PMA Hybrid Series

Cooled Hybrid-Photomultiplier Assembly

PicoQuant

User Manual

Document version 0.1 or PMA Hybrid Series version 2.4

Table of Contents

1. General safety information

CAUTION! Before using this device, make sure that you have read and understood the content of this user manual. Store this documentation in a safe and easily accessible place for future reference.

Incorrect handling of this product may result in personal injury or physical damage. The manufacturer assumes no responsibility and cannot be held liable for any injury / damages resulting from operating the device outside of the normal usage defined in this manual.

1.1. Warning Symbols and Conventions

The following symbols and conventions will be used throughout this manual. Please take time to familiarize yourself with their meaning before proceeding.

	The **general safety alert symbol** is used to alert you to hazards that may lead to personal injury or physical damage. Follow all associated safety instructions to avoid possible injury or death.
	A **high voltage warning symbol** is used to indicate the presence of un-insulated, dangerous voltage inside the enclosure. Note that this voltage may be sufficient to constitute a risk of shock.
	The **laser radiation warning symbol** alerts you that the device can generate laser radiation. Follow all applicable laser safety instructions to avoid injury or damages.
	The device's susceptibility to electrostatic discharge (ESD) is indicated by the **ESD warning symbol**. Ensure that you follow proper ESD protection rules to avoid damaging the device.
CAUTION!	Make sure to follow any instructions prefaced with "**CAUTION!**" to avoid personal injury or damaging the device.
WARNING!	The "**WARNING!**" label prefaces any instructions that shall be followed to avoid severe injury or death.
NOTICE	Important tips and information for device operation that do not include a risk of injury or damage are prefaced with the "***NOTICE***" label.
	This symbol indicates that an earth terminal shall be connected to the ground (to avoid risks of electrical shock).

1.2. Electrical Safety Instructions

WARNING! The connection of all conductive housings, electrical equipment with a grounded protective conductor and with the main earthing bar is the basis for protection against electric shock (*protective earthing*). Therefor all housings and power sockets must be grounded according to the standards **IEC 60364-4-41:2005 and DIN VDE 0100-410:2007-06** (for Germany).

The technical design for the equipotential grounding, the dimensioning of the cross-sections and the standardized terms are given in the international standard **IEC 60364-5-54: 2011** and the **DIN VDE 0100-540: 2012-06** (for Germany).

NOTICE	**To realize a functional earthing between each component, the PMA Hybrid Series must be grounded together with the PC, the PDL 820 laser driver as well as the PicoHarp 300 TCSPC unit (if present). If your lab supplies a functional earthing connection following the standards mentioned above, we recommend to connect the PMA Hybrid Series to it via the PDL 820 laser driver grounding connector. Please contact your electrical safety officer / facility staff in charge of electrical installations to ensure that equipotential grounding according to the standards mentioned above has been achieved before operating the PMA Hybrid Series.**

Never connect or disconnect any cable while the system is powered ON. Charged signal cables can damage electronic devices!

This device contains electrical components that are not user serviceable. Servicing of these internal electrical components is restricted to qualified personnel.

Disconnect the power cord from the electrical outlet before performing any maintenance.

2. Introduction

The PMA Hybrid is a compact single photon sensitive detector based on a fast Hybrid Photomultiplier Tube. The tube is cooled by a peltier element to reduce its dark count rate. The integrated electronics provide a stabilized high voltage power supply for the photomultiplier tube. The detector also features an overload protection that shuts down the high voltage supply of the photomultiplier tube to protect the detector from damage in case the count rate and therefore the incoming light level exceeds a predefined limit.

Overload protection, high voltage setup and temperature regulation are calibrated during production and do not require any adjustment. The detector also features a CAN Interface which enables easy system integration into PicoQuant's systems solutions.

The PMA Hybrid is built in a nickel coated aluminum housing to achieve a high level of RF shielding and protection against interference with other devices. The built-in pre-amplifier's design aims at timing sensitive applications such as Time-Correlated Single Photon Counting (TCSPC).

The PMA Hybrid has a high timing resolution and processes count rates up to 80 million counts per second. In contrast to other detector types, the afterpulsing is negligible. With these special characteristics, the PMA Hybrid is especially suited for e.g. Fluorescence Correlation Spectroscopy (FCS), where an afterpulsing peak at early lag times would complicate the analysis of the autocorrelation function. The high maximum count rate enables the acquisition of FLIM images of fast dynamic processes with an outstanding 5 ps time resolution (rapidFLIM^{HiRes}).

The PMA Hybrid interfaces directly with all PicoQuant TCSPC products such as the TimeHarp 260, PicoHarp 330, HydraHarp 500, and MultiHarp 150/160. Due to its large active area of 3-6 mm (model depending), the detector can be connected to spectrometers such as the FluoTime 250 or FluoTime 300. It can also be attached to Laser Scanning Microscopes in Non-Descanned Detection (NDD) setups via a C mount adapter. Integration in descanned detection mode or other systems, such as the confocal time-resolved microscopes Luminosa or MicroTime 200 is of course also possible.

The PMA Hybrid models feature two signal outputs on standard 50 Ohms SMA connectors: a negative voltage pulse for timing applications and an analog positive output voltage that can be connected to e.g. A/D converters. The module is supplied with a 12 V DC power supply.

2.1. Handling Photomultiplier Tubes

WARNING!

Do not attempt to modify the electronic control circuits inside the housing.
High Voltage!

WARNING!

