Kentech Instruments Ltd.

Scorpion-Z X-Ray Streak Camera

Unit 1 S/N J2104091

Version 1 rev. 1

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PLEASE READ THIS MANUAL CAREFULLY BEFORE USING THE CAMERA.

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Figure 1 The tube with the FO fiducial fitted.

1. DISCLAIMER

This equipment contains high voltage power supplies. Although the current supply capacity is small, careless use could result in electric shock. It should be noted that as the streak tube is a long way from the supplies the cables can contain significant energy. In many cases the cable live electrodes are protected for fingers ("finger safe") but there are situations where this cannot be achieved. It is assumed that this highly specialised equipment will only be used by qualified personnel.

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

2. SERIAL NUMBERS

There are four main components with serial numbers:

Streak Tube	J2104091-1
Rack Electronics	J2104091-2
Interface box 1	J2104091-3
Interface box 2	J2104091-4

3. ABBREVIATIONS

ADC or adc	Analogue to Digital Convertor
AWG	Arbitrary Waveform Generator
BB mode	Blankety blank mode - same as full frame gating
CPLD	Complex programmable logic device
CCD	Charge Coupled Device (camera)
cr	carriage return
DISC	Dim based X-Ray streak camera
DPCO	Double Pole Change Over
dv	desired value
EEPROM	Electrically programmable and erasable Read only memory, non-volatile
EHT or eht	Extra High Tension (high voltage)
eof	End of Frame
EPLD	Electrically programmable logic device
EPROM	Electrically programmable read only memory, non-volatile
FET	Field Effect Transistor
FN	Foot Note
FO	Fibre optic
GXD	Gated X-ray Diagnostic
HDISC	Neutron hardened version of DISC
HSLOS	Neutron Hardened Single Line of Sight Imager, also called SLOS2.
hw	hardware
IBC	User's control system, also called UCS.
INT	Intensifier
lf	line feed
LFC	Large Format Camera, Gated X-ray Imager
LLNL	Lawrence Livermore National Laboratory
m	metres (meters US)
MAX	A phosphor and MCP combination
MCP	Micro Channel Plate
MCU	Main Control unit
mv	measured value
PCD	Photo Conductive Detector
PSU or psu	power supply unit
RAM	Random access memory, volatile.
RHIC	Radiation Hardened Instrument Controller
RSCE	Remote Streak Camera Electronics
ro	read only
rw	read and write
SD	Standard Deviation
SLOS2	Alternative name for HSLOS
SW	sweep
sw	software
UCS	Users Control System (to be provided by the user), also called IBC
W/E	Write Enable
wo	write only
w.r.t.	with respect to

4. BILL OF MATERIALS

Quantities are 1 off except where stated.

4.1 TOP LEVEL ITEMS

Rack Controller, containing

- Control module
- Sweep module
- Max driver module
- High Voltage module - not removable.

0030-0252 HDISC Tube

Interface box - 2 off

0010-0159 Scorpion-Z   Streak camera for the Z machine

Sub assembly details

0060-0154 Scorpion-Z   Rack unit

- 0020-0652 Scorpion-Z   Backplane
- 0020-0601 High Voltage PSU module   revised from RSCE HV PSU module

0060-0169 Control module for Scorpion-Z Rack controller

- 0020-0600 RSCE trigger card
- 0020-0445 Artix AWG card

0060-0170 Sweep module for Scorpion-Z Rack controller

- 0020-0603 RSCE sweep output card
- 0020-0602 RSCE sweep main card
- 0020-0610 Scorpion-Z sweep bias card

0060-0171 Max module for Scorpion-Z Rack controller

- 0020-0646 Scorpion-Z Max Module card1   based on SPIDER card
- 0020-0647 Scorpion-Z Max Module card2   based on SPIDER card

0060-0172 HV module for Scorpion Rack controller

- 0020-0650 Scorpion-Z HV zener card
- 0020-0649 Scorpion-Z HV control card
- 0020-0648 Scorpion-Z HV card

0060-0155 Scorpion - Z interface box

Cables

4 off 0070-0161-002 Scorpion-Z HV leads interface box to tube
4 off 0070-0161-004 Scorpion-Z HV leads rack to interface box

1 off 0070-0162-002 Scorpion-Z corrector leads rack to interface box
1 off 0070-0162-004 Scorpion-Z corrector leads interface box to tube

1 off 0070-0163-002 Scorpion-Z blanking trigger lead rack to interface box
1 off 0070-0163-004 Scorpion-Z blanking trigger lead interface box to tube

1 off 0070-0164-005 Scorpion-Z sweep leads interface box to tube positive
1 off 0070-0164-006 Scorpion-Z sweep leads interface box to tube negative

1 off 0070-0165-005 Scorpion-Z sweep monitor leads tube to interface box positive
1 off 0070-0165-006 Scorpion-Z sweep monitor leads tube to interface box negative

1 off 0070-0166-002 Scorpion-Z phosphor leads rack to interface box
1 off 0070-0166-004 Scorpion-Z phosphor leads interface box to tube (max module)

1 off 0070-0166-007 Scorpion-Z phosphor return leads interface box to rack
1 off 0070-0166-009 Scorpion-Z phosphor return leads tube (max module) to interface box

4 off 0070-0167-002 Scorpion-Z MCP leads rack to interface box
4 off 0070-0167-005 Scorpion-Z MCP leads interface box to tube (max module)

1 off 0070-0168 Scorpion-Z HV enabled lead
1 off 0070-0169 Scorpion-Z interlock lead

1 off US style power lead - IEC

Streak Tube

0030-0252 HDISC Tube later than J2012101 SMA sweep monitor variant[1]

0020-0651 HDISC blanking switch

1 The standard tube uses Lemo 00.250 connectors for the sweep monitor. These are not easily compatible with a 5mm OD cable requested for this project.

