathode / dynode chain layout

The photocathode material determines the spectral response characteristics of different photomultipliers. The S900-B (blue sensitive version) contains the Hamamatsu model R1527 photomultiplier featuring a low noise bi-alkali photocathode, whereas the S900-R (red sensitive version) contains the model R955 with a multi-alkali photocathode.

The relevant spectral characteristic for photomultipliers used in photon counting applications is the quantum efficiency, i.e. the ratio (in percentage) of the number of photon pulses at the output of the photomultiplier in respect to the number of incident photons. The quantum efficiencies for both the red and the blue sensitive versions of the S900 are demonstrated below.



A low background count level is essential in photon counting applications. The blue sensitive photomultiplier has a low dark count level at room temperature (typically about 100 cps - counts per second). Red sensitive photomultipliers with mulialkali photocathodes have naturally much higher dark count levels at room temperatures (typically about 2000-3000cps). In order to achieve reasonable low dark count rates the red sensitive photomultiplier must be cooled. Appendix 1 shows a graph of the dark count rate versus temperature for the S900 red sensitive detector version.

1.2. Cooler

The cooler is based on a Peltier-element cooling system surrounding the photomultiplier. The generated heat of the Peltier-elements is removed by air ventilation. A maximum temperature difference of -50^{o}C can be achieved, resulting in a photomultiplier temperature of -20^{o}C to -30^{o}C under normal ambient temperatures.

The cooling head is connected to the cooler power supply by a shielded cable. The power supply features a large display showing either the target temperature or the actual temperature of the cooled photomultiplier, selectable by a toggle switch. The target temperature can be adjusted by means of potentiometer on the front panel. The potentiometer is locked in the normal position. To unlock, the outer part of the adjustment knob must be slightly pulled.

The photomultiplier does not reach its operating temperature until typically 20 min after the cooler unit has been switched on (see appendix 2).

2. Transit and Packing

In general the detector assembly will be an integral part of an Edinburgh Instruments spectrometer system and as such it will be packed for transit in a large spectrometer crate. The detector head(s) will be fitted to the emission monochromator exit slits. The cooler power supply (if applicable) will be in it's own packaging within the crate.

If, the detector assembly was purchased separately as a stand-alone unit or as an upgrade to an existing spectrometer, or if the detector needs to be shipped for service purposes, then the units will be delivered in a suitable container with its modules wrapped separately.

Both the blue and the red detector assemblies will be shipped with the detector fitted in place.

3. Installation

3.1. Delivery within a Spectrometer System

The S900 head comes fully integrated into the spectrometer system, i.e. the detector head is mounted to the monochromator exit. The high voltage cable is connected to the spectrometer controller CD920.

Connect the signal output of the S900 head to the signal processing unit of your spectrometer, i.e. PC plug-in cards TCC900 or PCS900.

The S900-R version requires the cooler power supply to be installed. Place the cooler power supply close to the cooling head, install the 15 way interconnecting cable, select the required mains input range, and finally connect it to the mains.

3.2. Separate Delivery

1. Mount the detector head to the monochromator exit or to other optics, if applicable. Ensure that the O-rings are fitted for light tight sealing.
2. (for S900-R only)
   a) Position the cooler power supply at an appropriate distance from the cooler head and connect the power cable between both units.
   b) Check that the mains input settings matches the mains voltage. The cooler power supply can be set up for the correct mains voltage by means of the selector switch provided on the rear side.
   c) Connect the mains cable.
3. Connect the signal output of the S900 head to the signal processing unit.
4. Connect the high voltage to the SHV connector on the cooling head. Note that the maximum voltage is –1400V. Switch the high voltage only on when there is no risk for over-exposure by light.

4. Operation

4.1. Operation within Spectrometer System

When the S900 is an integral part of the spectrometer system the detector will be biased as soon as the spectrometer controller is switched on and it will be shut off when the controller is switched off.

There is a shutter inside the emission monochromator. This shutter is interlocked with the sample chamber lids. Thus, ambient light can not reach the detector when the sample chamber is opened.

Never remove the monochromator lid while the spectrometer controller is switched on. This can cause damage to the detector by over-exposure of ambient light.

With the bias voltage supplied to the detector and no light reaching the detector (closed slits on the emission monochromator) the typical dark count rate at room temperature should be observed (refer to chapter 5).

The red sensitive version (S900-R) should be cooled for low dark count rate. The cooling process will start as soon as the PMT cooler unit is switched on. It will take about 30min to reach the final temperature of the photomultiplier tube. The final temperature can be adjusted by tuning the current supplied to the cooler head. The current can be adjusted on the front panel of the cooler power supply.

