Kentech Instruments Ltd.

Notes on the use of

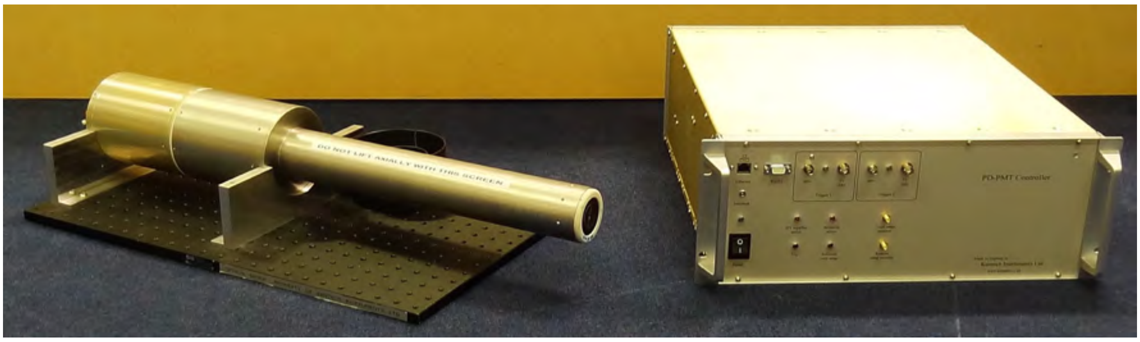
Pulse Dilation Photomultiplier

s/n J18XXXX [head]

& J18XXXX-2 [controller]

Tube s/n 31181012

Ethernet MAC address 00-80-A3-CC-90-71



Last Modified 3-1-20

PLEASE READ THIS MANUAL CAREFULLY BEFORE USING THE UNIT

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1 DECLARATION OF CONFORMITY

We:- Kentech Instruments Ltd.
The Isis Building
Howbery Park
Wallingford
Oxfordshire OX10 8BD, UK

Certify that this apparatus:
Kentech Instruments Ltd.
Serial no: J18XXXX

Conforms with the requirements of European Community Directives:

2006/95/EC	Low Voltage Directive
2004/108/EC	EMC Directive
768/2008/EC	CE Marking Directive

The following harmonized standards have been applied:
BS EN55011:2009 +A1:2010 Radio-Frequency disturbance characteristics.
Industrial, Scientific, Medical equipment

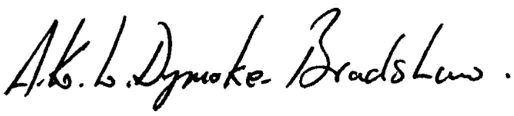
96/211711 DC Electromagnetic compatibility.
Generic Immunity Standard.
Part 2 Industrial environment (EN 50082-2)

BS EN 61010-1:2010 Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use

The following documents contain additional relevant information:-

Kentech file reference J18XXXX

Name: Signature:



A.K.L. Dymoke-Bradshaw

Date Last Modified 3-1-20

2 DISCLAIMER

There are high voltage power supplies present in this instrument when the unit is operating. Do not remove any covers from the unit or expose any part of its circuitry. In the event of malfunction, the unit must be returned to Kentech Instruments Ltd. or its appointed agent for repair.

The accessible terminals of this instrument are protected from hazardous voltages by basic insulation and protective grounding via the IEC power input connector. It is essential that the ground terminal of this connector is connected to the local earth/screened enclosure via the power lead to maintain this protection.

Kentech Instruments Ltd. accepts no responsibility for any electric shock or injury arising from use or misuse of this product. It is the responsibility of the user to exercise care and common sense with this highly versatile equipment.

Image intensifier tubes are very delicate and very expensive and must be handled with great care both in use and in storage. Read this manual before unpacking and using the instrument. If cleaning is necessary this should be performed with a soft dry cloth or tissue only.

3 EMC CAUTION

This equipment includes circuits intentionally designed to generate short high energy electromagnetic pulses and the EM emissions will be sensitive to the details of the experimental set up.

In practice emissions may exceed E55011 and the unit may cause interference with other equipment in its immediate environment. It is therefore suitable for use only in a laboratory or a sealed electromagnetic environment, unless it is used in a system that has been verified by the system builder to comply with EC directive 89/336/EEC. Use of this apparatus outside the laboratory or sealed electromagnetic environment invalidates conformity with the EMC Directive and could lead to prosecution.

4 ABBREVIATIONS

ASCII	American Standard Code for Information Interchange
ADC or adc	Analogue to Digital Convertor
AF	Across Flats
CCD	Charge Coupled Device (camera)
cr	carriage return
<cr>	send a cr character
EEPROM	Electrically programmable and erasable Read only memory, non-volatile
EHT or eht	Extra High Tension (high voltage)
EMC	Electromagentic Compatibility
FO	Fibre Optic
GXD	Gated X-ray Detector
IEC	International Electrotechnical Commission
JSON	JavaScript Object Notation
lf	Line Feed
MCP	Micro Channel Plate
MM	Multi Mode, in reference to Fibre optics
ND	Neutral Density
PC	Photo Cathode
PD-PMT	Pulse Dilation Photo Multiplier Tube
PD-PMTC	PD-PMT controller
PMT	Photo Multiplier Tube
PRF	Pulse Repetition Frequency
PSU or psu	power supply unit
scope	Oscilloscope
SD	Standard Deviation
SM	Single Mode, in reference to Fibre Optics
sw	software
URL	Uniform Resource Locator
w.r.t.	With Respect To
XML	Extensible Markup Language

5 CAUTION

When appropriately connected, this unit is safe for use by an educated user in a laboratory environment. You are warned, however, that the radiation from the system with an antenna or inappropriate load attached to the electronics, can damage sensitive equipment and corrupt data stored in computer and microprocessor based systems. It can cause terminal failure of vital medical electronic systems, such as pacemakers. This equipment is supplied on the understanding that the user will analyse these risks, accept responsibility for them, and take appropriate precautions in the use of this instrument.

The output from the pulse generator will destroy many types of power attenuators and electronic test equipment. It is the user's responsibility to ensure that any apparatus connected to the output is suitably rated.

Kentech Instruments Ltd. accepts no responsibility for any damage or liabilities incurred in the operation of this equipment.

Please read the manual carefully before applying power.

6 INTRODUCTION

The PD-PMT is a photomultiplier system that uses Pulse Dilation techniques to deliver enhanced temporal response. Standard PMTs are capable of about 100ps rise time but at this speed show significant ringing when exposed to a light impulse. Pulse dilation techniques can increase the bandwidth by up to ~ 40 times for short periods, typically several ns.

This device has been designed for use to look at Cherenkov radiation from detectors that see gamma rays from Inertially Confined Fusion experiments. Such experiments also produce neutrons and it is necessary that the device is protected from the effects of these.

The system comprises a special photo-multiplier tube (PMT) assembly, a HV bias supply and a fast photo-cathode pulse generator. These are provided in two separate modules which are connected by various cables.

The electronic package is housed in a grounded metal 19” rack mounted enclosure. The PMT tube assembly, which contains no power supplies or active electronics, is in a screened metal housing.

The pulsed dilation photo-multiplier tube (PD-PMT) requires an axial magnetic field in order to guide photo-electrons through the tube and this is provided by a solenoid within the photo-multiplier tube assembly. This is energised from a low voltage power supply included in the electronic package.

The PD-PMT is intended to provide a time resolution exceeding 5ps and will normally be used with short pulse laser sources. It can expand an input optical signal of duration approximately 500ps to an electrical output signal of duration approximately 20ns. The bandwidth of the recording oscilloscope need only be about 40 time less than that of the incident light pulse structure to be resolved.

6.1 PHOTOMULTIPLIER SPECIFIC CAUTIONS

This equipment incorporates a very sensitive PM tube. As with all PM equipment, care must be taken to avoid excessive exposure to light, especially continuous illumination, otherwise damage to the photo-detector tube may occur.

The cost of replacing the PM tube will be a significant fraction of the cost of the overall unit. Be certain of what you are doing at each stage before executing it. If you have any questions or uncertainties please contact the factory.

6.2 THE PULSE DILATION PRINCIPAL

The pulse dilation principal has been successfully applied to high speed x-ray imaging for several years. It is applicable to devices where the information is converted into an electron beam which can then be manipulated electrically.

In this device the electrons emitted from a photocathode are accelerated before coasting into an MCP just as in a conventional MCP based photomultiplier. However, the difference is that the acceleration is varied in time during the event of interest. In particular the acceleration is reduced during this period and the beam then allowed to coast towards the MCP over several hundred mm. As the beam has a varying acceleration near the cathode, electrons emitted later travel slower and hence by the time they reach the MCP the differential velocity results in a beam that is stretched in time and space. Consequently the current detected at the MCP is stretched in time. The amplified signal is then recorded on an oscilloscope of modest bandwidth and the data collected and re-compressed numerically to deliver the waveform of the original optical signal at the cathode.

Ideally the change in velocity of the electron beam should fall linearly in time. This gives a parabolic relationship between the beam energy (and hence the accelerating voltage) and time.

The beam of electrons is constrained radially within the tube by a modest DC axial magnetic field.

6.3 ELECTRON DETECTION

The electrons are detected by an MCP after drifting down the tube. However, the detection sensitivity of the MCP depends upon the energy of the incident electrons and during the stretched out event the electron energy falls significantly. To compensate for this the gain of the MCP can be ramped up in time. The electronics package has this capability. Note that this occurs in dilated time which is significantly slower that the event time. Also the change in voltage necessary on the MCP is small because the gain is a strong function of applied voltage.

6.4 ARBITRARY WAVEFORM GENERATORS

Kentech has recently developed techniques to deliver high voltage fast waveforms with a degree of arbitrary shape control. This is used at both ends of the device. At the cathode to deliver a velocity dilation that is approximately linear in time (as compared to energy dilation) and at the MCP to deliver a constant sensitivity during the detection of the dilated signal.

6.5 SIGNAL AMPLITUDE

The output of the tube can be as much as -100 volts. However, the useful output is generally 0 to -1 volt. When testing it is a good policy to fit a 20dB SMA (high bandwidth) attenuator before the scope input. When the signal level has been established and known to be stable the attenuator can be reduced or removed if necessary to improve the signal to noise ratio. All testing was done with 20dB in place.

6.6 CONNECTIONS TO THE TUBE

The tube has many electrodes. At the input end there is the cathode and two meshes. At the detection end there is an MCP input, MCP output, a grounded mesh and then the anode from where the signal is taken. Electrodes need a combination of pulsed and DC signals for the tube to operate.

In addition there is a ramp monitor signal, a current supply for the solenoid and a solenoid temperature monitor.

All the required signals are all supplied by an electronics package that can be sited up to ~ 50m away, so as to avoid neutron damage for typical sources under investigation.

The signal output is expected to be sent to a fibre optic Mach-Zehnder interferometer where the electrical signal will be converted to an optical one with high bandwidth for transmission over 50m to a photo detector and oscilloscope.

6.7 FIDUCIALS

In order to recompress the recorded signal it is useful to have a fiducial system to cross time the event with the cathode ramp. The unit described here has two fibre optic inputs that can deliver fast optical pulses to the cathode without restricting the collecting aperture significantly.

The ramp monitor output also provides timing information that can be compared to the event time.

6.8 THE VACUUM TUBE

The PD-PMT uses a sealed off vacuum tube supplied by Photek in the UK. The tube is based upon their 100ps fast PM tubes but has a long drift tube inserted between the cathode and MCP input face. It also has two control meshes placed immediately after the cathode which are used for the dilation ramp. The cathode response is similar to their standard S20 devices. The tube represents a significant fraction of the overall unit cost. Please treat it with suitable care.

6.9 SPECIFICATIONS

6.9.1 OVERALL

No. of optical inputs	1 main (~ø9mm) + 2 x FO fiducials
Cathode type	S20 see Section 15 on page 44
Outputs from head	Signal - can be as high as -100 volts.
	Ramp monitor with built in x 100 attenuator
Maximum rep. rate	10 Hz
Impulse response	Expected to be <10ps
Jitter	<= 20ps RMS
Trigger 1 - electrical	~5V into 50 ohms, <5ns rise time
Optical	Standard LLNL fast trigger level
Trigger 2[1] - electrical	~5V into 50 ohms, <5ns rise time
Optical	Compatible with Broadcom HFBR-14X2XX transmitter
Delay	Depends upon cable lengths used.

6.9.2 ELECTRONICS PACKAGE

LED indicators

Power	Green
Trigger 1	Amber
Trigger 2	Amber
HV supplies active	Amber
Solenoid active	Amber
Trip	Red
Solenoid over temperature	Red.

Front Panel connections

Ethernet LAN	i/o	RJ45 socket	
RS232	i/o	9 pin D-sub, female pins	
Interlock	input	Lemo ERA 00 S (NIM jack) short to enable	
Trigger 1 electrical	input	BNC ~5V into 50Ω	
Trigger 2 electrical	input	BNC 5V into 50Ω unassigned	
Trigger 1 optical	input	ST	Standard LLNL trigger threshold.
Trigger 2 optical	input	ST	unassigned
Local ramp monitor	output	SMA jack	~10V into 50Ω
Remote ramp monitor	output	SMA jack	~10V into 50Ω

Controls

Power switch	Toggle

Rear Panel Connections

Remote ramp monitor input	input	SMA jack	10V, 50Ω
PC ramp	output	N type jack, 5kV, 3ns, pulse energy 2mJ[2]	
Interlock out	output	Lemo 0S 302 jack	
MCP gate	output	BNC jack	500V, 50Ω pulse energy 0.5mJ[2]
PC	output	SHV jack	5kV, 100μA max, stored energy <12mJ[2]
Mesh 1		SHV Jack (not used)	
MCP out	output	SHV jack	500V, 50Ω, stored energy 0.5mJ[2]
Drift MCP in[3]	output	SHV jack	4kV, 100μA max, stored energy <5mJ[2]

1 Trigger 2 is not used
2 All stored and pulsed energy figures are "typical".
3 Note "in" here means the input face of the MCP

Solenoid	output	SMA jack	48V, 2A max
Solenoid temp. mon.	input	BNC	5V, 10k
Power inlet	input	IEC	

Rear Panel controls

Boot Enable	push button

General

Dimensions	4U high x 84 HP wide x 500 mm deep. 19 inch rack mount
Power supply	100 to 240 V AC, 50/60 Hz, 50 W max
Weight	~16kg

6.9.3 HEAD UNIT[4]

Connectors

J1 Solenoid temperature	output	Lemo ERA 0S 302 jack
J2 Output signal	output	SMA jack
J3 Solenoid supply	input	SMA jack
J4 Cathode ramp monitor	output	SMA jack
J5 Photo Cathode bias	input	SHV jack
J6 Not used		
J7 Drift tube bias	input	SHV jack
J8 MCP DC bias	input	SHV jack
J9 MCP compensation pulse	input	BNC jack
J10 Photo Cathode Ramp	input	N type
J11 Opto fiducial 1	input	FC-PC jack, MM[5] ClearCurve®OM_4 fibre
J12 Opto fiducial 2	input	FC-PC, MM[4] ClearCurve®OM_4 fibre

General

Weight	~8.8kg
Dimensions	See figure Figure 3 on page 13
Location of C of G	See figure Figure 3 on page 13

Environmental

Ambient temperature	5 to 35 °C
Humidity	< 95% non-condensing
Altitude	< 1000m

7 FIDUCIAL INPUTS

The two fiducial inputs are nominally the same.