CAUTION! **The PMA Hybrid is an extremely sensitive device. It can be permanently damaged by over-exposure to intense light, despite of the built-in overload protection (see also section 4.3).**

Never open or disassemble the PMA Hybrid housing when the power supply unit is connected. The light leaking into the housing will reach the photo-cathode and will destroy the hybrid PMT despite of the automatically closed shutter.

Handle the PMA Hybrid detector with care. Do not drop it or expose it to excessive mechanical shocks or vibrations.

CAUTION! **While room light can reach the entrance window of the PMA Hybrid:**

Do not attach the delivered LEMO plug to the shutter interlock connector.
Do not close the shutter interlock circuitry.

CAUTION! **When the PMA Hybrid detector is mounted on another instrument, take care that the connection is light-tight, especially if the detector is used for single photon counting.**

3. Hardware Description

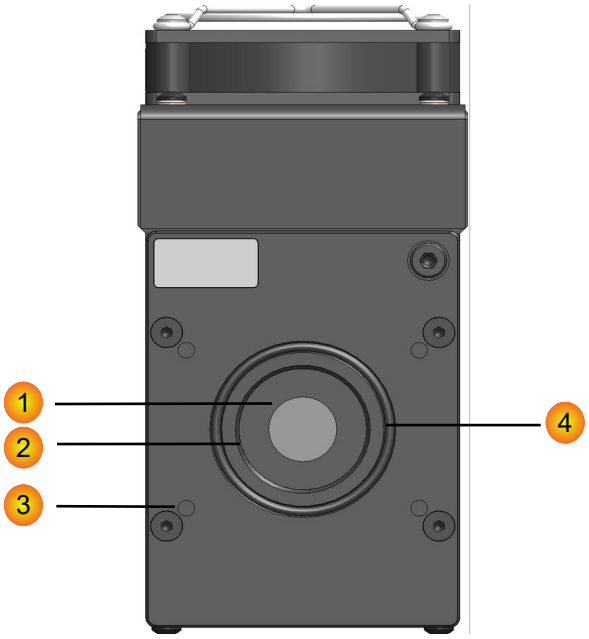


Fig. 1 PMA Hybrid Unit Front View with:
1 - Detector window (shutter closed)
2 - Four threaded holes (3.2 mm diameter suited for M3 screws)
3 - C-mount thread, 1-32 UN.
4 - O-ring (inner diameter = Ø 31.47 mm).

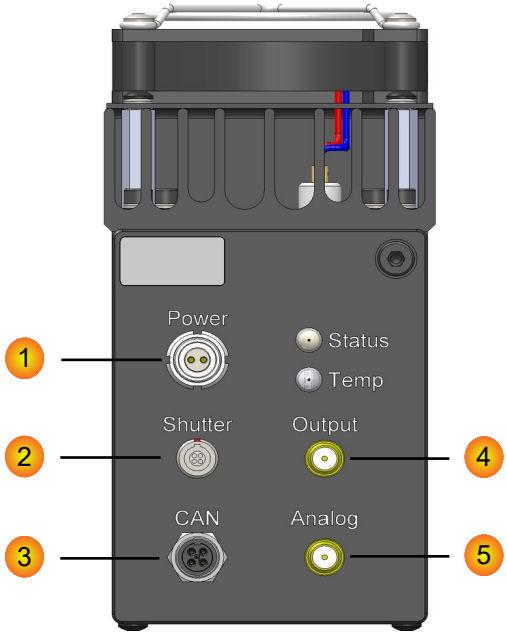


Fig. 2: PMA Hybrid Unit Rear View:
1 - Power supply connector (LEMO, EXG.0B.302, female)
2 - Shutter interlock (LEMO, EGG.00.304.CLL, female)
3 - CAN interface
4 - Timing output (SMA, female)
5 - Analog output signal (SMA, female)

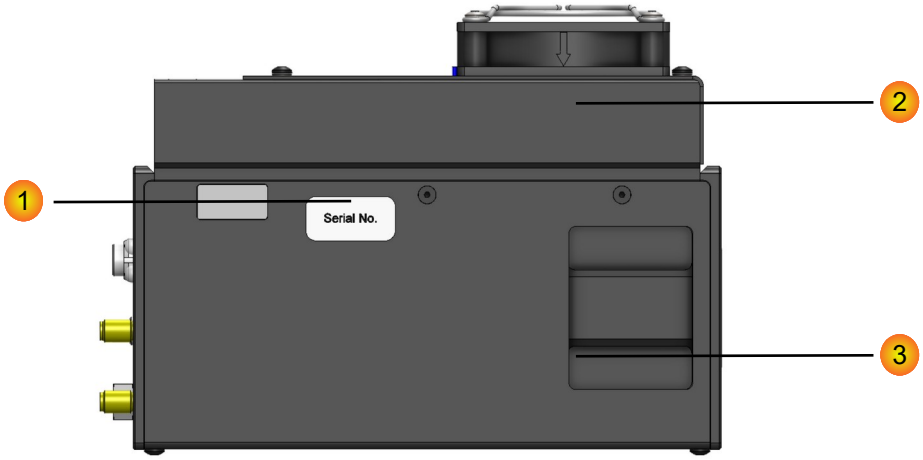


Fig. 3 PMA Hybrid Unit Side View:
1 - Product Label
2 - Cooling Unit, with Fan
3 - Recess for accessing the M3 Mounting holes (Fig. 1 - 2)

3.1. Mounting the PMA Hybrid Detektor

The PMA Hybrid Detector provides three options for mounting the unit:

1. Mounting the detector via the 4 threaded holes (3.2 mm diameter suited for M3 screws) as shown in Fig.4
2. Mounting the detector via the 1-32 UN (C-Mount) thread as shown in Fig.4