The detector saturation limit is approx. 10^7 cps. Please note that the saturation limit of the processing electronics might be lower.

4.2. Operation of Separate S900 Units

Principally all instructions given in chapter 4.1 will also apply for detector units not operated within an Edinburgh Instruments spectrometer system. Before operating the S900 first time please ensure the detector is operated in dark conditions. Too much light can damage the detector.

5. Technical Specification

5.1. Photomultiplier Detectors

The table below lists the relevant information of the blue and the red sensitive photomultiplier used in the S900. Particular focus is made on the use of those detectors in single photon counting operation. For further details refer to Hamamatsu publications.

	blue sensitive version S900-B	red sensitive version S900-R	Unit
Photomultiplier Model	R1527	R955	
Physical characteristics			
Type	side window	side window	
Photosensitive area	8 x 24 (min.)	8 x 24 (min.)	mm
Number of dynodes	9	9	
Spectral characteristics			
Spectral range	185-670 (typ.)	160-870 (typ.)	nm
Photocathode material	low noise bialkali	multialkali	
Photocathode type	reflection	reflection	
Window material	UV glass	fused silica	
Gain	1 x 10^7 (typ.)	1 x 10^7 (typ.)	
Dark count rate			
@ 20°C	50 (max.)	3000 (max.)	cps
@ -20°C	5 (max.)	50 (max.)	cps
Time characteristics			
Anode pulse rise time	2.2 (typ.)	2.2 (typ.)	ns
Electron transit time	22 (typ.)	22 (typ.)	ns
Transit time spread	0.5 (typ.)	0.5 (typ.)	ns
Electrical settings			
high voltage (max.)	-1400 (typ.)	-1400 (typ.)	V
Threshold (recom-d.)	-25 (typ.)	-25 (typ.)	mV

Remarks and Definitions:

(1) Spectral Range: The spectral range quoted is defined as the lower and the upper end of the wavelength range covered by the photomultiplier response, at which the quantum efficiency becomes 1% of the maximum value.

(2) Gain: The gain is the single photon pulse amplification.

(3) Gain, dark count rate, and time characteristics are specified for the typical operating voltage of -1400V. The values differ from Hamamatsu publications, in which the specifications are usually given for lower operating voltage.

(4) For side window photomultipliers the transit time of secondary electrons as well transit time spread of the electrons at the anode are dependent of the position and the size of the illuminated area of the photocathode. The data demonstrated here are typical values for an illuminated area of approx. 0.5mm x 10mm at the centre of the photocathode.

5.2. Detector Head and Cooler Power Supply

	blue sensitive version S900-B	red sensitive version S900-R	Unit
Detector Head			
Type	Uncooled	Cooled: Peltier Cooler	
Coolant	N/A	Air ventilation	
Size	See page 2	See pages 2,3	mm
Weight	1.0	1.5	kg
Lens material	Spectrosil B	Spectrosil B	
Cooler Power Supply			
Type	N/A	CPS20	
Adjustments	N/A	Target Temperature	
Readings	N/A	Target Temp. / PMT Temp.	
Size	N/A	See page 3	mm
Weight	N/A	1.0	kg
Mains Voltage	N/A	115Vac, 230Vac switch selectable	
Fuse Rating	N/A	630mA, 250V, A/S	

6. Warranty

1 a) The Company guarantees the equipment forming the subject of the contract/quotation against defective materials and workmanship for a period of one year from the date of delivery to the Purchaser.
   b) In the case of sub-assemblies of equipment not manufactured by the Company, but incorporated in the equipment ordered, the Purchaser will be entitled only to the benefit and/or limitations of any guarantee given by the makers of such assemblies.
   c) In no event shall the Company be liable for any consequential loss or damage arising from failure of the equipment under warranty.
   d) At the end of the one year period referred to herein, all claims upon all liability of the Company shall be absolutely at an end.

2 a) The Company also warrants that the equipment conforms to specifications contained in current brochures or to extra specifications confirmed in writing at the time of order acknowledgement.
   b) No warranty is made or implied as to the suitability of any equipment for the Purchaser's intended use beyond such performance specifications as form part of the contract.

3.The purchaser warrants:
   a) That he will carefully examine and list all parts of the equipment supplied by the Company and notify the Company in writing of any shortage, defect or failure to comply with the contract, which is or ought to be apparent upon such examination and test, within 48 hours of the equipment being delivered to or collected by the Purchaser.
   b) The equipment will be operated in accordance with the instructions and advice detailed in the appropriate operating instructions manual, or any other instructions which may be provided by the Company. The Company shall not be held responsible for any defect arising from the Purchaser's failure to comply with these recommendations and instructions or from damage arising from negligence or exposure to adverse environmental conditions.