They are made from ~ 1 metre of graded index fibre (see on page 10). We have tested the tube response to these inputs. The laser used was a 30ps 630nm laser diode. Its nominal peak power output was 700mW and this was coupled to a SM fibre with a microscope objective. The peak power in the fibre was likely to be <100mW.

The input connectors are FC-PC and will accept light from both SM and MM FC-PC connectors. Do not fit FC-APC connectors as this could damage the polished surface of the FO connector n the head.

4 J numbering as per LLNL requests

5 These will accept single mode fibre inputs. The fibre used from the connectors to the cathode is a graded index multimode fibre with small minimum bend radius needed to interface to the PC.

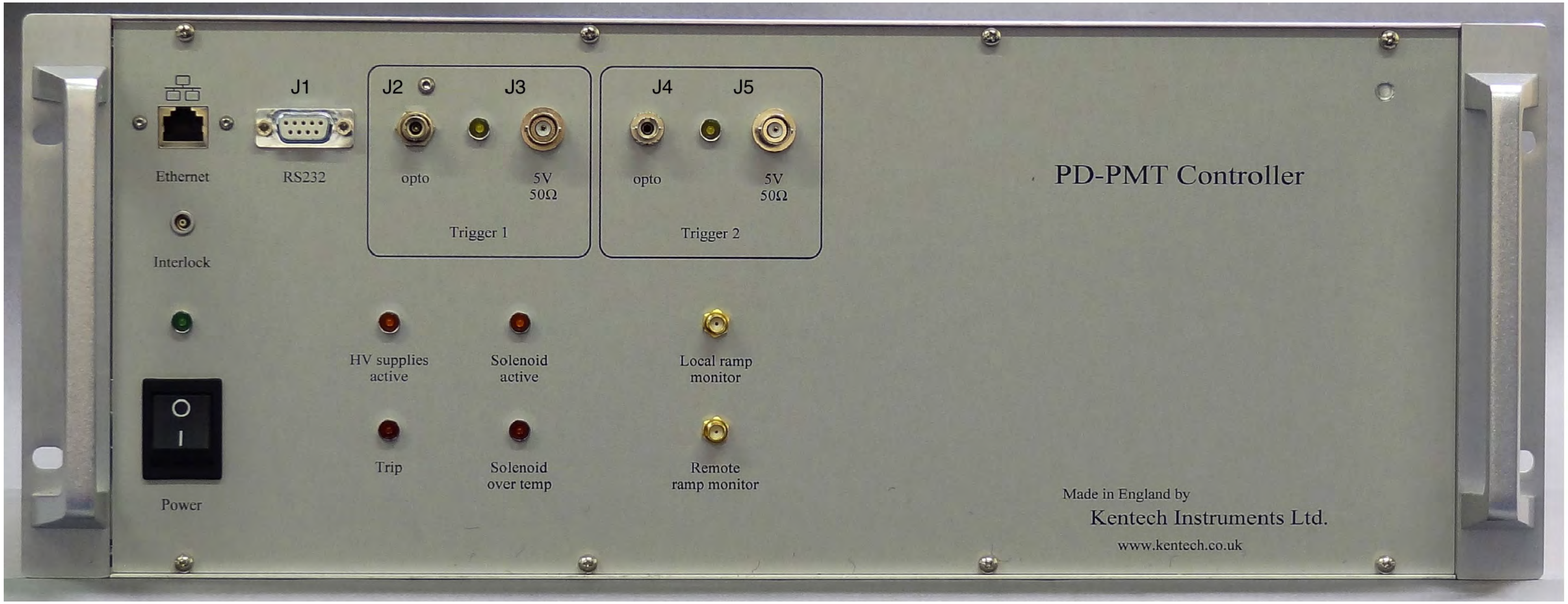


Figure 1 Control unit Front panel

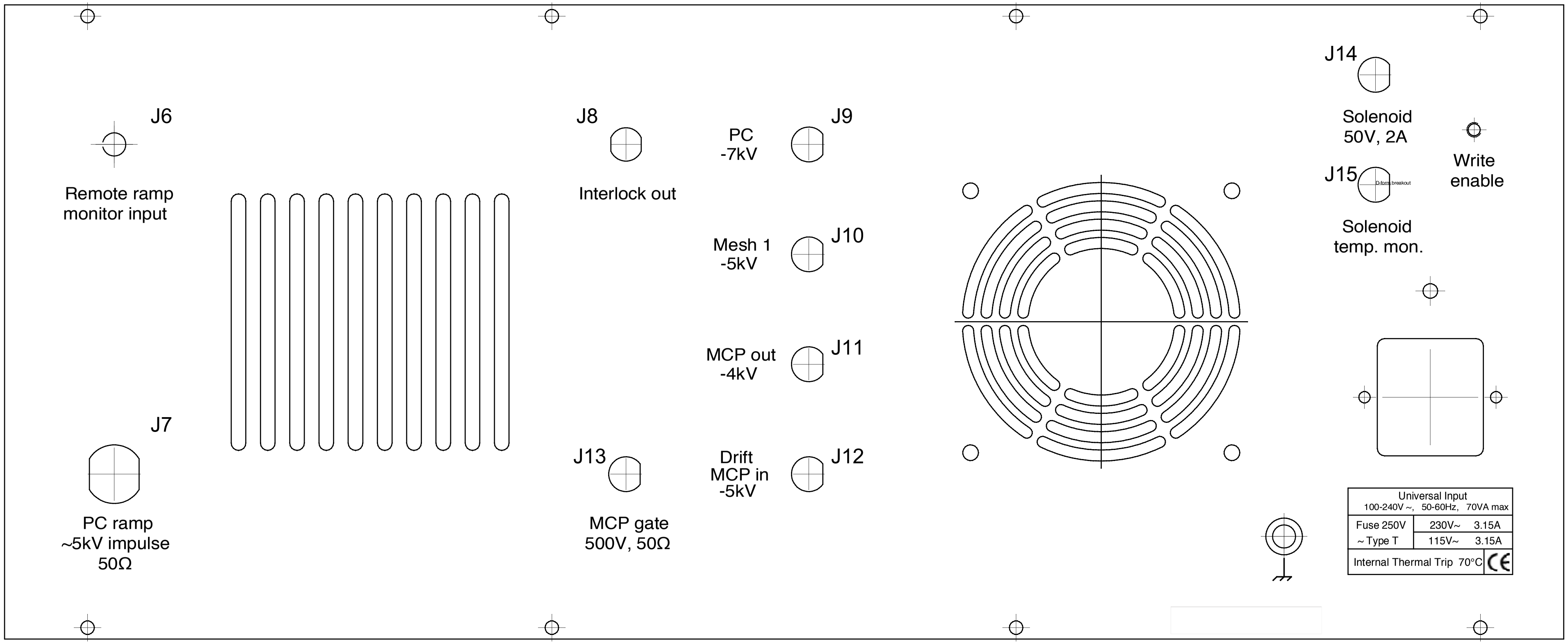


Figure 2 Control unit rear panel schematic

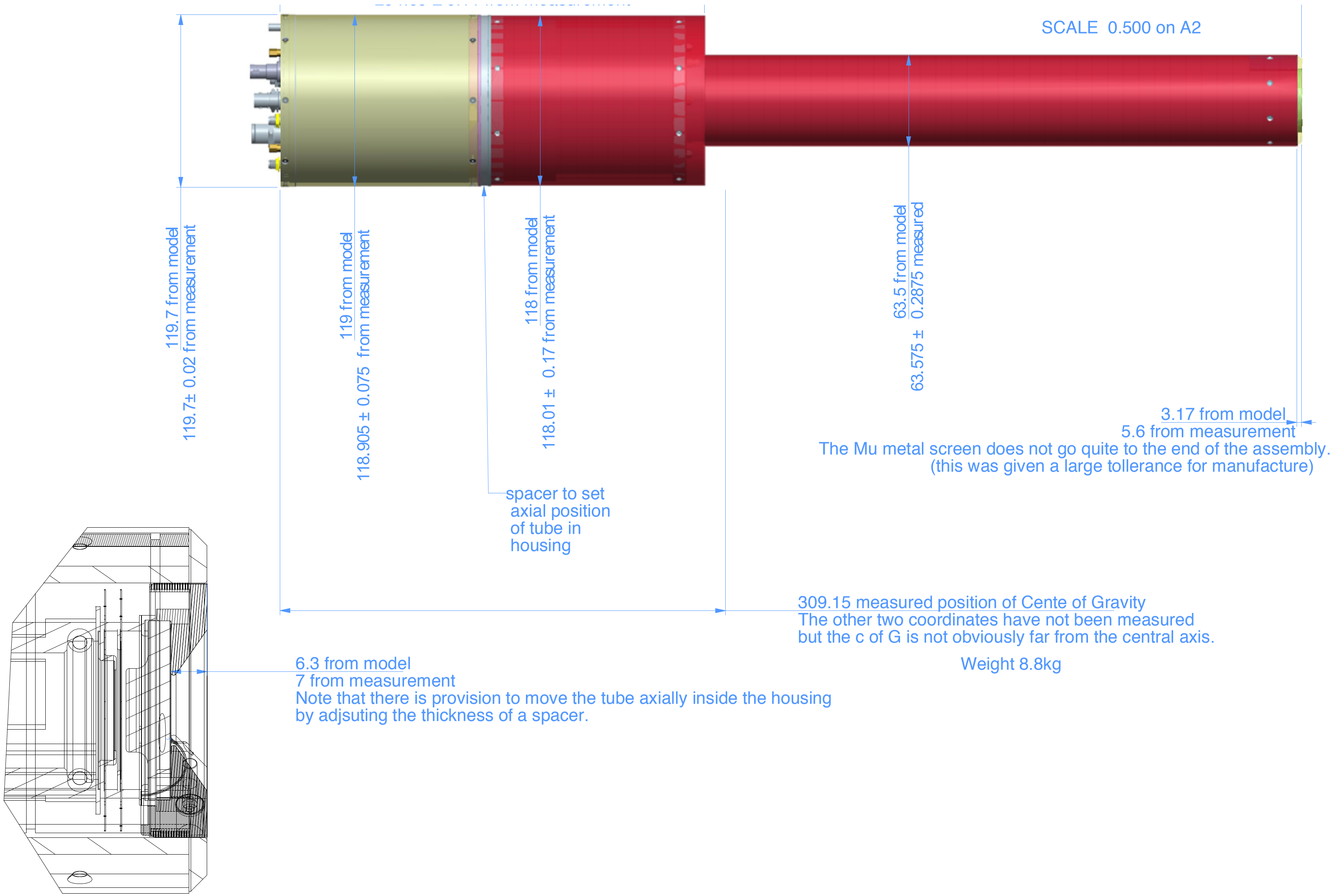


Figure 3 Head metrology

Table 1 Connector and Terminal assignments

PD-PMT head Labels

Labelling	Terminal	Description
Temp.	1	Floating connection to thermistor
Sig.out	2	Output signal
Solenoid	3	Solenoid current input
Ramp monitor	4	Monitor output of PC ramp
PC HV	5	PC bias voltage input
M1 HV	6	Unused
Drift HV	7	Voltage to second mesh and drift tube bias input
MCP HV	8	MCP output face bias input
MCP Comp.	9	MCP output face pulsed compensation input.
PC Ramp	10	Pulsed ramp input to 1st. Mesh - fround referenced here.
Opto 1	11	Optical finducial input 1 of 2
Opto 2	12	Optical finducial input 2 of 2

PD-PMT controller labels

Labelling	Terminal	Description
Ethernet	1	
Trigger 1 opto	2	Fast trigger optical input
Trigger 1 5V	3	Fast trigger electrical input
Trigger 2 opto	4	Spare optical trigger input - unassigned
Trigger 2 5V	5	Spare electrical trigger input - unassigned
Remote ramp monitor input	6	accepts signal from moinotor output on head.
PC Ramp	7	Ramp signal output to PC on head
Interlock out	8	Standard LLNL shorted = HV enabled.
PC	9	HV bias output for PC
Mesh 1	10	HV biasoutput for 1st. Mesh
MCP out	11	HV bias for MCP output face
Drift MCP in	12	HV bias for second mesh, drift tube and MCP input face
MCP gate	13	MCP gate/compensation output to MCP output face
Solenoid	14	Current supply for solenoid
Solenoid temp. mon.	15	Floating thermistor monitor input.

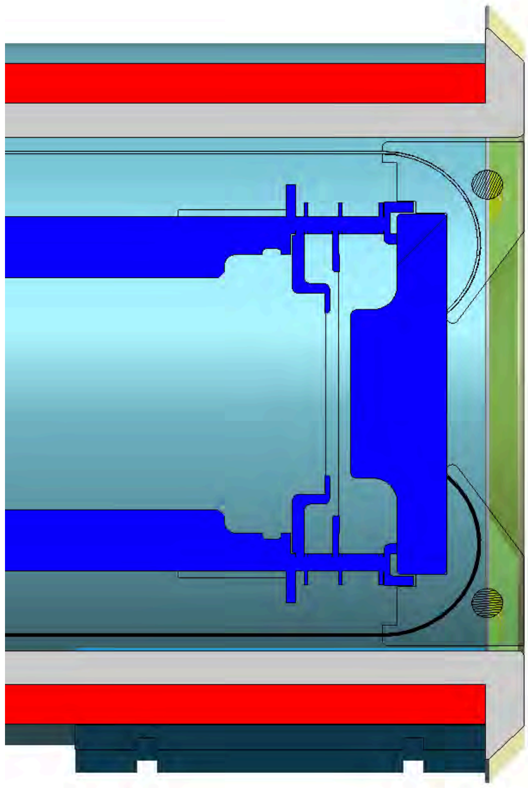


Figure 4 Front end showing input aperture and FO fiducials.

The fibres from the bulkhead go to the front end of the tube and are either close to or contact the input face of the tube, at a radius just outside that of the black plastic cover on the front face. The fibre ends are cleaved and are not coupled with index matching gel as was originally thought desirable. Index matching gel could result in the light being totally internally reflected at the quartz-PC interface. No artefacts were seen as a result of the coupling method used, although on faster time scales one might expect to see some.

The fibres used are significantly longer than needed and should it be necessary to adjust them, the fibre may be re-cleaved or polished many times.