CAUTION!	**Note that you still have to support the weight of the detector when this mounting style is used.**

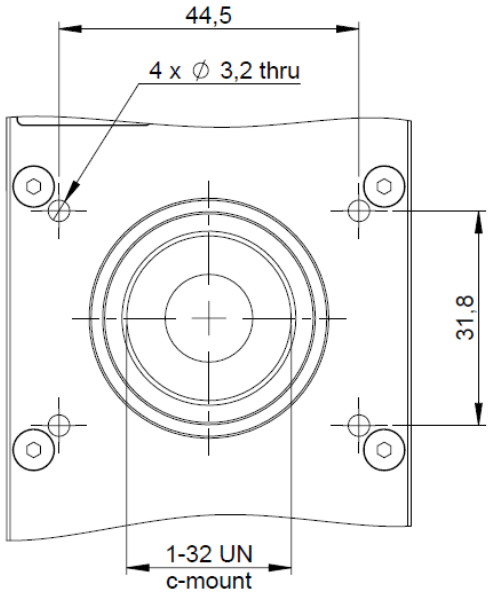


Fig. 4: Mounting options on the front side of the PMA Hybrid Unit with pitch and dimensions

3. Four Screws (M3x6) at the bottom of the detector fix the detector housing to the detector base plate. These screws can be replaced in order to mount the detector on a custom designed base plate. Remove the existing screws and replace them with screws long enough to hold base plate and housing.

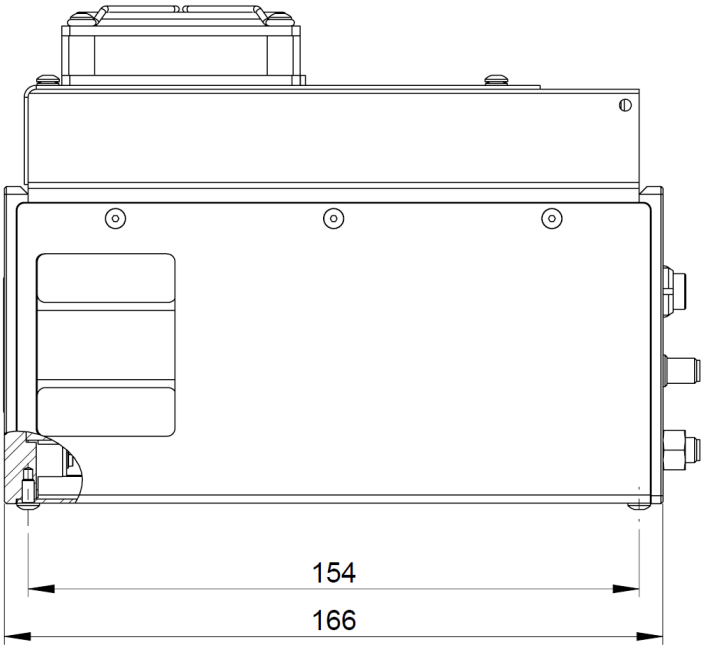


Fig. 5: Mounting options on the Bottom of the PMA Hybrid Unit with pitch and dimensions

3.2. Sensor Location

The distance between the entrance window and the active area of the PMA Hybrid is 17.0 mm as shown in Fig. 6.

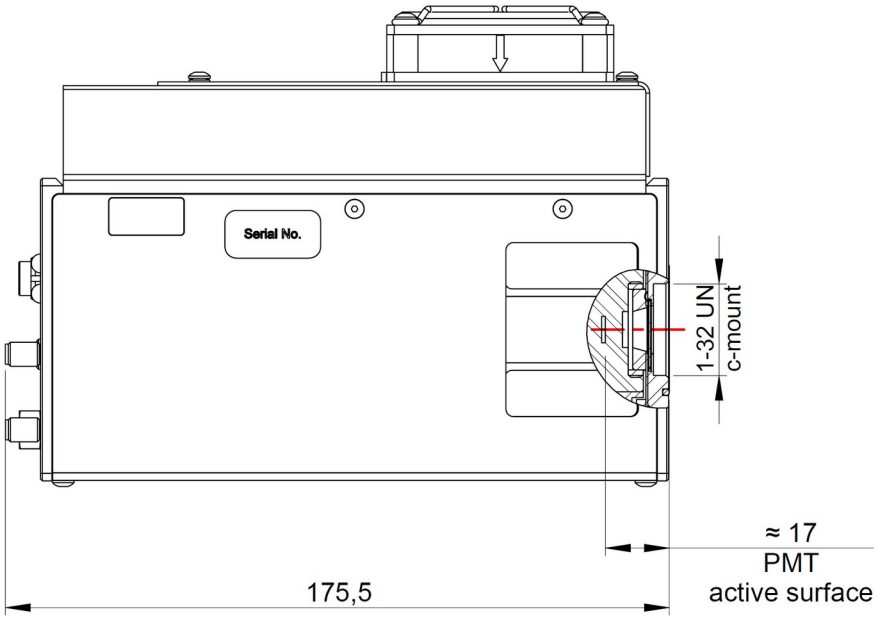


Fig. 6: Distance between entrance window and the active area of the PMA Hybrid Unit

3.3. Electrical Connections

In Fig. 7 the electrical connectors on the rear side of the PMA Hybrid Detector are shown:

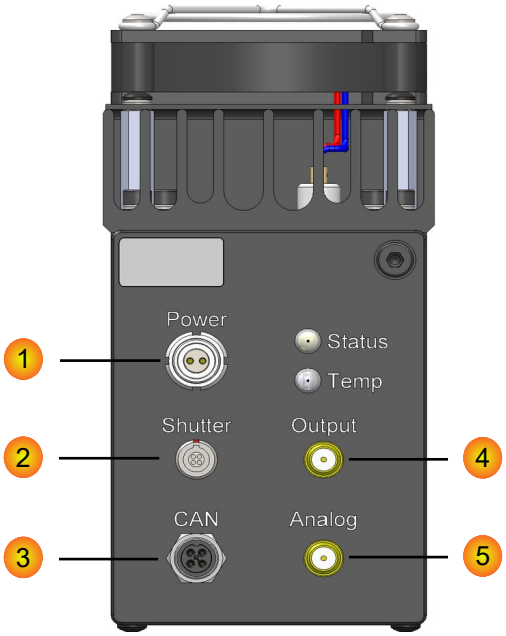


Fig. 7: PMA Hybrid Unit Rear View:
1 - Power supply connector (LEMO, EXG.0B.302, female)
2 - Shutter interlock (LEMO, EGG.00.304.CLL, female)
3 - CAN interface
4 - Timing output (SMA, female)
5 - Analog output signal (SMA, female)

1. Power supply (2-pin LEMO connector, type EXG.0B.302, pin at key position +12V, other pin GND)
2. Shutter interlock (4-pin LEMO EGG.00.304.CLL, female connector).

   To open the Shutter attach the LEMO plug delivered with the PMA Hybrid unit.

   Alternatively, you can use the provided interlock cable with loose ends to integrate e.g. a mechanical switch to shunt pins 2 and 3.

   Please do not apply any voltage.
3. CAN interface (for communication with PicoQuant equipment only)
4. Timing output

   Timing output signal (standard 50 Ohms SMA female). Provides NIM pulse for every detected photon (see section 4.7)
5. Analog output

   Analog output signal (SMA female, designed for > 1k Ohm impedance). Provides a voltage proportional to the count rate measured by the detector. (see section 4.5)

4. Operation

4.1. Wiring and Turning on the PMA Hybrid

Step 1

Connect a suited SMA signal cable (for optimal performance use a double shielded RG233/U coaxial cable) to the connector labeled 'Output' (Fig. 7, 4) or 'Analog' (Fig. 7, 5) on the rear of the detector.

Step 2

Connect the other end of the SMA signal cable connected to the connector labeled 'Output' (Fig. 7, 4) to your data acquisition electronics (such as PicoQuant's TCSPC modules like the TimeHarp 260, PicoHarp 300, HydraHarp 400 or MultiHarp 150/160).

> **CAUTION!** **Do not connect the 'Analog' connector to a PicoQuant TCSPC module, this could cause damage to the TCSPC module.**

Step 3

> **CAUTION!** **Powering up the detector turns the single photon sensitive sensor operational and therefore sensitive to damage caused by over illumination.**

Make sure that the LEMO plug delivered with the PMA Hybrid unit is **not** connected to the connector. Make sure that pins 2 and 3 at the connector labeled 'Shutter' are **not** shunt.
In both cases the shutter of the detector would open once the detector is powered up.

Connect the power supply cable to the connector labeled 'Power'. Plug the power supply into a power outlet.

Step 4

> **ATTENTION!** **Before opening the shutter, make sure that the detector entrance window is connected light-tight to your experimental setup to avoid detector overload.**

Open the detector shutter by inserting the interlock plug into the shutter connector or short circuit the connection using the supplied interlock cable.

The PMA Hybrid unit is now fully operational.

4.2. Temperature stabilization

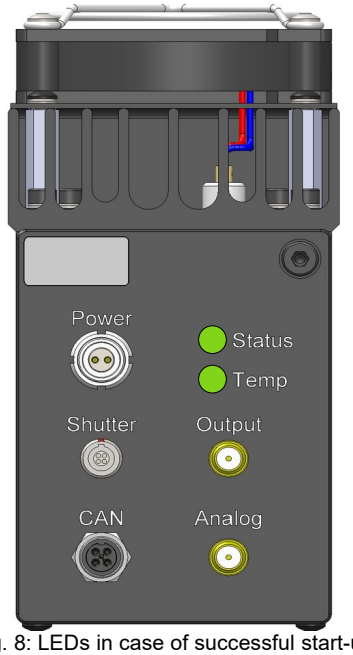


Fig. 8: LEDs in case of successful start-up

When the PMA Hybrid is switched on, the thermoelectric cooling is activated and both the power status LED and the temperature LED are **green**. If no problems are detected during the start-up procedure both LEDs switch off after two seconds to avoid stray light during measurements. If the LEDs do not turn off please check section 4.6 for troubleshooting.

It approximately takes 5 minutes for the sensor temperature to stabilize. You may want to use this time for preliminary measurements. Cooling reduces only the dark count rate without any effect on temporal resolution or photon detection efficiency.

4.3. Overload Protection

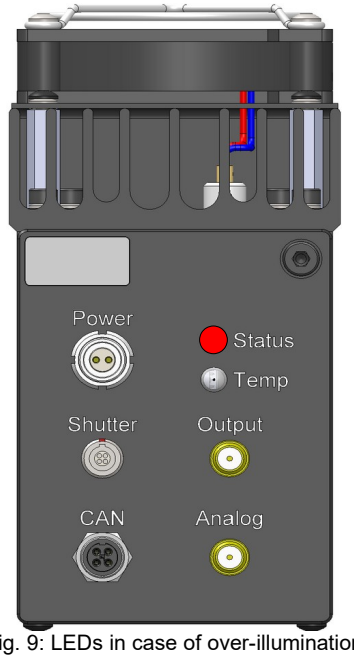


Fig. 9: LEDs in case of over-illumination

In order to avoid permanent damage to the PMA Hybrid, a fully automatic circuitry closes the shutter in front of the detector when the detector count rate reaches a critical level. This happens at a photon flux of 80 million photons per second (see also section 4.4).