4.The warranty is effective when:
   a) Any defects in the equipment supplied are notified immediately by the Purchaser to the Company.
   b) The equipment is returned to the Company at its Edinburgh premises, transportation and insurance prepaid, and undamaged by the failure to provide sufficient packaging.
   c) The Purchaser has made payment in full for the contract in accordance with the Company's normal trading terms, i.e. 30 days from date of invoice.

5.The warranty covers:
   a) Engineer's time costs during inspection and repair.
   b) Any materials or components, which require to be replaced.
   c) Return carriage costs to the Purchaser

6.However, if the Purchaser requests a service engineer to carry out the necessary inspection and repair of the equipment covered by the warranty on site, the Purchaser will be liable, at the Company's discretion, for:
   a) Engineer's travelling time costs.
   b) Engineer's travelling and accommodation expenses.

The timing of the inspection and repair of the equipment will be determined entirely at the discretion of the Company.

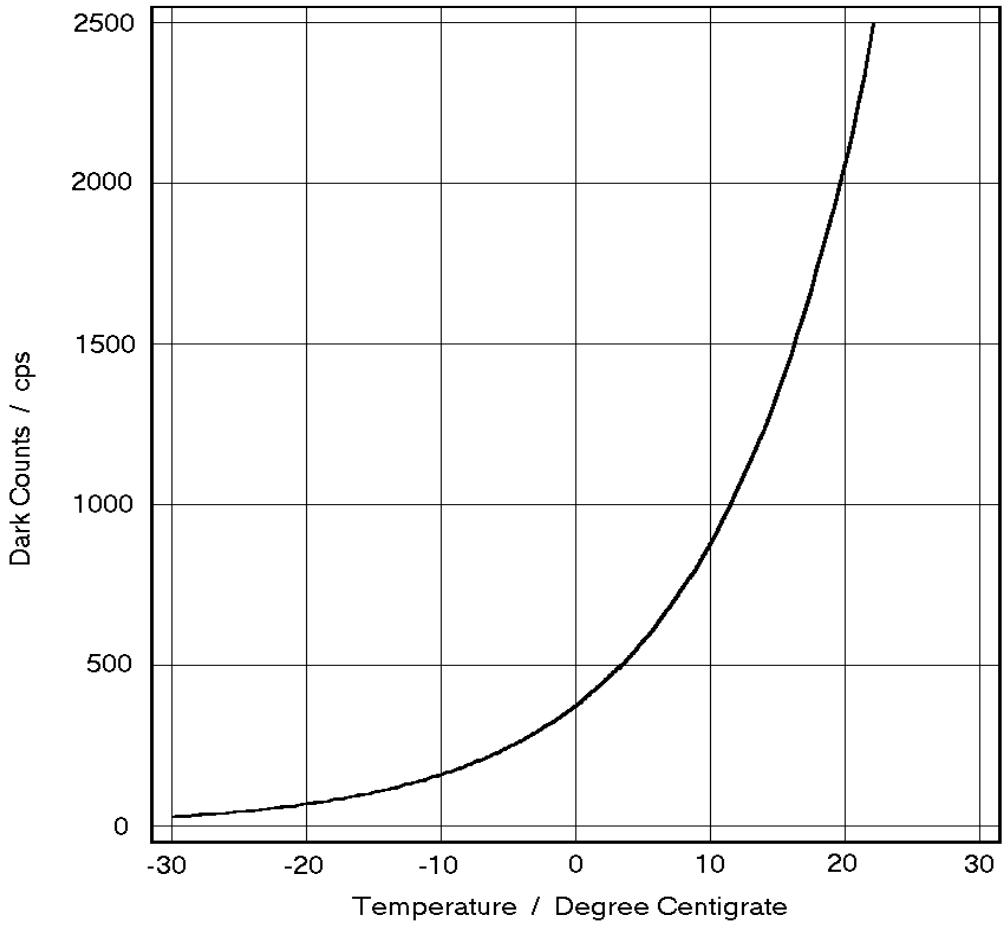
7. CE Declaration of Conformity

CE

Manufactured by:	Edinburgh Instruments Ltd. 2 Bain Square Livingston EH54 7DQ Tel.: + 44 1506 425 300 Fax.: + 44 1506 425 320	
Applicable Standards:	Generic Immunity	EN 50082-1 : 1992
	Generic Emission	EN 50081-1 : 1992
	Electrical Safety Standards	EN 61010-1 : 1993