7.1 RESTORING THE ORIGINAL SIGNAL - RE-COMPRESSION

In order to recover the original signal from the dilated one, the signal must be recorded and re-compressed. Whilst we have provided calibration of the dilation caused by the various PC ramps (see Figure 13 on page 38, it is recommended that the user calibrates the system themselves. A calibration is easily generated with a short pulse laser diode and a delay generator. Low jitter between the laser diode and the PC ramp is not needed as long as the laser can provide a low jitter sync. pulse. The timing of this with respect to the PC ramp can be measured along with the timing between the peak of the recorded laser pulse and the PC ramp. Indeed the jitter can help by providing more data. One just needs a table of laser pulse to PC ramp time versus recorded pulse to PC ramp time. This gives the dialtion at each recorded point after the PC ramp, up to the end of the useful temporal window. With such a data set any recorded signal can be recompressed as the local dilation (local in time) will be known.

Kentech Instruments has not provided any automated way to do this reconstruction but it is fairly straightforward. The details will depend upon the exact scope used.

Figure 5 Rear Bulkhead of Head unit

8 SAFETY FEATURES & NOTES

8.1 SOLENOID OVER TEMPERATURE INDICATOR AND PROTECTION

If the over temperature indicator illuminates the solenoid power will automatically shut down. Wait until the over temp indicator goes out before resetting the over-temp trip which will automatically re-start the solenoid supply.

The solenoid also incorporates a back up over temperature self resetting switch ~ 70°C and a diode to prevent high switch off voltages appearing. If the temperature exceeds 70°C the solenoid will be disabled until the temperature is lowered. This is not under software control and is a back up device.

In free air the solenoid will run continuously at 20 volts. The driver can deliver up to 48 volts. We have found that during setting up 20 volts was sufficient. However, it may be that in places where there are other magnetic fields a high applied field may be needed to constrain the electrons so they hit the MCP.

8.2 SAFETY TRIPS

Kentech Instruments strongly recommends that if safety trip is set that the user should investigate why and make the reason is understood before proceeding to use the device.

8.2.1 SAFETY TRIP BEHAVIOUR

There are safety trips on both the solenoid temperature and on the various HV supplies. Once a trip has been set the relevant supply will be disabled. Clearing the trip by issuing the relevant command will immediately re-enable the relevant supply or supplies. If the user does not wish this to happen then the supply should be de-energised before resetting the trip. See the energise command on page 33

8.3 SAFE ILLUMINATION

The PD-PMT will be in an ON condition when the HV PSUs are enabled and gate mode 0 is selected. Do not allow a DC light source to be present on the photo-cathode when the tube is in the DC ON condition.

8.4 POWER UP AND SETTING THE OPERATING PARAMETERS

The operating parameters are set via the computer interfaces. The unit will power up in a disabled condition with all supplies off.

8.5 CONTROLLER - ELECTRONICS PACKAGE:

Grounded metal enclosure with ground bonded front and rear panels

Protective fuses on AC supply

Stored energy less than 10J

Maximum current supply on any high voltage output is <1mA

Finger safe HV connectors (SHV)

Suitable wire and AC power fittings (UL certified)

The pulse width of all pulsed signals of amplitude >50V is <100ns

8.6 PD_PMT DETECTOR HEAD:

There is a flyback diode fitted to the solenoid to avoid a back EMF in the event of accidental disconnection.

The solenoid supply voltage is less than 50V

Finger safe HV connectors (SHV)

Stored energy <100mJ

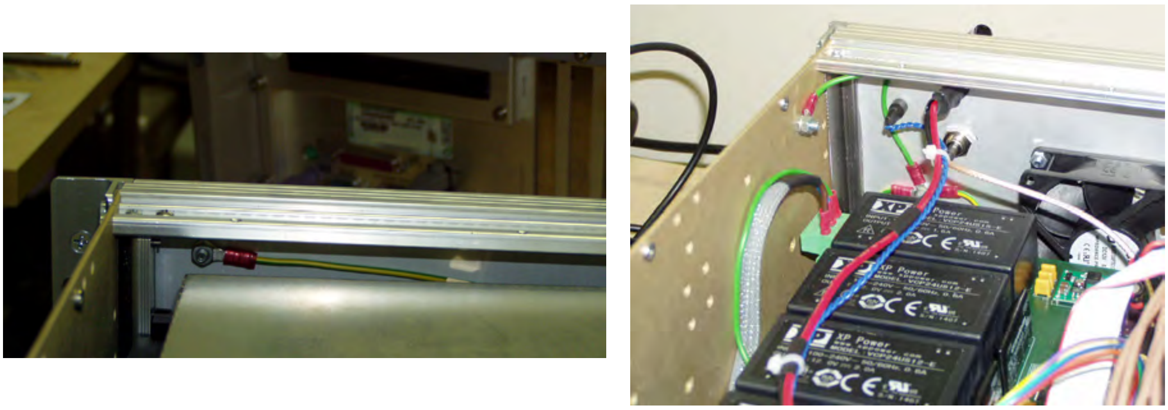


Figure 6 Earth bonding of the front and side panels

9 SETTING UP AND OPERATING

9.1 MODES

There are two sets of operating modes. One set, Ramp Mode, determines how the photocathode is driven. The second, the Gate Mode determines how the MCP is driven. One mode from each set needs to be selected to set the unit up. Both are set to default values of 0 at power up.

9.1.1 RAMP MODE

There are 20 Ramp Modes, numbered 0 through 19. Only 0 through 5 are set up. Consult the factory if more modes are required. The different ramp modes generate different ramps at the PC and give different time windows and temporal magnification. See figure Figure 13 on page 38. 0 is the default mode at power up.

9.1.2 GATE MODES

There are three Gate Modes numbered 0 through 2. See figures Figure 14 on page 39 and Figure 15 on page 39

0 = MCP on DC, the default.
1 = MCP pulsed with a flat top pulse, constant gain.
2 = MCP pulsed with a shaped waveform which contains a ramp.

9.2 FIRST TIME SET UP

A short pulse illumination source is required together with an electrical pre-trigger signal and a delay generator. The maximum trigger rate of the PD-PMT is 10Hz so the pulsed illumination source should not repeat at a higher frequency than 10Hz. Single shot operation is also acceptable. Kentech Instruments recommends that the MCP is operated in DC mode for setting up. This is achieved by sending the appropriate command to the Ethernet or RS232 interface, see 10 on page 27. Initially operate the detector in static mode (no dilation ramp). Read through the following instructions before proceeding. Text in square brackets is text to send. Do not send the brackets.

1. Connect all the cables as per the instructions above.
2. Ensure the interlock input to the electronics package is shorted out [short centre pin to ground to do a hardware enable].
3. Do not apply a trigger signal to the main ramp trigger input. In this condition the tube operates as a conventional PMT and, when enabled, an electrical replica of the input illumination signal is produced at the SMA output on the head rear bulkhead, as measured by an oscilloscope.
4. Ensure that the photo-cathode is receiving only pulsed illumination and that all stray light is excluded.
5. Turn on the power to the electronics package and read the self-test-flag [@>tr]. The first parameter returned is the self-test-flag and should read zero.
6. From your chosen interface (Ethernet or RS232) send a <cr> to the unit to enable the desired interface.
7. Set 20V for the solenoid supply. [20000 !sol <cr>]
   The solenoid supply will go to 48 volts. Generally, this is unnecessary and will cause excessive heating.
8. Set the MCP gain to minimum [0 !gai <cr>].

9. At power up the unit will be in Gate mode 0 and Ramp mode 0 with supplies disabled Enable the supplies [1 1 1 1 1 1 !ene <cr>] and observe the output signal as the gain is gradually increased [1 !gai <cr> etc.]
10. It is assumed that the duration of the illumination pulse is <100ps. Arrange that the oscilloscope will display ~20ns of the output signal from the output SMA connector (on the rear bulkhead of the head) immediately after light strikes the photo-cathode. Initially the scope can be set to trigger internally on a negative signal from the SMA output connector. Expect this signal to be at a level around -1V, slope negative.
11. While observing the signal from the SMA output on the scope gradually turn up the MCP gain and establish that the input signal level and MCP gain are appropriate to produce an output level around -1V at the scope. As a guide, this signal level should be reached at a gain ~6 when a typical 100ps laser diode source is used.
12. Now trigger the scope externally and delay the scope triggering suitably so that the same electrical replica of the optical signal is displayed.
13. Having set the oscilloscope trigger timing and sensitivity to display a static signal the user may now make use of the pulsed dilation to enhance the temporal resolution. The pulsed dilation is triggered following the application of a trigger signal to the front panel trigger input connector.
14. Set up the trigger input, e.g. for electrical triggering enter [1 0 1 0 !trg <cr>]
15. Apply a trigger signal to the trigger input such that the rising edge of the PC ramp pulse precedes the optical pulse by approximately 5ns at the head. Note that if using long cabling between the electronics and the head, allowance must be made for this. Use the monitor output at the head to determine the time at which the PC ramp arrives at the head. This monitor signal arrives at the bulkhead of the head about 4ns after the PC ramp arrives at the PC. The correct timing can be found by observing the scope trace of the output signal while adjusting the delay. If the application of the trigger pulse makes the output signal disappear then the trigger it too early. If it has no effect then the trigger is too late. By means of a binary search, the trigger delay may be set to the point at which the displayed signal starts to be delayed on the scope screen. This occurs as the pulsed dilation starts.

9.2.1 ENABLING THE SUPPLIES

See lists the commands section 10.8 on page 31.

A suitable procedure for enabling the supplies would be:

1. Power up and read the self-test-flag
2. set the gate mode
3. read back the gate mode
4. set the ramp mode
5. read back the ramp mode
6. set the solenoid voltage
7. read back the solenoid voltage
8. set the trigger mode
9. read back the trigger mode
10. check the trip statuses
11. request enabling of the supplies
12. read back the enable request

13. read back what has been enabled.

If all has been enabled the system should be working.

Table 2 UL Certifications

Sheet1

1	Switch	AC main switch	Arcolectric	C1350ALAAF	E45221 / EN61058-1	AC switch on front-panel
2	Switch	Thermal, NC, 70C	Microtherm	R2803EN1503470/55	UL873 E43272	Switch opens AC live at 70C
3	Connector	AC Power inlet	Schurter	5200.0623.1	UL1283 / EN133200	AC Power inlet
4	Converter	AC/DC Universal input	Traco	TXL 035-12S	UL60950-1 E188913	12V Main supply
5	Converter	AC/DC Universal input	XP	VCP24US12-E	UL60950-1	Solenoid card supply
6	Converter	AC/DC Universal input	XP	VCP24US15-E	UL60950-1	Solenoid card supply
7	Relay	DC relay	Crydom	DC60S3	EN60950-1	32V DC interlock relay
8	Wire	AC Power	Various	-	UL1015	AC wiring, 600V rated
9	PCBs	FR4 1.6mm DS PTH	Various	-	E421281	Printed Circuit Board laminate