Overload is indicated by a red Power status LED at the rear panel and a beep sound. The PMA Hybrid continues to work normally with closed shutter and the typical dark count rate (dependent on the cooling status, which is not affected by the overload) should be detectable at the signal output. The shutter opens again after three seconds. In case the count rate is still too high it closes again. This procedure is repeated until the count rate has again dropped below the critical level.

CAUTION!	**The overload protection has a few milliseconds of latency. It is meant to be a last resort for protection. Please protect the PMA Hybrid against over-illumination as much as possible.**

4.4. Overload Shutdown Count Rate

The overload shutdown count rate is determined by measuring the current flow through the detector. In case the current has reached a critical limit, a fully automatic circuitry closes the shutter in front of the detector. This happens at a photon flux of approx. 80 million photons per second (see also section 5.1).

NOTICE

A photon flux of 80 million photons per second does not necessarily mean that it is possible to measure up to count rates of 80 Mcps (Mcps: million counts per second). This is due to the fact that typical counting electronics can not discriminate between single photon events and multi-photon events, i.e. situations in which several photons hit the detector at the same time. Consequently, the relation between current and measured count rate becomes non-linear at conditions that favor multi-photon events. Typical conditions are operation at pulsed excitation with a high photon flux in a short time interval. At these conditions the measured shut down count rate decreases with decreasing excitation rate as illustrated in the plot below.

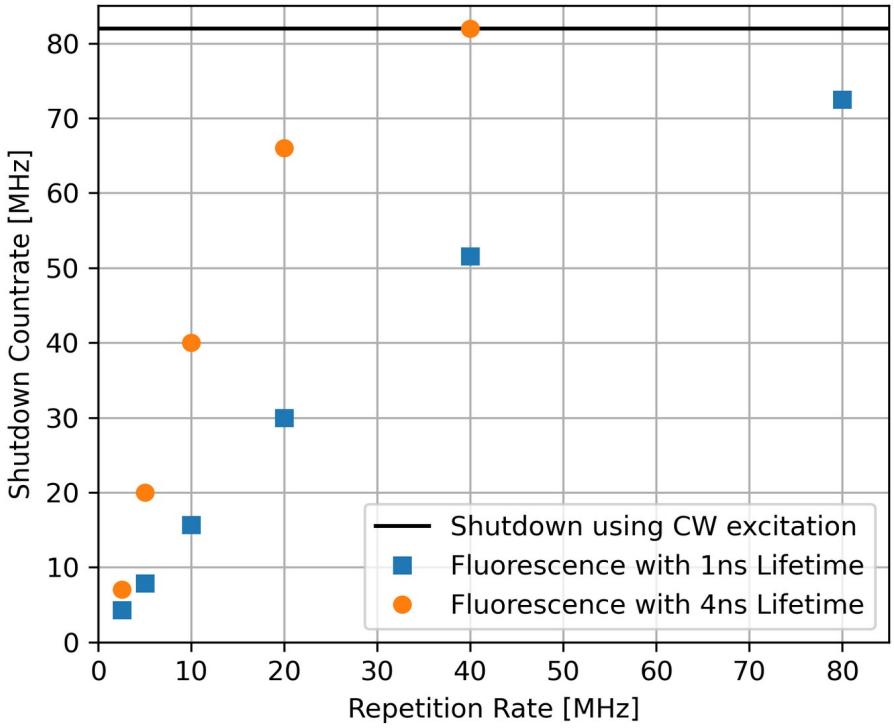


Fig. 10: Shutdown Countrate vs Laser Repetition Rate

In Fig. 10 the measured shutdown count rate using pulsed excitation and samples with different fluorescence lifetimes are shown. The PMA Hybrid used had a preset shutdown count rate of approximately 80 Mcps under cw excitation. As can be seen, the measured shutdown count rate depends on the characteristics of the sample signal. In addition, a low duty cycle of the light source (e.g. due to a low laser repetition rate) can decrease the shutdown count rate, as the multi-photon probability will be increased.

4.5. Analog output

The analog output signal is related to the photo current from the detector. It is obtained by amplifying the detector current (internal time constant of the amplifier is 20 µs). The slope of the amplifier is factory set using cw light and corresponds to a maximum output voltage of +10V at 50 Mcps (output voltages of +5V or +3V on customer request).

4.6. LED color code

The following tables describe the color code of the LEDs labeled ‘Status’ and ‘Temp’:

Status LED:

Color	Cause	Action
red	overload	reduce light intensity on the detector, see section 4.3 and 4.4
green	normal operation condition - LED turns off after two seconds	
orange	No connection at shutter interlock	connect shutter interlock plug or cable, see section 3.3
off	normal operation condition	

Temp LED:

Color	Cause	Action
red	Housing temperature limit out of bounds (>40° C)	optimize heat transfer by e.g. mounting the detector on a suitable heat sink
green	normal operation condition - LED turns off after two seconds	
orange	Target temperature (17±1° C) at peltier element out of bounds	wait until target temp is reached (The environment temperature of the detector needs to be higher than 17° C)
off	normal operation condition	

4.7. Typical performance

4.7.1. Temporal Response

The PMA Hybrid series units are suited for time-resolved applications such as time-correlated single-photon counting (TCSPC) measurements. A typical electrical response of a PMA Hybrid unit to a single photon incident on the active area is shown in Fig. 11.