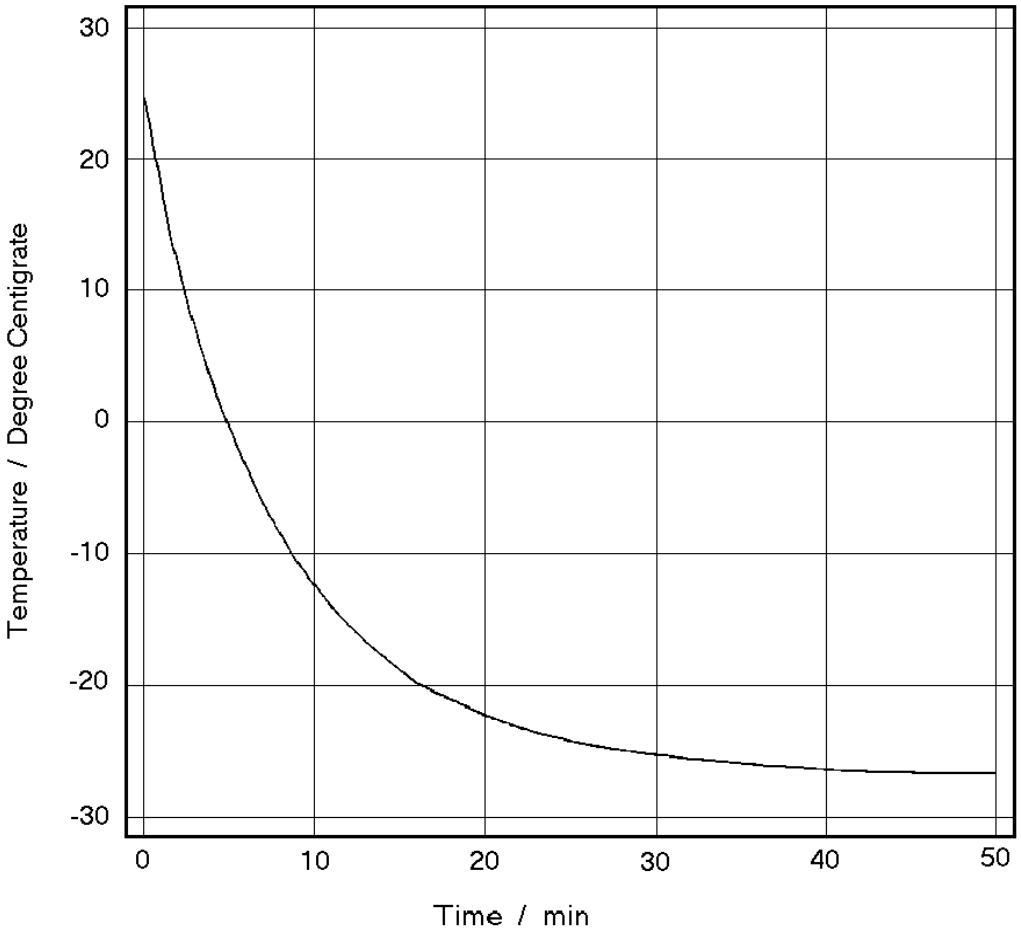
Edinburgh Instruments Ltd. certify that this equipment conforms with the protection requirements of the above Directives.

Appendix 1: Dark Count Rate versus Temperature



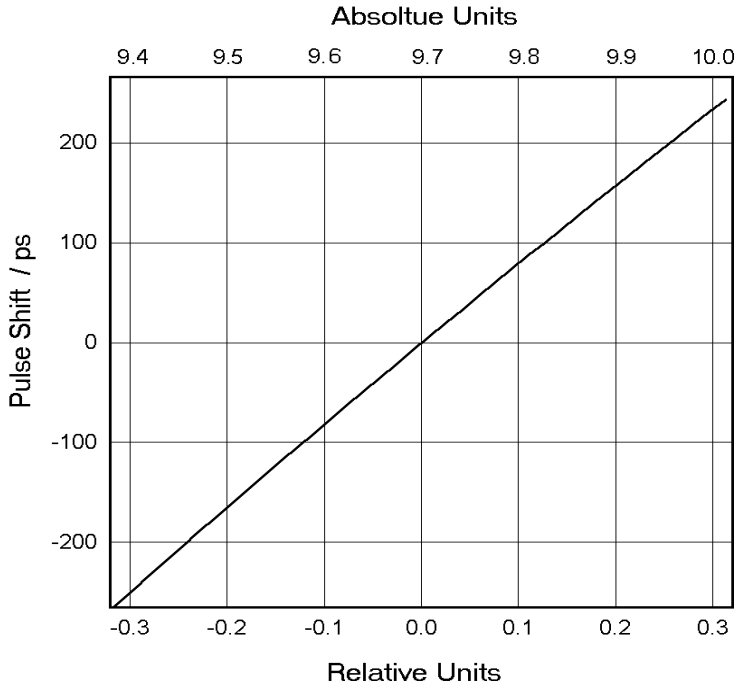
Typical function of the red sensitive photomultiplier dark count rate versus temperature.