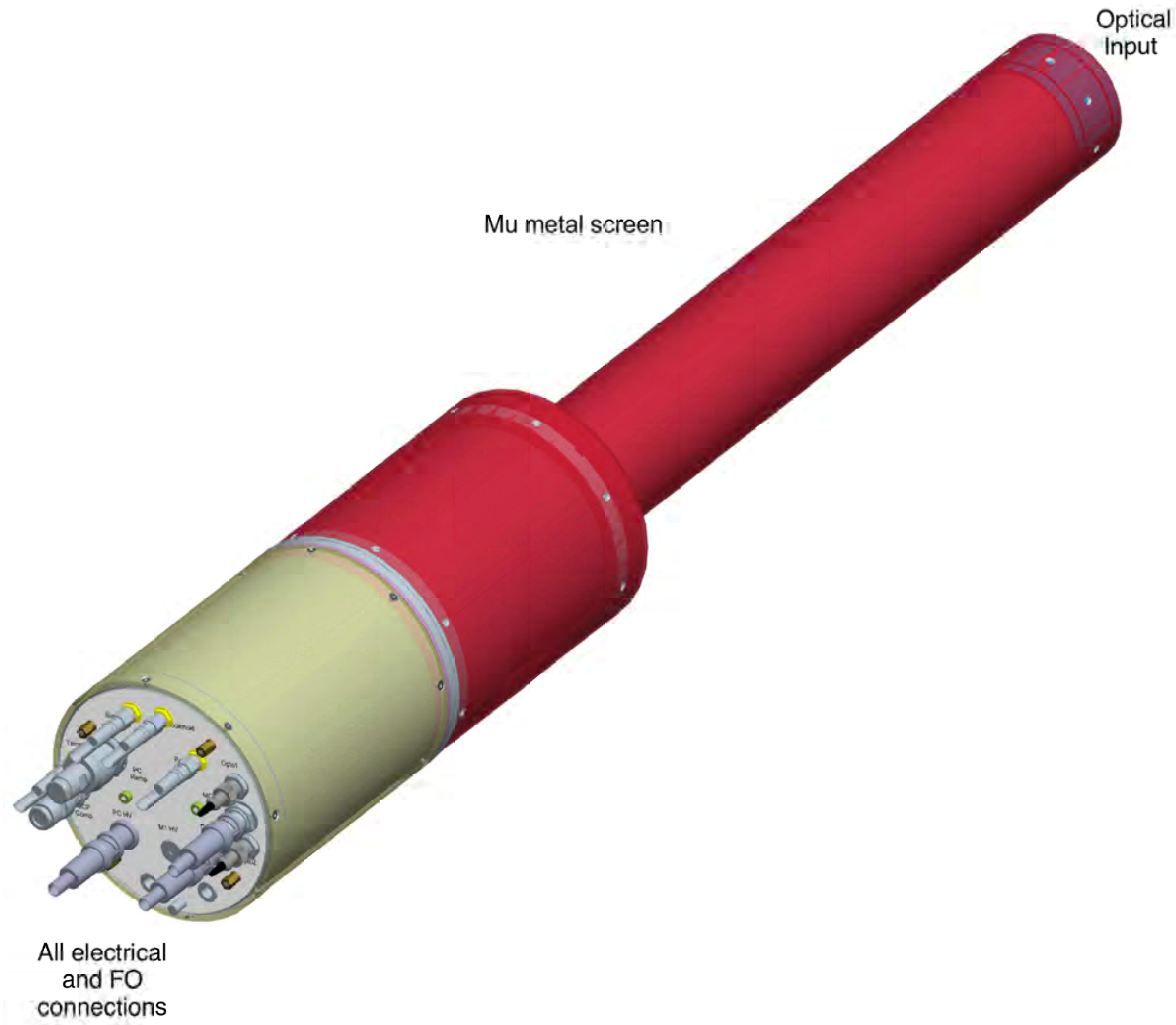


Figure 7 The head showing the optical input and connections

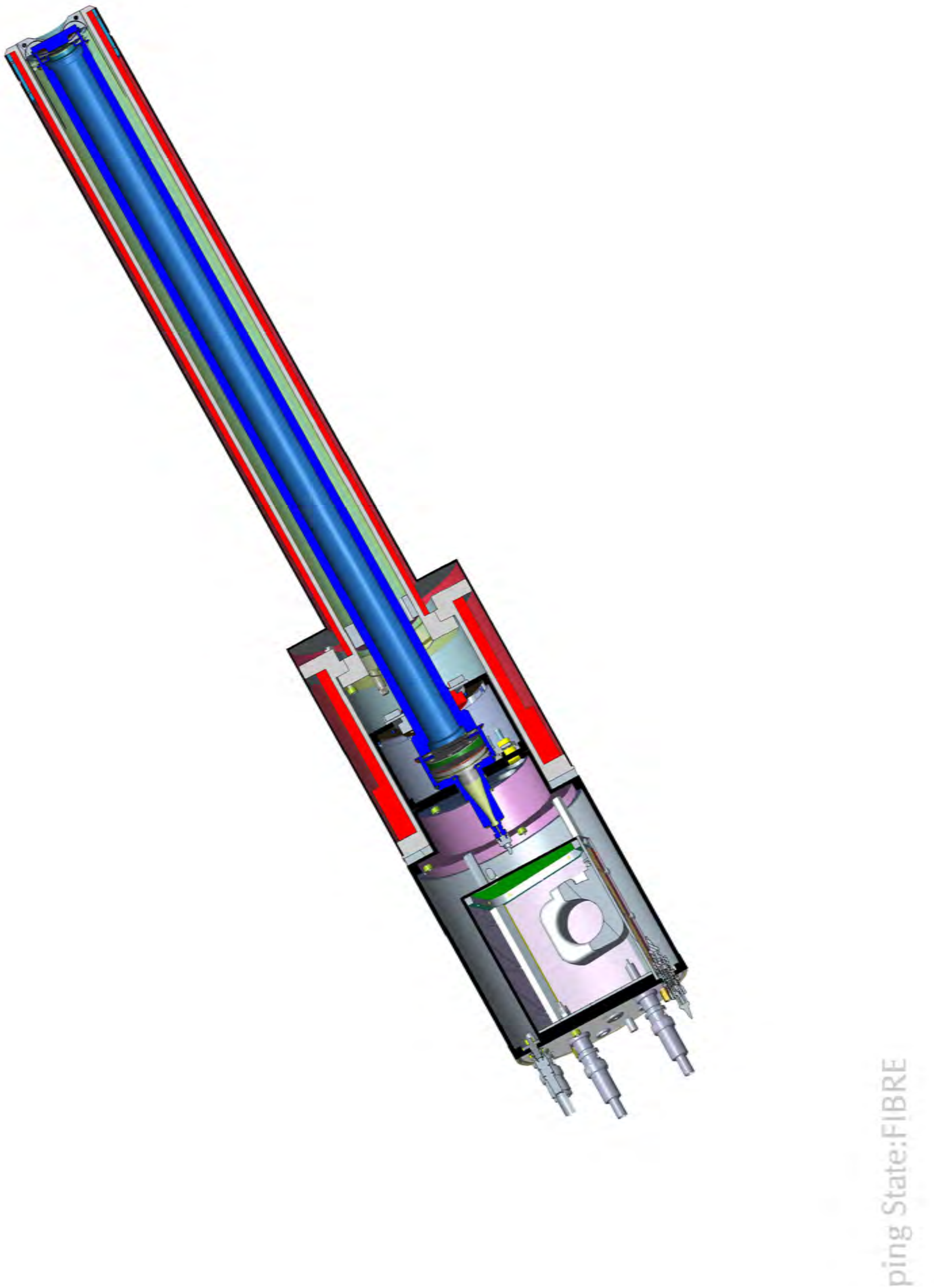


Figure 8 A cross-section of the head.

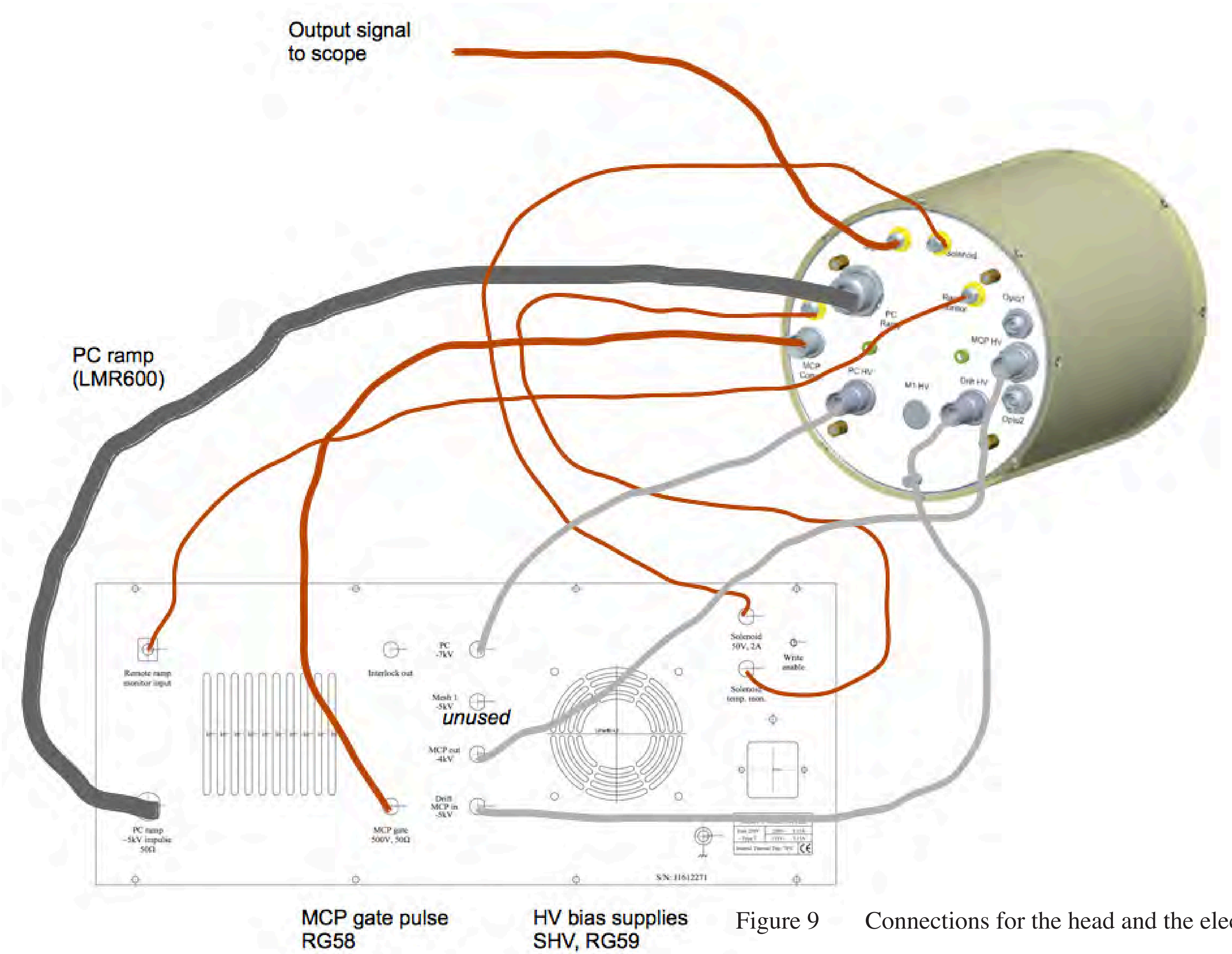


Figure 9 Connections for the head and the electronics package..

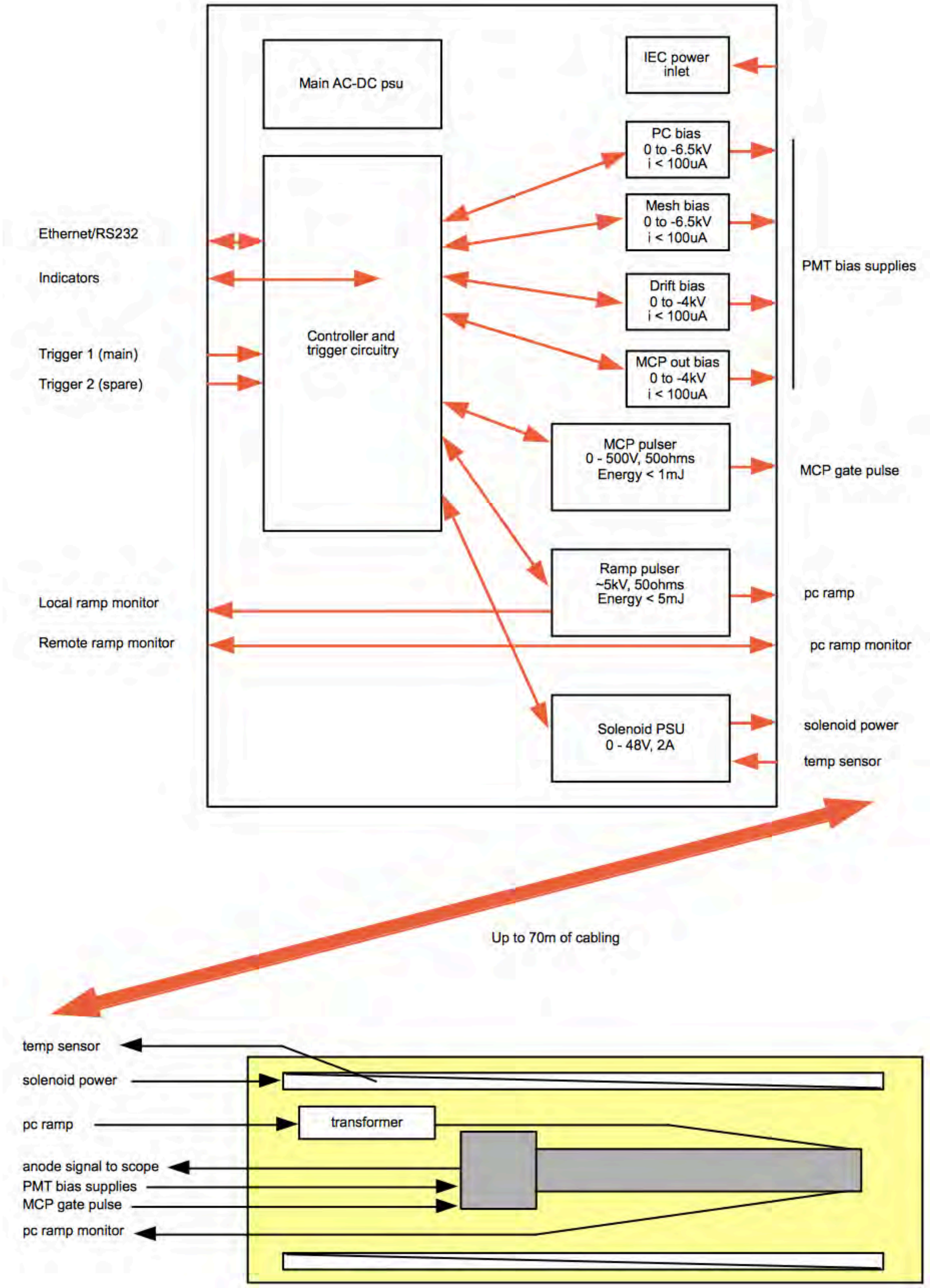


Figure 10 Showing the individual systems and connections to the remote PMT head

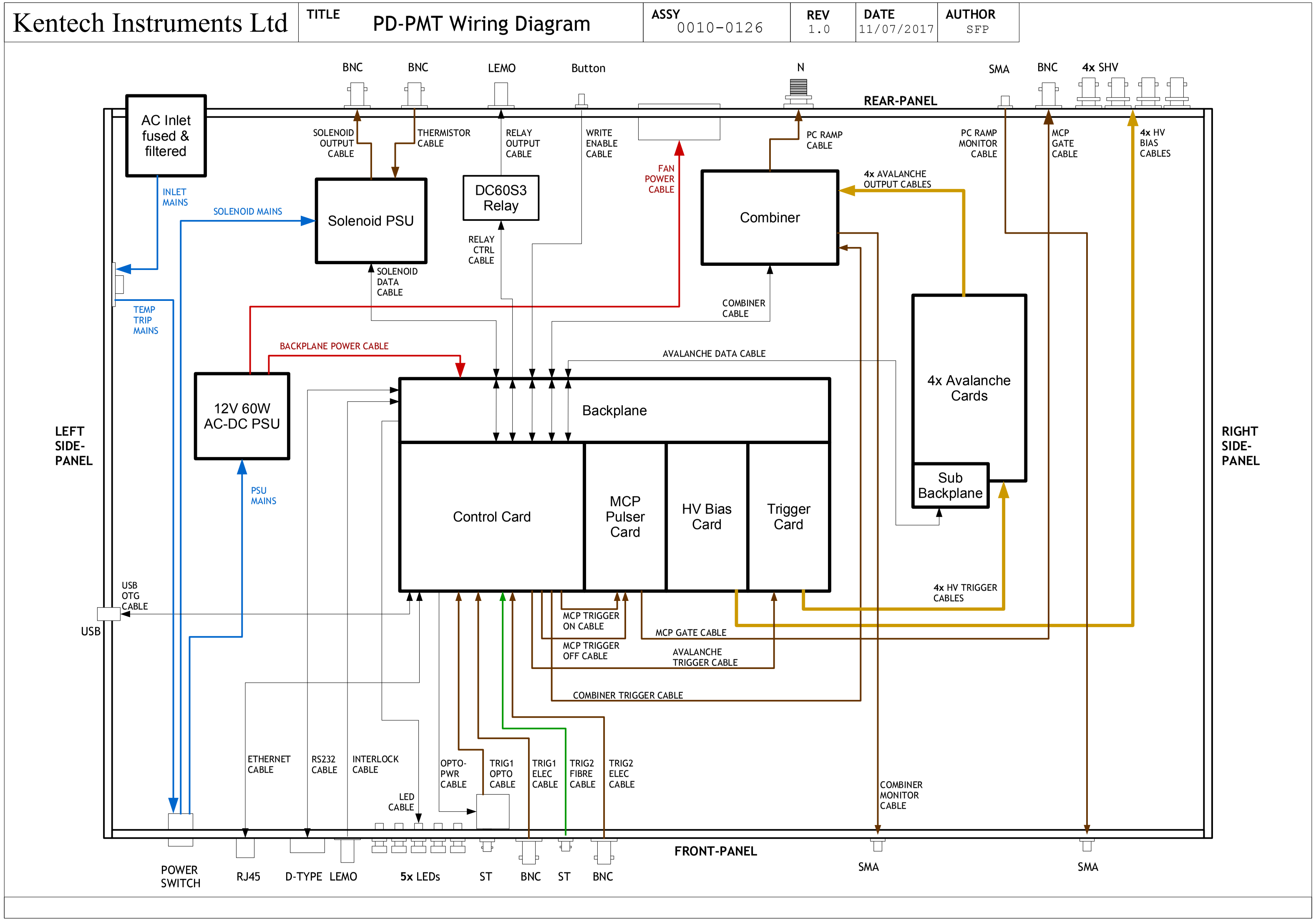


Figure 11 Wiring diagram of the electronics package

10 SOFTWARE CONTROL

The PD-PMT emulator contains an mBed processor together with USB, Ethernet and RS232 interfaces plus a calibration EPROM. It is provided with firmware to emulate the PD-PMT electronics package. The USB supply is for firmware control.