The output signal is a short, negative going voltage pulse with an amplitude of approximately -200 mV into 50 Ohms. Note that the voltage output of the PMA Hybrid scales linearly with the number of impinging photons, i.e. two photons generate twice the amplitude.

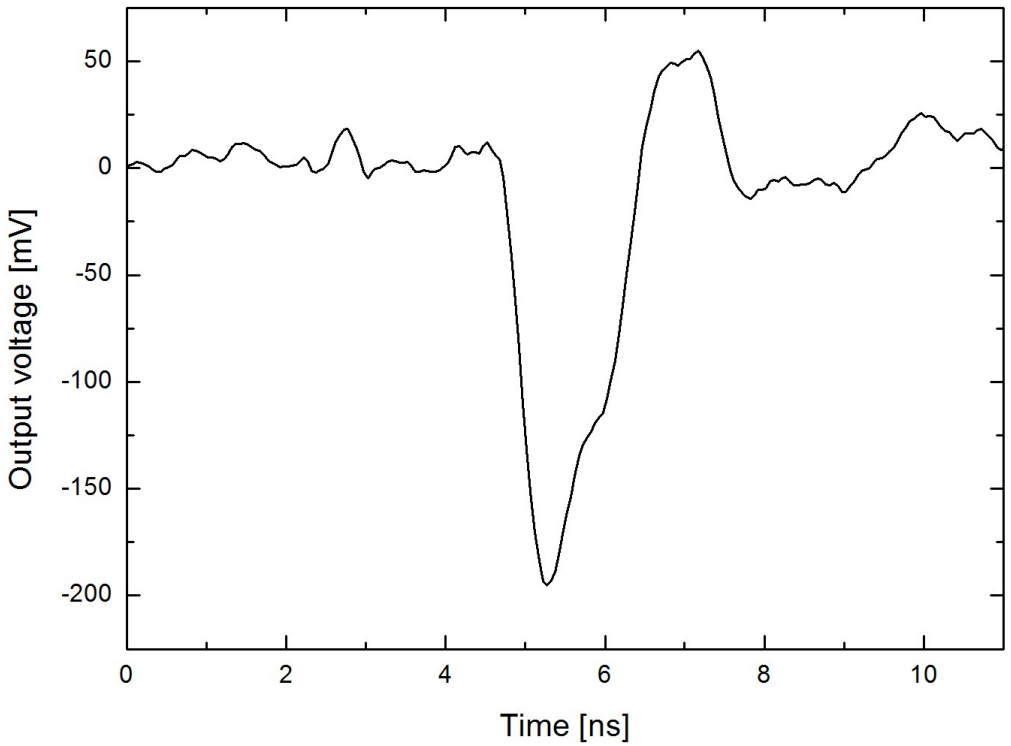


Fig. 11: Typical output pulse shape generated by a photon event

The pulse length is approximately 1.2 ns (full width at half of the maximum, FWHM). However, the ultimate time resolution achievable with a PMA Hybrid is determined by the steepness of the leading edge and the photo-electron transit time spread (TTS). The leading edge of a typical output pulse has less than 300 ps rise time and the TTS of the photomultiplier incorporated in PMA Hybrid series varies typically between 50 ps and 160 ps depending on the cathode type see section 5.1.

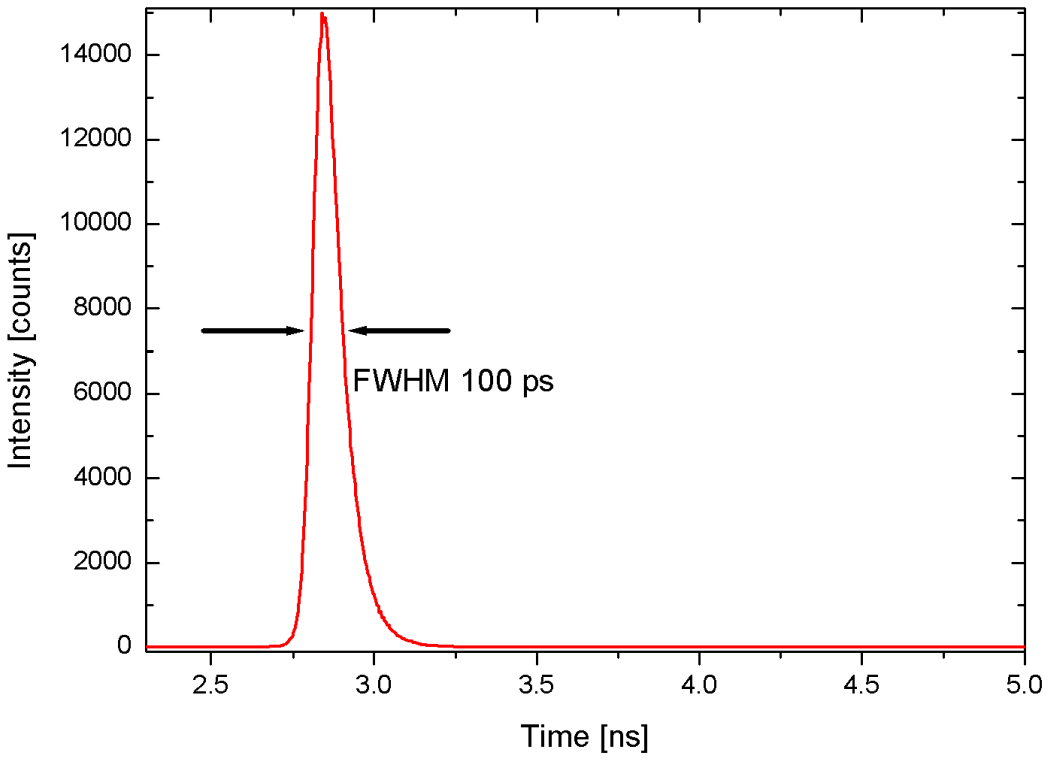


Fig. 12: Typical IRF measured by a FluoTime 300 equipped with a PMA Hybrid 40 and a PicoHarp 300

An exemplary IRF measurement for a PMA Hybrid 40 detector is shown in Fig. 12. This IRF has been recorded on a FluoTime 300 spectrometer equipped with PMA Hybrid 40 detector and PicoHarp 300 TCSPC module. The sample was a strongly diluted Ludox scattering solution irradiated with 375 nm light pulses of approximately 70 ps optical duration from an LDH-P-C-375 picosecond pulsed laser diode.