Appendix 2: Cooling Characteristics

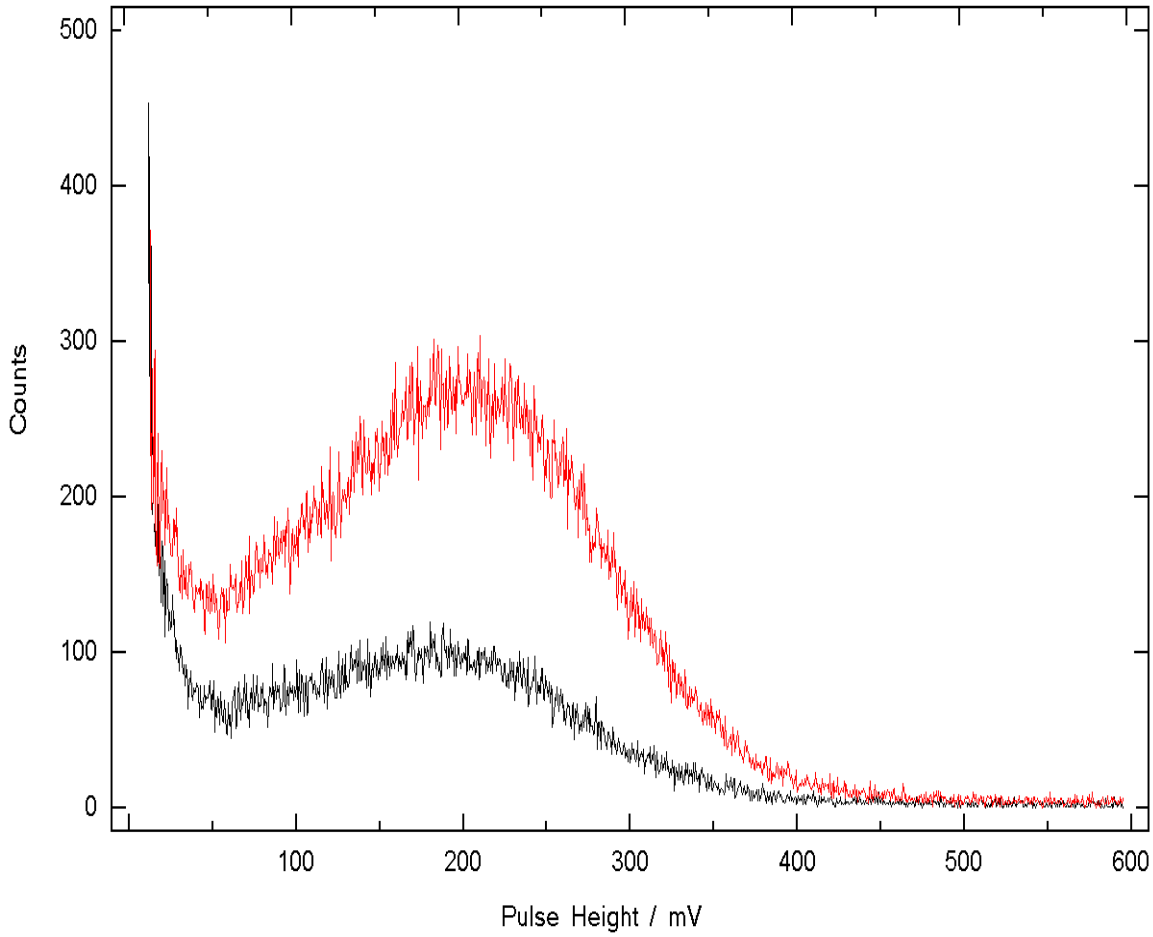


Typical function of cooler temperature versus elapsed time after switching on the photomultiplier cooler. Note that there is a hysteresis between the temperature demonstrated at the cooler power supply and the actual temperature of the photomultiplier photocathode. For a stable photocathode temperature an additional cooling time of approx. 15 min should be allowed.

Appendix 3: Photomultiplier Voltage Characteristics



Appendix 4: Pulse Height Distribution



Typical pulse height distribution curves for the blue and the (cooled) red sensitive photomultiplier. Please note that the pulse height is scaled for a 500MHz input.