All normal commands to the PD-PMT electronics package are via either RS232 or Ethernet. At power-up the firmware scans the Ethernet and RS232 interfaces and the first to receive a character is taken as the active interface. Thereafter all data to the unused interface will be ignored until the next power cycle.

10.1 POWER-UP INTERFACE SELECTION

On power up the control software will scan the interface ports (USB, Ethernet and RS232) looking for a character sent to the device. The software will latch on to the first interface to send a character and will only use that until the next power-up cycle.

After power-up send a few characters to the interface you plan to use. These characters will not be used as part of a command, they just set the interface to be used.

10.2 ETHERNET

If the Ethernet interface is to be used then the user may need to set up the internal XPORT module which is used to provide TCP communication protocol. An installer for windows can be found at:

http://www.lantronix.com/products/deviceinstaller/

and this can be used to set the IP address of the package. There is no Mac version.

The serial port of the XPORT should be set to 115200 baud, no hardware control, 8 data bits, no parity, 1 stop bit. As shipped the XPORT is set with these serial parameters. The MAC address is shown on the front page.

By default, TCP should communicate with port 10001. This shows a Hyperterminal connection dialogue:

10.3 RS232:

For RS232 use simply send a carriage return (ASCII code 13) to the RS232 port at the pre-set RS232 baud rate. A few seconds later the instrument will respond with a banner message. As shipped the RS232 port is set to 9600 baud however the user can choose between 9600, 19200 and 115200 baud for startup. As shipped the setting for the control terminal should be 9600 baud, no hardware control, 8 data bits, no parity, 1 stop bit.

Refer to the factory for commands to change the power-up RS232 baud rate.

10.4 CONTROL INTERFACE

The electronics package will respond to the high-level command set. The list of instructions and arguments is provided below. The control interface may be toggled between normal mode (in which only the normal command set is recognised) and DEBUG mode (in which all typed text is processed).

10.5 DEBUG MODE

To enter DEBUG mode type:

+debug <cr>

to the control interface and there should be an ok response to indicate that the full Forth interface is available.

Note that when the unit is in debug mode the control interface will produce many responses and will not adhere to the standard protocol. It will produce a prompt line where new commands can be entered. For more information on how to use the unit in debug mode please consult the factory.

To leave DEBUG mode type:

-debug <cr>

to the control interface to which there should be **no** ok response.

The ‘debug’ state is stored in EPROM so the unit will power-up in the same state in which is was

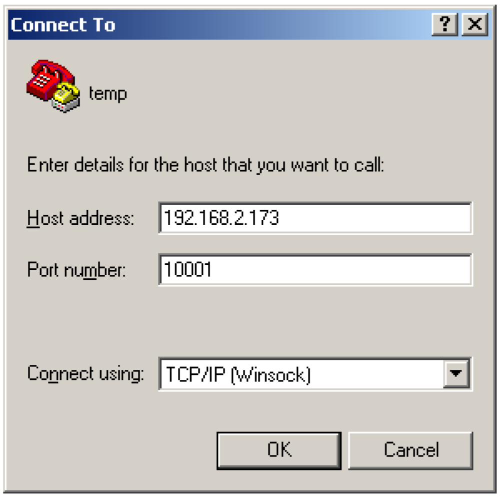


Figure 12 A Hyperterminal dialogue box.

turned off.

As shipped the unit is in normal (non-debug) mode so the Ethernet and RS232 interfaces will only respond to correctly formatted PD-PMT commands. At power-up there is a start-up message transmitted to the active control interface immediately after receipt of the first serial character. Unlike some other Kentech units, this occurs even if the unit is not set to debug mode so the first action of the control software should be to issue a <cr> character and then drop the returned text. Thereafter the unit will adhere to the standard protocol.

Standard PD-PMT control commands can be sent via either interface.

10.6 SOME EXAMPLES

Assuming the IP address has been set up using the Lantronix device installer as above, power up the unit.

To communicate via Ethernet under MacOSX open a terminal window and type:

telnet 192.168.2.2 10001 <cr>

but substituting the IP address previously chosen.

Note that 10001 is the port number specified for TCP protocol in the Xport Ethernet interface in the unit.

Here we are using Telnet for the serial coms. Although this is not ideal it is convenient for a quick test. Note that Telnet echoes characters as they are typed so even in -debug mode it appears that typed text is echoed.

After typing a carriage return (and assuming that Telnet starts without errors) something like this should appear:

Freds-MacBook-Pro:~ fredshare$ telnet 192.168.2.185 10001
Trying 192.168.2.2...
Connected to 192.168.2.2.
Escape character is '^]'.
PD-PMT
Kentech Instruments Ltd 2017

It should now be possible to type commands to the unit. A slight complication is that Telnet does not function as a conventional terminal emulator and only sends text as complete lines after a <cr>. Furthermore, it echoes typed text as it is typed as noted above.

Assuming that the unit is not in debug mode, it will only respond to correctly formatted commands e.g.

Type:

@del <cr>

and the response should be:

{@trp;0 ;0 ;0 ;0 }

which lists various trip settings

To exit from Telnet type:

ctrl]

which escapes the serial session followed by:

close <cr>

A similar session can be achieved on a Windows machine with Hyperterminal.

10.7 PROTOCOL

The following protocol is supported via the RS232 and Ethernet interfaces in non debug mode.

It will not be possible to download code to the PD-PMT controller (PD-PMTC) under the normal operating protocol. The PD-PMTC will generate responses to valid commands and will not generate any unsolicited output. Invalid commands will be ignored. All commands and response will be in ASCII characters. Commands are case sensitive.

In the interest of simplicity, all commands will be parsed by the PD-PMTC using the Forth interpreter, so the parameters need to be delimited by spaces and the command line will be terminated by carriage return and linefeed characters. The Forth interpreter will not recognise any commands other than those needed in the command set.

The PD-PMTC will not echo command characters as they are received and no output will be generated until a valid command is recognised. (Note the comment about the use of a Telnet interface above.)

When a valid command is recognised, the PD-PMTC will output a response. Responses are preceded with a cr and lf, then an ASCII { character and end with an ASCII }. The response will be delimited into fields by an ASCII ; character. The first field in the response will be a repeat of the command.

If the interpreter is unable to carry out the command it will return an error. Error types are:

?stack - the command interpreter has detected a wrong stack depth error, i.e. the wrong number of parameters have been received.

?param - the command interpreter has detected an out of range parameter

After an error, the command is not executed, the stack is cleared and no values are returned other than the error code. Following a stack error, the stack is cleared then dummy parameters (generally -1 or 65536) are added for the purpose of formatting the response only.

All status commands expect and deliver data as decimal numbers and all numeric data should be decimal, no decimal points or other punctuation should be used.

10.7.1 EXAMPLE:

1) to set the desired value of the solenoid voltage to 24V the command would be:-

24000 !sol

and the response if the command can be completed would be:-

{24000 ! sol;0}

2) as above but with a missing parameter (an error):-

!sol

and the response would be:-

{-1 !sol;?stack}

10.8 STANDARD PD-PMT CONTROL COMMANDS

Explanatory notes:-

In Forth terminology, a @ character implies a fetch or read operation and a ! character implies a store or write operation.

All input and output parameters are numerical. For logical inputs and outputs use TRUE = 1 or -1, FALSE = 0

Name **safe**

Explanation Power down all modules in PD-PMT

Format **safe**

parameters: none

returned values:

r1 = error flag

Notes safe is equivalent to 0 0 0 0 0 0 !ene

Name **!gate_mode**

Explanation Set gate mode of MCP

Format **p1 !gtm**

parameters:

p1 = gate mode range 0 though 2

returned values:

r1 = error flag

Notes default gate_mode at power up is 0
Gate_mode determines the requested mode for gating
0 = DC mode
1 = pulsed mode - simple gate
2 = ramped mode - gain compensation during dilation.

Name **!gain**

Explanation Set MCP gain

Format **p1 !gai**

parameters:

p1 = gain mode range 0 through 9

returned values:

r1 = error flag

Notes default gain_mode at power up is 0
0 = minimum gain
9 = maximum gain
The error flag contains no information and is for software consistency.

Name **!ramp_mode**

Explanation Set ramp mode of photo cathode

Format **p1 !ram**

parameters:
p1 = ramp mode range 0 through 19
returned values:
r1 = error flag

Notes default ramp_mode at power up is 0
Ram_mode determines the requested value for
PC bias
Mesh bias
Drift bias
Currently only modes 0 through 5 are set up.
The error flag contains no information and is for software consistency.

Name **@gate_mode**

Explanation Read back gate mode setting

Format **@gtm**

parameters: none
returned values:
r1 = gate_mode setting 0 through 2

Notes This is a simple readback of the value set with !gtm

Name **@gain**

Explanation Read back gain setting

Format **@gai**

parameters: none
returned values:
r1 = gain setting 0 through 9

Notes This is a simple readback of the value set with !gai

Name **@ramp_mode**

Explanation Read back ramp mode setting

Format **@ram**

parameters: none
returned values:
r1 = ramp_mode setting 0 through 19

Notes This is a simple readback of the value set with !ram

Name !energize

Explanation Request power up of specified modules

Format p1 p2 p3 p4 p5 !ene

parameters:
p1 = TRUE = req enable HV bias (PC bias, Drift bias, Mesh bias, MCP bias)
p2 = TRUE = req enable trigger pulser
p3 = TRUE = req enable ramp pulser
p4 TRUE = req enable mcp pulser
p5 = TRUE = req enable solenoid
returned values:
r1 = error flag

Notes The solenoid will be enabled only if temp trip and interlock latch are zero
The HV bias will be enabled only if the interlock latch is zero
The measured power status of the modules can be read with @>en
The error flag contains no information and is for software consistency.

Name @energize

Explanation Read back requested power up status of modules

Format @ene

parameters: none
returned values:
r1 = TRUE = req enable HV bias
r2 = TRUE = req enable trigger pulser
r3 = TRUE = req enable ramp pulser
r4 = TRUE = req enable mcp pulser
r5 = TRUE = req enable solenoid

Notes This is a simple read back of values set with !ene
The measured power status of the modules can be read with @>en

Name @>energize

Explanation Read back actual power up status of modules

Format @>en

parameters: none
returned values:
r1 = TRUE = HV bias enabled
r2 = TRUE = trigger pulser enabled
r3 = TRUE = ramp pulser enabled
r4 = TRUE = mcp pulser enabled
r5 = TRUE = solenoid enabled

Notes This is the measured power status of the modules
Interlock latch set will disable HV bias and the solenoid supply.
Solenoid temp trip set will disable the solenoid supply.

Name **!trig**

Explanation Set up triggering

Format **p1 p2 p3 p4 !trg**

parameters:
p1 = TRUE = enable trigger logic
p2 = TRUE = enable one shot mode
p3 = TRUE = reset trigger latch
p4 = TRUE = enable optical trigger
returned values:
r1 = error flag

Notes *If one shot mode is enabled, the PD-PMT will not trigger when the trigger latch is set*
Only one trigger source (electrical or optical) is active at a time, activating one disables the other.
The error flag contains no information and is for software consistency.

Name **@trig**

Explanation Read trigger setup and trigger latch

Format **@trg**

parameters: none
returned values:
r1 = TRUE = trigger logic enable
r2 = TRUE = one shot enable
r3 = Trigger latch, TRUE = triggered
r4 = TRUE = optical trigger enabled

Name **@trips**

Explanation Read trip latches

Format **@trp**

parameters: none
returned values:
r1 = TRUE = solenoid trip
r2 = TRUE = interlock latch
r3 = TRUE = solenoid hot
r4 = TRUE = interlock input

Notes *Solenoid trip is set TRUE if solenoid temperature exceeds trip limit*
Solenoid hot is a non latched status bit, TRUE = solenoid over trip limit
Interlock latch is set TRUE if interlock circuit is NOT ok
Interlock input is a non latched status bit, TRUE = NOT ok.
The solenoid trip removes power from solenoid module
The interlock latch removes power from solenoid and HV bias modules
The measured temperature of the solenoid can be read with @>tu
Resetting a trip will immediately re-energise a supply unless the supply has been separately de-energised.

Name **0trips**

Explanation Reset solenoid trip and reset interlock latch

Format **0trp**

parameters: none

returned values:

r1 = error flag

Note The error flag contains no information and is for software consistency..

Name **!solenoid**

Explanation Set requested solenoid voltage

Format **p1 !sol**

parameters:

p1 = Requested solenoid voltage in mV, range 0 through 48000

returned values:

r1 = error flag

Notes Power will only be applied to the solenoid if the solenoid is energised using !ene and interlock latch is false and solenoid trip is false.

The measured voltage applied to the solenoid can be read with @tu

The error flag contains no information and is for software consistency.

Name **@solenoid**

Explanation Read back requested solenoid voltage in mV

Format **@sol**

parameters: none

returned values:

r1 = requested solenoid voltage in mV

Notes This is a simple readback of the value set with !sol

The measured voltage applied to the solenoid can be read with @>tu

The unit will operate for extended periods in free circulation at 20 volts.