4.7.2. Spectral Response

The spectral sensitivity of a detector based on PMA Hybrid is mainly determined by the photo-cathode material as shown in Fig. 13.

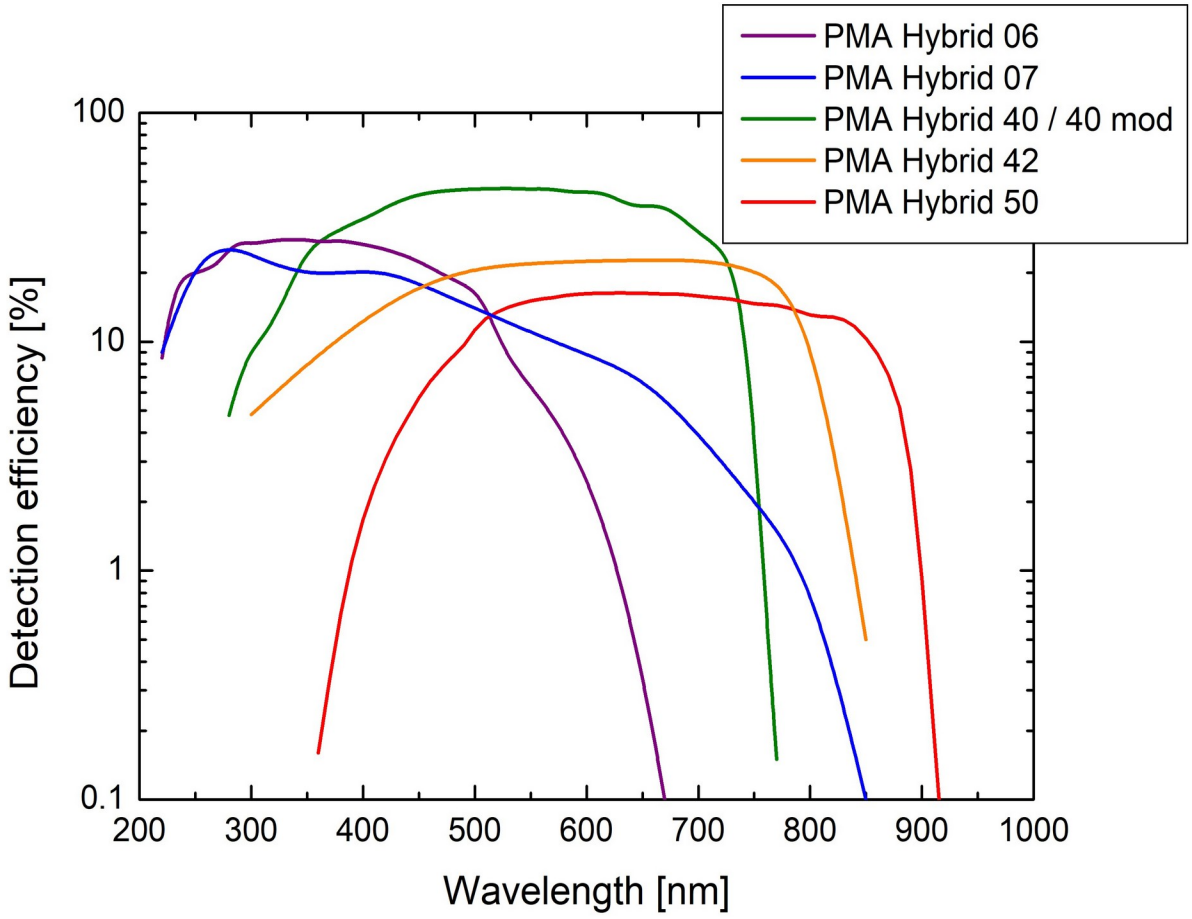


Fig. 13: Detection efficiency vs Wavelength by photo-cathode type

5. Technical Data / Specifications

5.1. Electrical Parameters

Model	-06	-07	-40	-40mod	-42	-50
Wavelength range	220-650 nm	220-850 nm	300-720 nm	300-720 nm	300-870 nm	380-890 nm
Dark counts (cooled, typ. value)	10 cps	100 cps	100 cps	300 cps	150 cps	250 cps
Dark counts (cooled, max. value)	20 cps	250 cps	300 cps	1000 cps	320 cps	600 cps
Transit time spread (FWHM, typ. value)	<50 ps	< 50 ps	< 120 ps	<120 ps	< 130 ps	<160 ps

Max. count rate..... 80 MHz (with cw excitation, lower values at different conditions, see ..... section 4.4)

5.2. Signal Output (Timing)

Connector..... SMA female
Impedance..... 50 Ohms
Polarity..... negative

5.3. Signal Output (Analog)

Connector..... SMA female
Impedance..... >1k Ohms
Polarity..... positive
Max. output voltage..... +10V (corresponds to 50 Mcps)
Time constant of the amplifier..... 20 µs