Name **@>tubeadcs**

Explanation Read measured values from tube and solenoid monitors

Format @>tu

parameters: none

returned values:

r1 = measured solenoid voltage in mV

r2 = measured solenoid current in mA

r3 = measure solenoid temperature in 1/10 of a °C

r4 = measured PC bias voltage in V

r5 = measured Drift voltage in V

r6 = measured MCP out voltage in V

r7 = HV bias settled flag

Notes HV bias settled flag is false for approx 10 seconds after any of the HV bias voltages are changed

Name **@>trigadcs**

Explanation Read measured diagnostic voltages from the trigger pulser, combiner and self test error flag

Format **@>tr**

parameters: none
returned values:
r1 = self test error flag
r2 = not used – currently returns zero
r3 = trigger ts monitor
r4 = trigger v1 monitor
r5 = trigger v2 monitor
r6 = trigger v3 monitor
r7 = not used – currently returns zero

Notes self test error flag should be read after power up
Zero = ok, Not zero = test fail, contact the factory should this persist.
Other returned value in this word are for diagnostic purposes only

Name **@>ramp0adcs**

Explanation Read measured diagnostic voltages from ramp pulser 0

Format **@>r0**

parameters: none
returned values:
r1 = ramp 0 ts monitor
r2 = ramp 0 a0 monitor
r3 = ramp 0 a1 monitor
r4 = ramp 0 a2 monitor
r5 = ramp 0 b0 monitor
r6 = ramp 0 b1 monitor
r7 = ramp 0 b2 monitor

Notes Diagnostic purposes only

Name **@>ramp1adcs**

Explanation Read measured diagnostic voltages from ramp pulser 1

Format **@>r1**

parameters: none
returned values:
r1 = ramp 1 ts monitor
r2 = ramp 1 a0 monitor
r3 = ramp 1 a1 monitor
r4 = ramp 1 a2 monitor
r5 = ramp 1 b0 monitor
r6 = ramp 1 b1 monitor
r7 = ramp 1 b2 monitor

Notes Diagnostic purposes only

Name **@>ramp2adcs**

Explanation Read measured diagnostic voltages from ramp pulser 2

Format **@>r2**

parameters: none

returned values:

r1 = ramp 2 ts monitor

r2 = ramp 2 a0 monitor

r3 = ramp 2 a1 monitor

r4 = ramp 2 a2 monitor

r5 = ramp 2 b0 monitor

r6 = ramp 2 b1 monitor

r7 = ramp 2 b2 monitor

Notes Diagnostic purposes only

Name **@>ramp3adcs**

Explanation Read measured diagnostic voltages from ramp pulser 0

Format **@>r3**

parameters: none

returned values:

r1 = ramp 3 ts monitor

r2 = ramp 3 a0 monitor

r3 = ramp 3 a1 monitor

r4 = ramp 3 a2 monitor

r5 = ramp 3 b0 monitor

r6 = ramp 3 b1 monitor

r7 = ramp 3 b2 monitor

Notes Diagnostic purposes only

Name **@>mcpadcs**

Explanation Read measured diagnostic voltages from ramp pulser 0

Format **@>mc**

parameters: none

returned values:

r1 = mcp_pulse monitor

r2 = mcp_ramp monitor

r3 = not used – currently returns zero

r4 = not used – currently returns zero

r5 = not used – currently returns zero

r6 = not used – currently returns zero

r7 = not used – currently returns zero

Notes Diagnostic purposes only

11 RAMP MODES

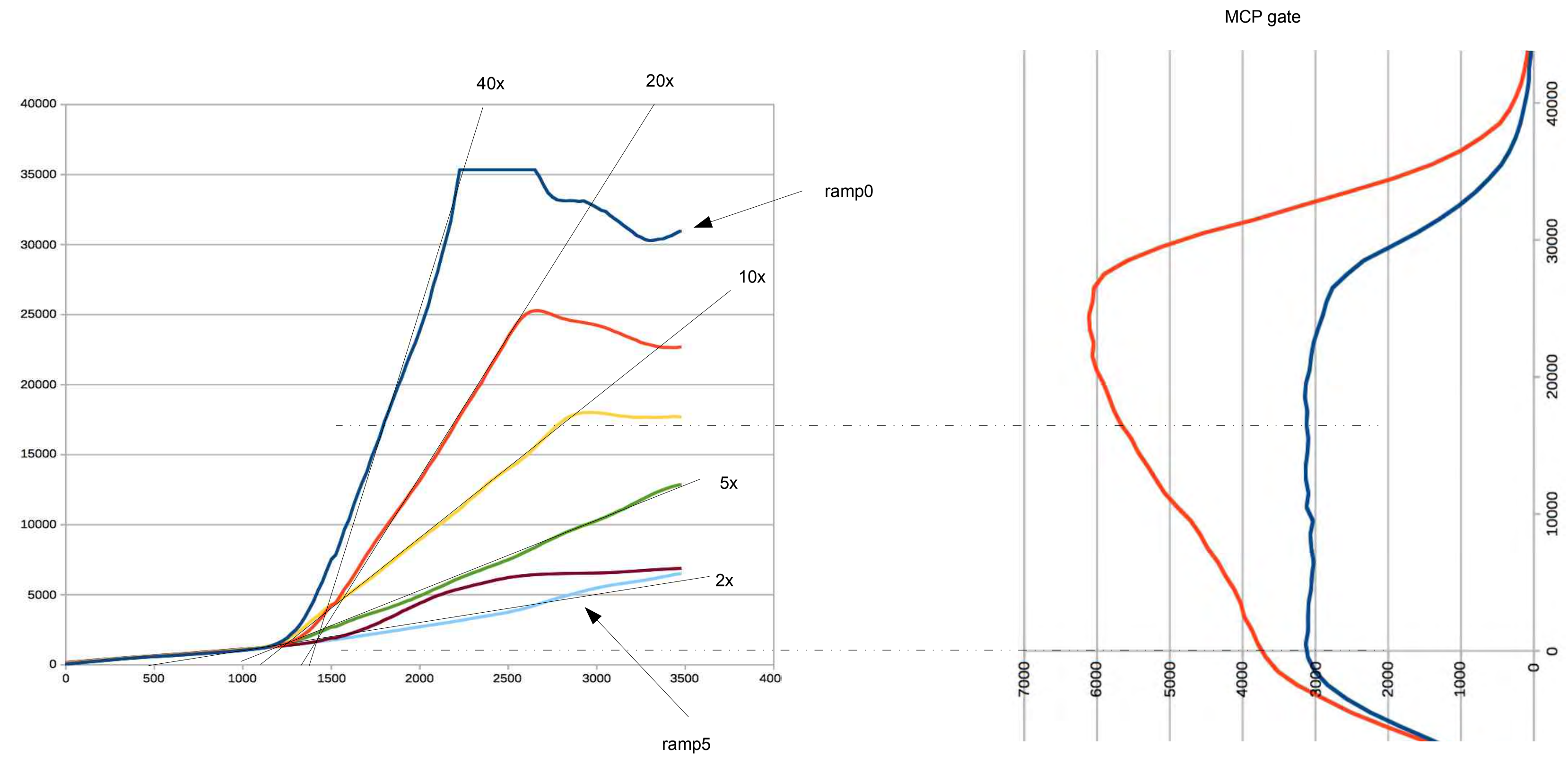


Figure 13 The left hand graph shows the relative timing between input and output signals. The abscissa is the timing of the light signal input to the photocathode. The ordinate is the timing of the electrical output signal to the scope. Timing is relative to the peak of a gaussian signal. The approximate slopes (dilation factors) are shown for each ramp 0 through 5. On the right hand graph is the MCP response with compensation on (red) and off (blue). The relative timing w.r.t. the dilated output pulse is indicated by showing the graph rotated.

12 GATE MODES

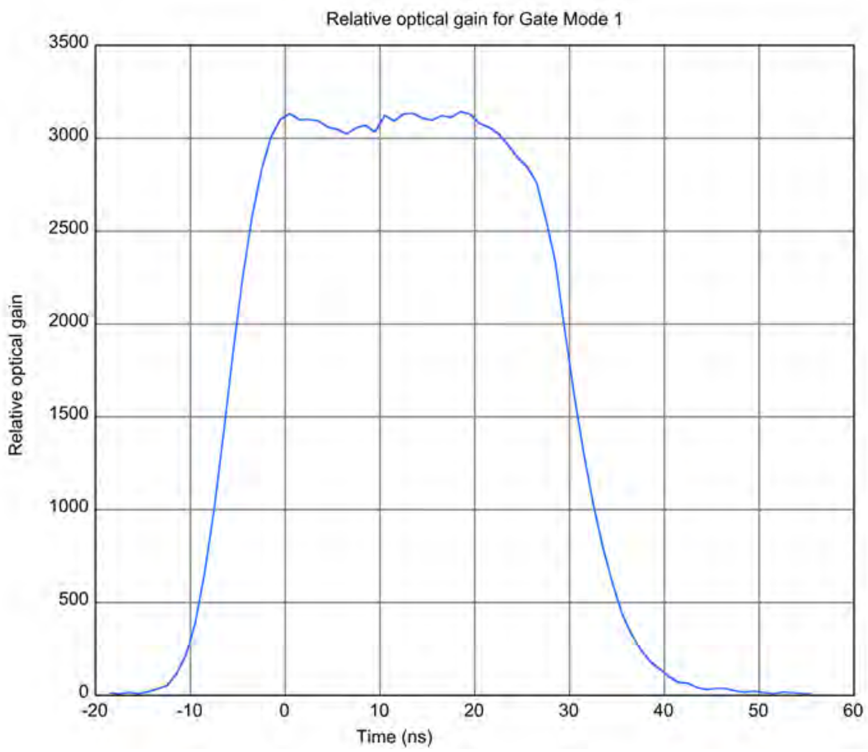


Figure 14 MCP Gate Mode 1
Showing the optical gain as a function of time for an undilated signal.

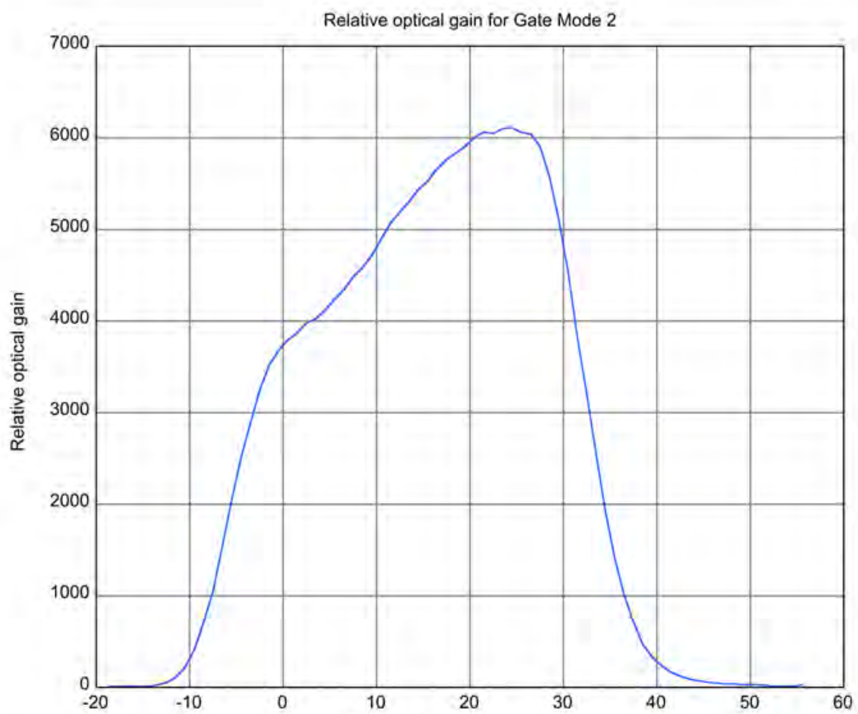


Figure 15 MCP Gate Mode 2
Showing the optical gain as a function of time for an undilated signal. The voltage and hence the gain is ramped up during the MCP drive pulse and can be used to compensate for the reduction in MCP sensitivity during a dilated pulse due to the gradually fall in energy of the incident electrons due to the dilation.

13 RAMP MONITORS

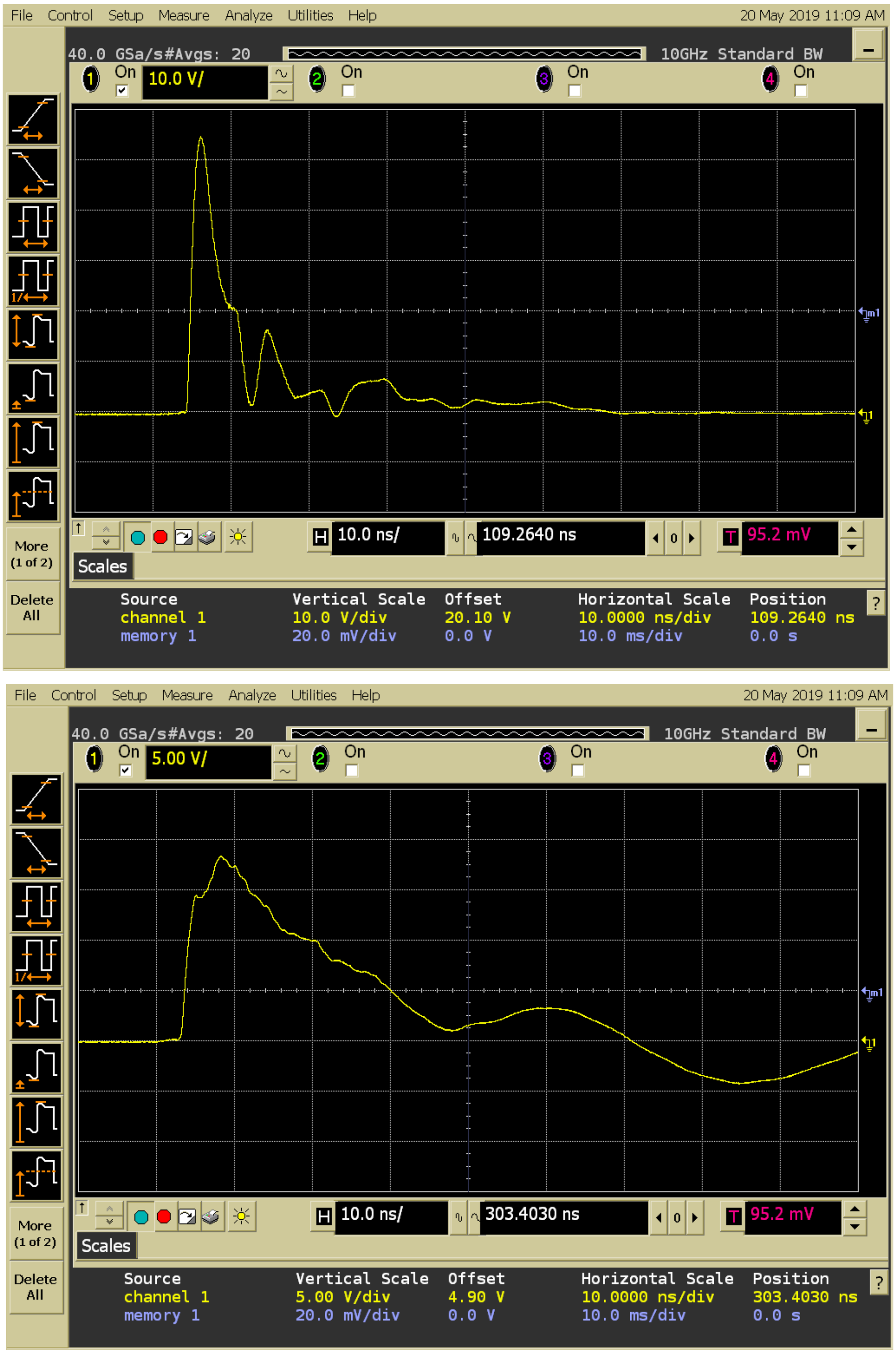


Figure 16 The local (upper) and head (lower) PC ramp monitors.
The head is driven over long cables (as will be used).
The head monitor is connected directly to a scope (It does not come back through long cables).

14 EXAMPLES OF DILATION

The figures in this section are typical data, i.e. not taken with this particular tube. They are to show the principal of dilation and see its effects in oscilloscope traces.

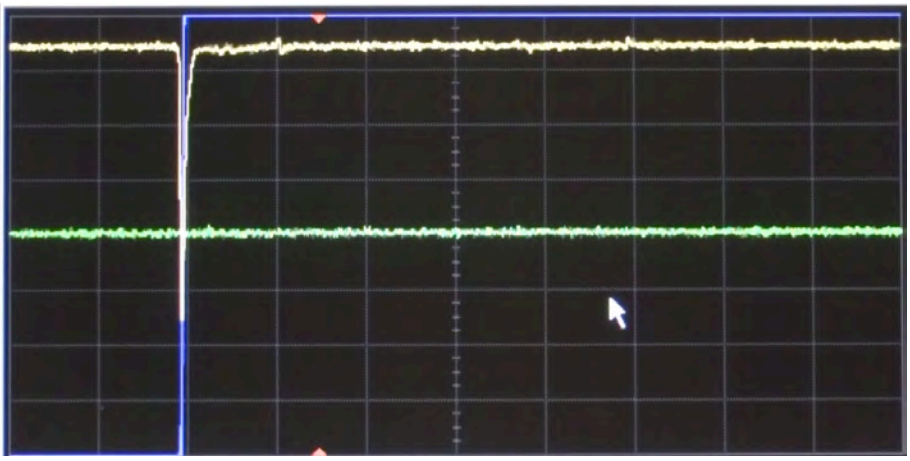


Figure 17 An undilated signal -PC ramp off - 5ns/div
Yellow is the signal output, Green is the ramp monitor and Blue is a sync. pulse from the laser diode..

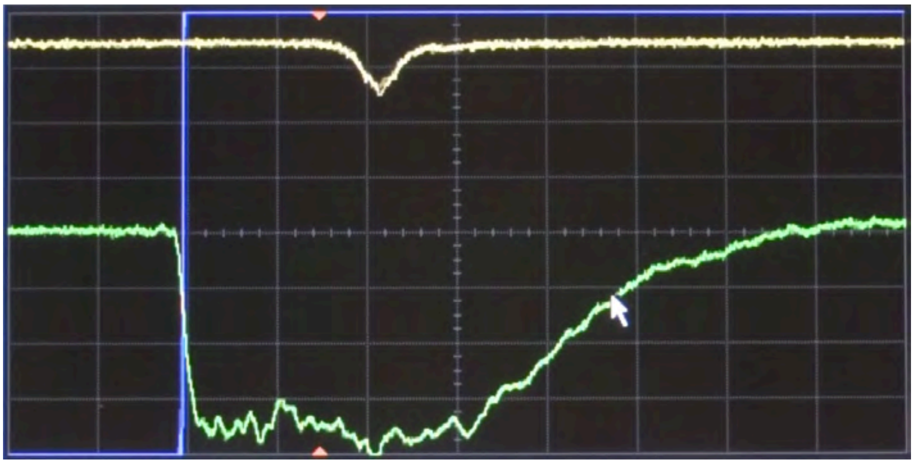


Figure 18 A dilated signal with the PC ramp on - 5ns/div.
Yellow is the signal output, Green is the ramp monitor and Blue is a sync. pulse from the laser diode.

14.1 PROGRESSIVE DILATION

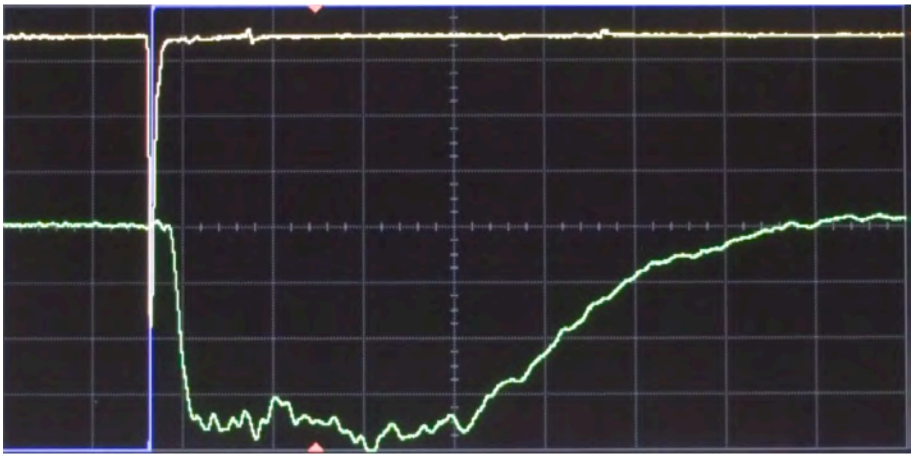


Figure 19 An undilated signal with the light arriving before the PC ramp - 5ns/div. Yellow is the signal output, Green is the ramp monitor and Blue is a sync. pulse from the laser diode.

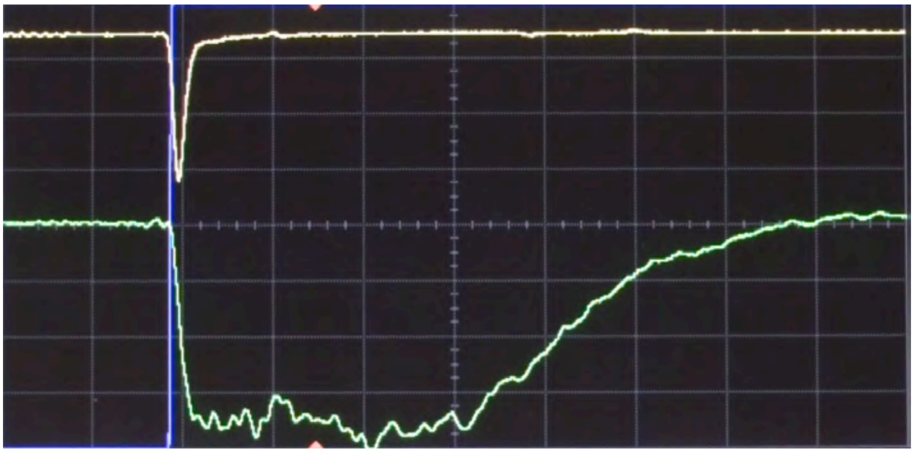


Figure 20 Dilation is just starting with the light arriving at the beginning of the PC ramp - 5ns/div. Yellow is the signal output, Green is the ramp monitor and Blue is a sync. pulse from the laser diode.

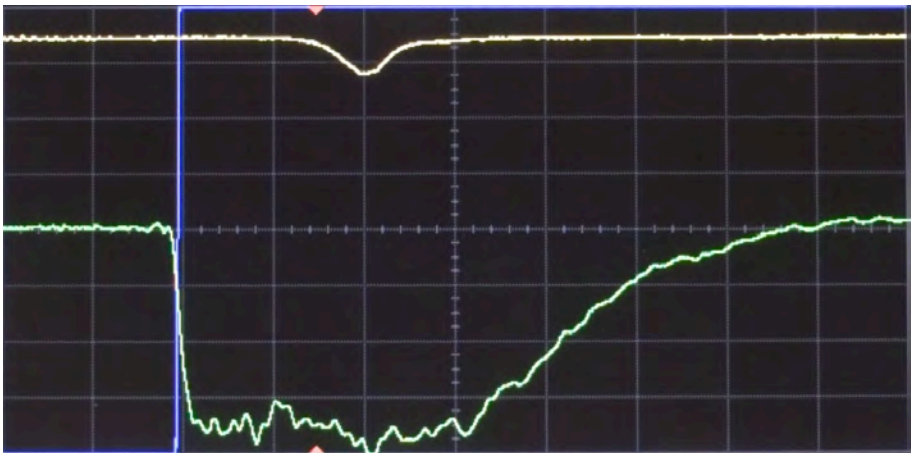


Figure 21 A well dilated signal with the light arriving in the centre of the PC ramp - 5ns/div. Yellow is the signal output, Green is the ramp monitor and Blue is a sync. pulse from the laser diode.

14.2 INVALID DILATION

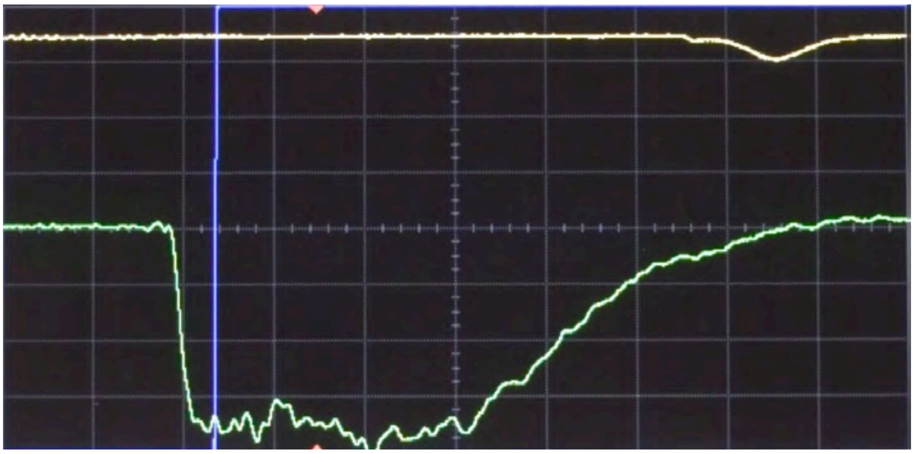


Figure 22 If the light arrives late after the linear part of the ramp the data is not valid.- 5ns/div. Yellow is the signal output, Green is the ramp monitor and Blue is a sync. pulse from the laser diode.

15 BASIC TUBE RESPONSE WITH NO DILATION

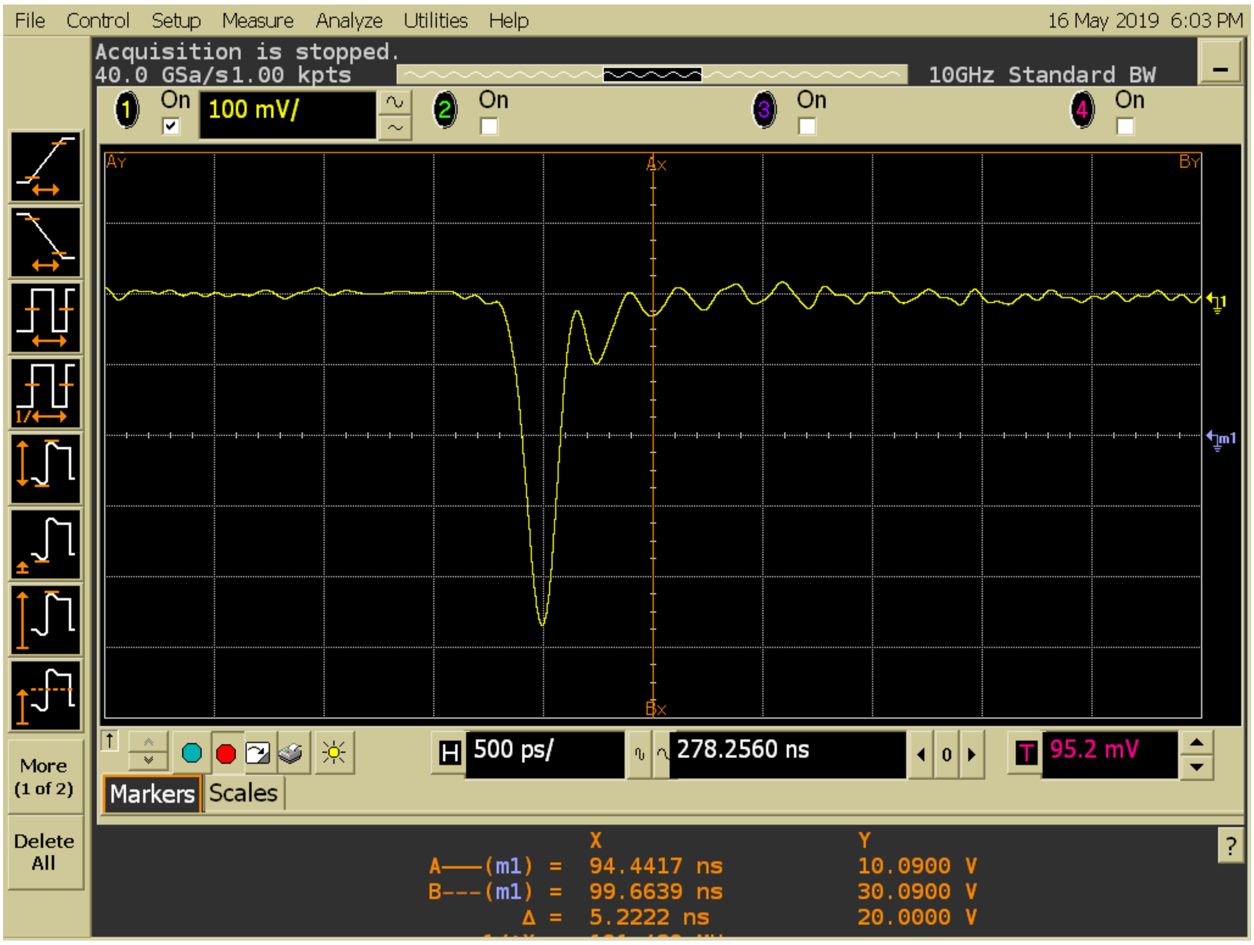


Figure 23 The output from the tube with no dilation Mode 1, gain 7. when illuminated with a short (40ps) laser pulse. This shows the well documented characteristic ringing of the MCP structure. This is for the tube supplied with J18XXXX.