5.4. Operating conditions

Input ..... typ. 12 V DC
..... (max: 13.5 V, min: 10.5 V)
Current consumption..... <1.0 A
Environmental temperature..... 17°C to 35°C (normal: 25°C)

5.5. Dimensions

Model	-06	-07	-40	-40mod	-42	-50
Detector area diameter	6 mm	6 mm	3 mm	5 mm	3 mm	3 mm

Housing (w × d × h)..... 114.5 × 175.5 × 60 mm
Optical adapters ..... C-mount, 4 mounting holes
Weight..... approx. 1 kg

5.6. Shutter Connection

4-pin LEMO EGG.00.304.HLN, female connector, possible matching plug: LEMO FGG.00.304.CLAD35Z

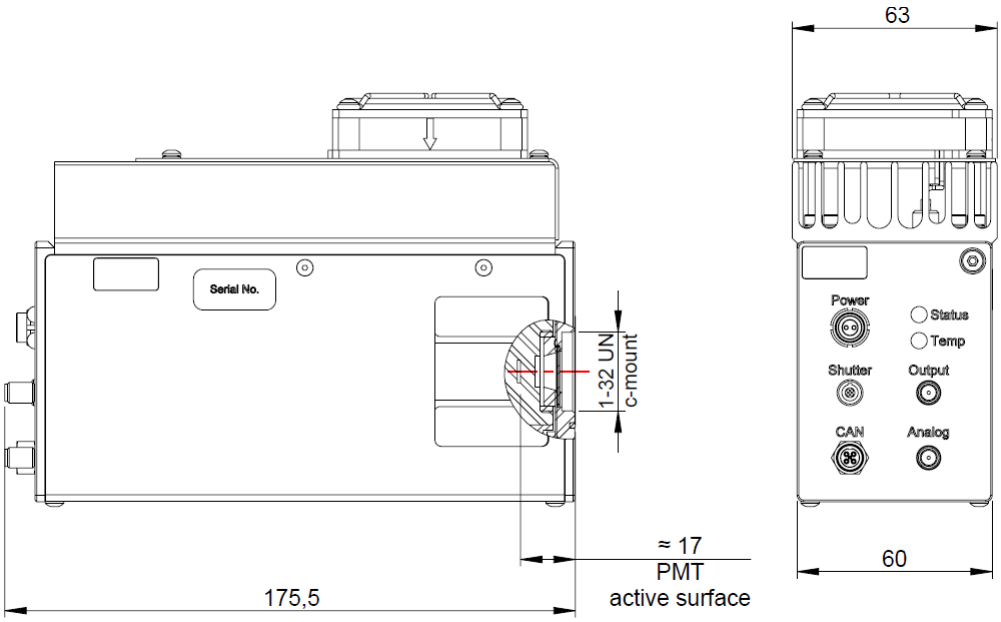
Fig. 14: Pinout Shutter Connector

In order to open the shutter shunt pins 2 and 3.

5.7. Power Pin Connection

2-pin LEMO EXG.0B.302.CLL, female connector, possible matching plug: LEMO FGG.0B.302.CLAD52

5.8. Mechanical Layout



6. Support

The PMA Hybrid Series detectors have gone through testing at PicoQuant. It is stable and reliable. Nevertheless, we continually make improvements that will be incorporated into future versions.

In any case, we would like to offer you our complete support. Please do not hesitate to contact PicoQuant if you would like assistance with your system. If you observe any errors, please e-mail a detailed description of the problem and relevant circumstances, to support@picoquant.com.Your feedback will help us to improve the product and documentation.

Of course we also appreciate good news. If you have obtained exciting results with one of our systems, please let us know, and where appropriate, mention us in your publications. At our website we maintain a bibliography of hundreds of publications related to our instruments and research. See http://www.picoquant.com/biblio. Please submit your references for addition to this list.

6.1. Returning Products for Repair

Should you encounter problems that require sending the device in for inspection / repair, please contact us first at: https://support.picoquant.com or support@picoquant.com and request an RMA number before shipping the device. Please include the serial number of your device. Observe precautions against static discharge under all circumstances during handling, packaging and shipping. Use original or equally protective packaging material. Inappropriate packaging voids any warranty.

7. Legal Terms

7.1. Warranty

Please note that the sensitivity of the detector may degrade with usage, especially if operated continuously under high count rates. Additionally, dark count rates can increase over time. A reduction of the detection efficiency or an increase in dark count rate is therefore normal and is not covered by warranty.

7.2. Copyright

7.3. Trademarks

Other products and corporate names appearing in this manual may or may not be registered trademarks or subject to copyrights of their respective owners. PicoQuant GmbH claims no rights to any such trademarks. They are used here only for the purposes of identification or explanation and to the owner's benefit, without intent to infringe.

8. Further Reading

8.1. PicoQuant Bibliography

PicoQuant maintains a database of publications mentioning PicoQuant devices. It can be found at our website https://www.picoquant.com/scientific/references. It is a valuable source if you would like to know which laboratories are using PicoQuant products or how broad the field of various applications is.

8.2. Download of Technical Notes / Application Notes

PicoQuant, along with our customers, continuously writes and publishes short documents about techniques, methods and applications that are possible with our hardware or software. The download section can be found at https://www.picoquant.com/scientific/technical-and-application-notes

9. Appendix

9.1. System Delivery Report

Your PMA-Hybrid unit was delivered with the following accessories:

1x Power Supply
1x Detector Protection Cap
1x Connector to shunt the Shutter (Lemo-Plug)

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