16 TUBE DATA

PHOTEK
ENVISAGE THE FUTURE

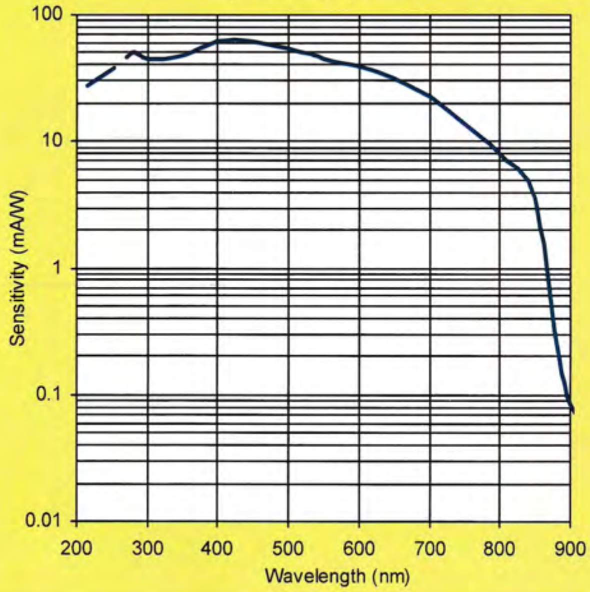
Test Data Summary

17 December 2018

DeviceType	Input Window	Cathode	Anode	Screen ITO
PD-PMT110	Quartz	S20	Solid	No

SerialNo:	31181012	Customer:	KENTECH INSTRUMENTS LIMITED
PhotekRef:	18-114	Specification No:	SPM110PH04-DR, 20th Sept 2018

Spectral Response



Sensitivity: *207 μA/lm*

	mA/W	%QE
214nm	27.30	15.82
254nm	38.50	18.80
270nm	45.40	20.85
290nm	48.20	20.61
300nm	45.30	18.72
350nm	47.90	16.97
400nm	61.70	19.13
450nm	62.30	17.17
500nm	53.30	13.22
532nm	49.30	11.49
550nm	44.10	9.94
650nm	30.90	5.89
750nm	14.10	2.33
800nm	7.92	1.23
850nm	3.61	0.53
900nm	0.09	0.01

Electron Gain 4.60E+03

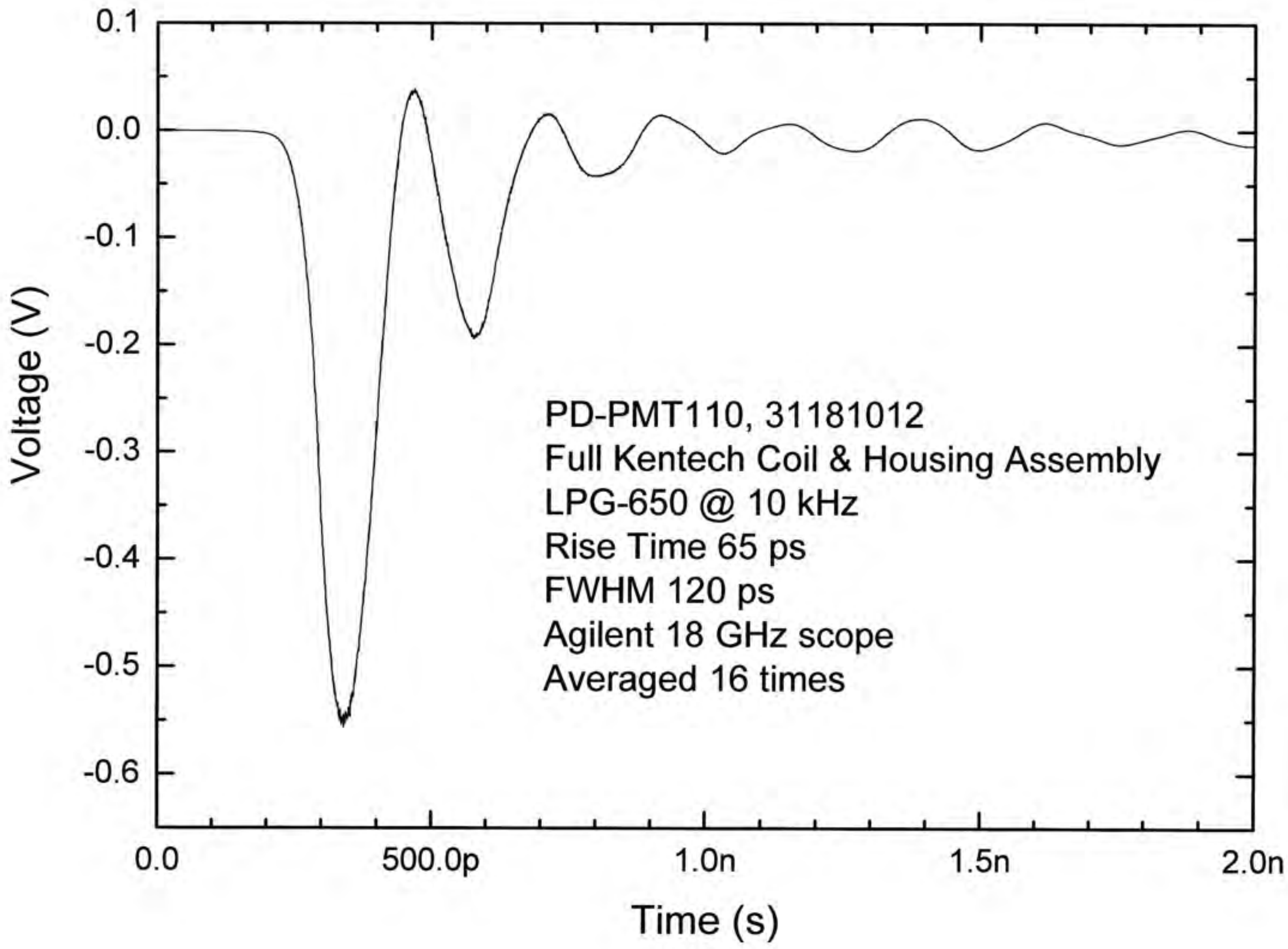
Maximum OperatingVoltages:

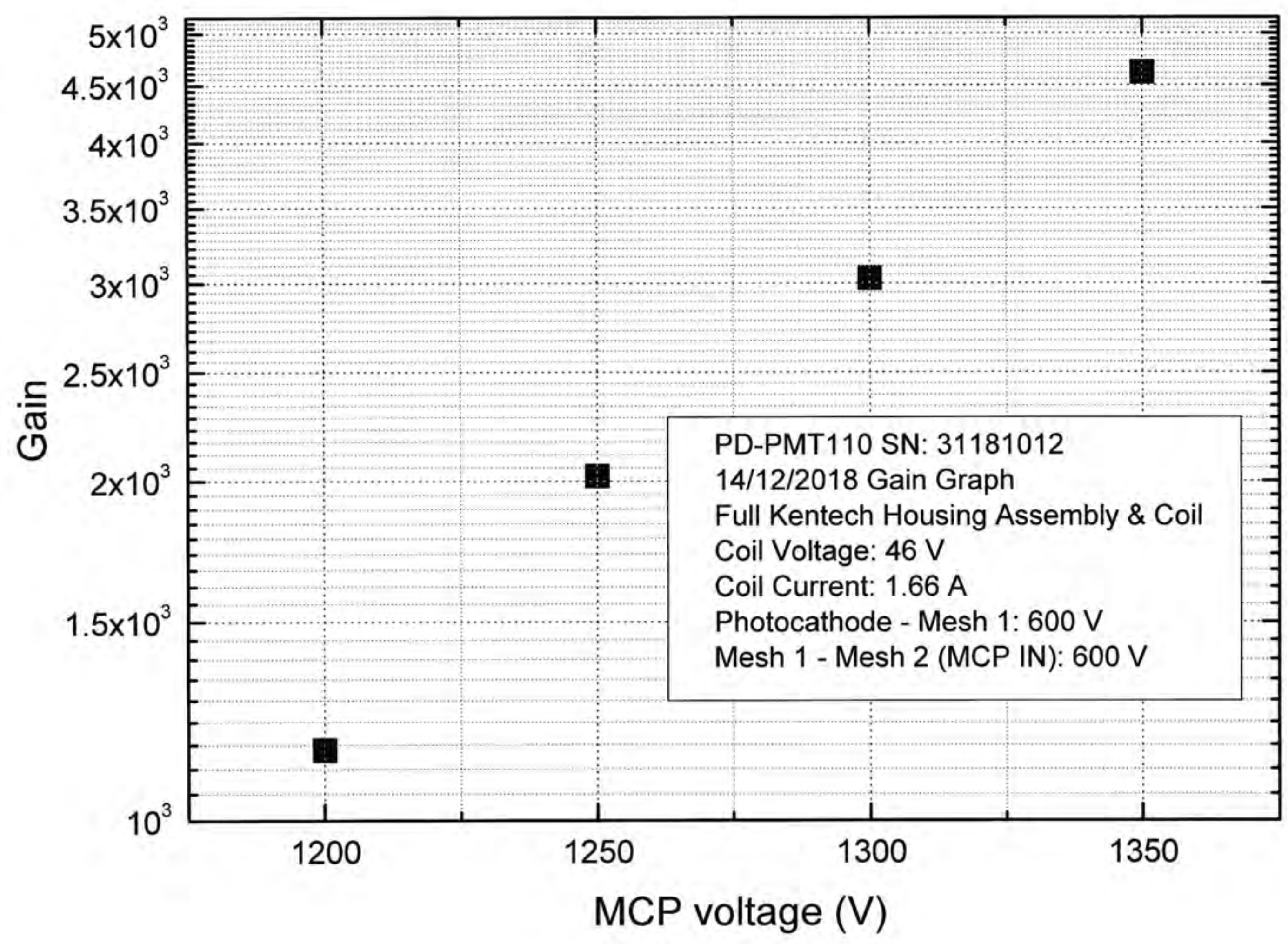
Comments:

Maximum Voltages:
Photocathode to Mesh 1: -4 kV
Mesh 1 to Mesh 2: -3 kV
MCP In to MCP Out: -1.35 kV
MCP Out to Anode: -3 kV

Tested:.. QA: D. Wheeler..................

Photek Ltd. Tel: +44 (0) 1424 850555 Fax: +44 (0) 1424 850051 E-mail: sales@photek.co.uk Web Site: http://www.photek.co.uk


PD-PMT110, 31181012
Full Kentech Coil & Housing Assembly
LPG-650 @ 10 kHz
Rise Time 65 ps
FWHM 120 ps
Agilent 18 GHz scope
Averaged 16 times
Voltage (V)
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
0.0
500.0p
1.0n
1.5n
2.0n
Time (s)


5x10^3
4.5x10^3
4x10^3
3.5x10^3
3x10^3
2.5x10^3
2x10^3
1.5x10^3
10^3
Gain
1200
1250
1300
1350
MCP voltage (V)
PD-PMT110 SN: 31181012
14/12/2018 Gain Graph
Full Kentech Housing Assembly & Coil
Coil Voltage: 46 V
Coil Current: 1.66 A
Photocathode - Mesh 1: 600 V
Mesh 1 - Mesh 2 (MCP IN): 600 V

Corning® ClearCurve® Multimode Optical Fiber

Product Information

CORNING

Bend Performance and Compatibility

Corning® ClearCurve® ultra-bendable, laser-optimized™ multimode optical fiber delivers enhanced macrobending performance while maintaining compatibility with current optical fibers, equipment, practices and procedures. ClearCurve® OM_2, OM_3 and OM_4 multimode fiber is designed to withstand tight bends and challenging cabling routes with substantially less signal loss than conventional multimode fiber.

Standards Compliance	ClearCurve® OM_4 fiber	ClearCurve® OM_3 fiber	ClearCurve® OM_2 fiber
ISO/IEC 11801	Type OM_4 fiber	Type OM_3 fiber	Type OM_2 fiber
IEC 60793-2-10	Type A1a.3 fiber	Type A1a.2 fiber	Type A1a.1 fiber
TIA/EIA	492AAAD	492AAAC-B	492AAAB-A
ITU	ITU G651.1	ITU G651.1	ITU G651.1

Optical Specifications

Bandwidth

	High Performance EMB* (MHz.km)	Overfilled Modal Bandwidth** (MHz.km)	
Corning Optical Fiber	850 nm only	850 nm	1300 nm
ClearCurve® OM_4 fiber	4700	3500	500
ClearCurve® OM_3 fiber	2000	1500	500
ClearCurve® OM_2 fiber	950	700	500

*Ensured via minEMBc, per ITA/EIA 455-220A and IEC 60793-1-49, for high performance laser-based systems.
** OFL BW, per TIA/EIA 455-204 and IEC 60793-1-41.

Attenuation

Wavelength (nm)	Maximum Value (dB/km)
850	≤2.3
1300	≤0.6

No point discontinuity greater than 0.2 dB. Attenuation at 1380 nm does not exceed the attenuation at 1300 nm by more than 3.0 dB/km.

Macrobend Loss

Mandrel Radius (mm)	Number of Turns	Induced Attenuation (dB) 850 nm	Induced Attenuation (dB) 1300 nm
15	2	≤0.1	≤0.3
7.5	2	≤0.2	≤0.5

Numerical Aperture

0.200 ± 0.015

Dimensional Specifications

Glass Geometry

Core Diameter	50.0 ± 2.5 µm
Cladding Diameter	125.0 ± 1.0 µm
Core-Clad Concentricity	≤1.5 µm
Cladding Non-Circularity	≤1.0%
Core Non-Circularity	≤5%

Coating Geometry

Coating Diameter	242±5 µm
Coating-Cladding Concentricity	<12 µm

How to Order

Contact your sales representative, or call the Optical Fiber Customer Service Department:
Ph: 1-607-248-2000 (U.S. and Canada)
+44-1244-525-320 (Europe)
Email: cofic@corning.com
Please specify the fiber type, attenuation, and quantity when ordering.

PI1468 | Issued: July 2014 Supersedes: January 2014 | TL9000/ISO 9001 Certified

Environmental Specifications

Environmental Test	Test Condition	Induced Attenuation 850 & 1300 nm (dB/km)
Temperature Dependence	-60°C to +85°C*	≤0.10
Temperature Humidity Cycling	-10°C to +85°C and 4% to 98% RH	≤0.10
Water Immersion	23°C ± 2°C	≤0.20
Heat Aging	85°C ± 2°C	≤0.20
Damp Heat	85°C at 85% RH	≤0.20

*Reference temperature = +23°C
Operating Temperature Range: -60°C to +85°C

Mechanical Specification

Proof Test

The entire fiber length is subjected to a tensile stress ≥100 kpsi (0.69 GPa).*

*Higher proof test levels available

Length

Fiber lengths available up to 17.6 km/spool.

Performance Characterizations

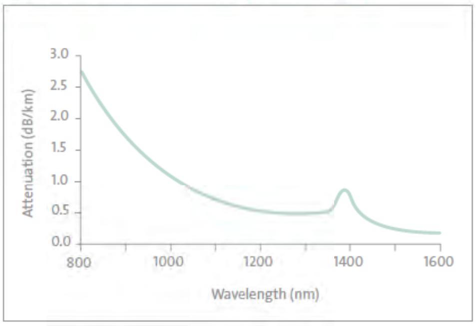
Characterized parameters are typical values.

Refractive Index Difference	1%
Effective Group Index of Refraction (N_{eff})	850 nm: 1.482 1300 nm: 1.477
Fatigue Resistance Parameter (N_d)	20
Coating Strip Force	Dry: 0.6 lbs (2.7 N) Wet, 14 days in 23°C water soak: 0.6 lbs (2.7 N)

Chromatic Dispersion

Zero Dispersion Wavelength (λ_0): 1295 nm ≤ λ_0 ≤ 1315 nm
Zero Dispersion Slope (S_0): ≤ 0.101 ps/(nm^2•km)

Spectral Attenuation (Typical Fiber)



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