5. HAZARDOUS MATERIALS

Below is a list of construction materials. None is very hazardous. The quantity of lead used is small and only used in hand built electronics and cable connectors. Much of the electronics is not hand built. Hand built electronics using lead free solder has resulted in low reliability and is consequently avoided. Some of the very specialised types of circuit used in this device are not amenable to machine building. The aluminium used in the tube is not coated (Alochrom or Iridite).

5.1 THE TUBE

Aluminium Alloy (the main construction material)
PEEK
Tantalum (the anode)
lead solder used for electrical connections where crimping has proven to be unreliable.
copper, cables
PTFE
Silicone rubber, potting but none in vacuum facing parts
gold (on connectors) and in the LLNL cathode pack
Chromium (plating on connectors)
Brass
Stainless steel - non magnetic.
Nickel (meshes)
Epoxy adhesives
PCB material (FR4) but none in vacuum facing parts
Electronic components but none in vacuum facing parts except a few ceramic resistors.
Nitrile rubber (O rings) - all preheat treated - supplied by LLNL
Nylon but none in vacuum facing parts

5.2 THE ELECTRONICS

Aluminium Alloy (the main housing) with anodised and Iridite Chromium free conductive coatings
lead solder
copper, cables
PTFE
Silicone rubber, potting
gold (plating on connectors)
Chromium (plating on connectors)
Brass
Stainless steel
epoxy adhesives
PCB material (FR4)
Electronic components
ink

6. INTRODUCTION

This manual describes the operation and use of the Scorpion-Z x-ray streak camera. The camera is based upon a standard Kentech Low magnification tube design with the latest upgrade as the current HDISC tubes, i.e. with the corrector mesh assembly within the grounded lens 2 and a neutron resistant blanking switch. The main electronics package (rack unit) is a 6U x 19 inch rack mount assembly mounted 16m from the tube and is linked by various cables. The software control interface uses similar techniques to the RSCE for control of the unit. The streak tube is designed to be used with a variety of electron sensors but initially set up for use with a customer supplied MAX module. This comprises an MCP for electron detection and multiplication and a phosphor. A CCD camera will need to be fitted to the output of the MAX module. No CCD system is included with this package. The Streak tube can also accept a LLNL type HCMOS camera but no trigger support for such a detector is included with this system.

For users not familiar with X-ray Streak cameras or indeed any streak camera, some information may be found at http://www.kentech.co.uk/tut_xrsc.html and http://www.kentech.co.uk/PDF/Slide_show2003.pdf

6.1 RECENT CHANGES TO THE STREAK TUBE

Following requests from customers, materials in the tube that are vacuum facing have been modified. The main issue was to remove solder from vacuum facing components. This has been partially achieved with small design changes that avoid the need to solder components, particularly the high voltage feed-throughs that are now clamped. Some electrical connections have been made by clamping or crimping.

“O” rings have been provided by LLNL and are baked out before fitting. Small amounts of approved vacuum grease (Krytox™ XHT-ACX) have been used. Silver loaded epoxy has been used to attach the corrector mesh. Hook up wire for the corrector electrode is made from single stranded copper wire covered in PTFE. All vacuum facing components have been degreased prior to assembly and untouched by human hand during assembly.

6.2 SPECIFICATIONS OF THE SYSTEM

The system is designed to operate with the electronics remote (~16m) from the tube. This is mainly achievable but the blanking switch is mounted on the tube and there is also an interface box fairly close to the tube (~2.5m) which contains passive components to help prevent damage to the tube in the event of breakdowns. The cabling between the remote control electronics and the tube can contain enough stored energy to damage tube components in the event of breakdowns. The use of a local interface box with current limiting resistors helps dissipate the energy. It also provides a suitable platform from which to switch from heavy cables to smaller and lighter more flexible ones for local connection. The interface box also contains an RC divider circuit for monitoring the phosphor voltage on Max modules that have a second connection to the phosphor. The Max module supplied for testing did not have such a provision and there is no simple way to check remotely that the phosphor is connected.

Streak tube	Low magnification Kentech design with corrector electrode and mesh. The tube also has independent control of 4 of the lens elements giving control over the magnification.
Photocathode	The system is supplied fitted with a LLNL photocathode pack (supplied by the user).

Overall tube voltage range	0 to -15 kV[2]
Cathode length	>25 mm (28 mm is probably useful)
Cathode to extraction grid spacing	1 to 5 mm dependent upon spacers and vacuum quality
Electron detector	The unit is designed for the user to fit their own direct electron bombardment sensor. Kentech can supply an adaptor and a standard phosphor.
Sweep speeds	The duration of the sweep can be set from ~1ns to ~20 ns
Power requirements	typically 115/240 AC 50/60 Hz.
Dimensions	
Rack Unit	19 inch rack mount, 6U high x 400 mm deep - plus connectors, front and rear.
Sweep bias voltage on each plate	-800 V to +800 V
Maximum repetition rate	Sweep unit >5 Hz but see 12.1.2 on page 36
	The blanking and crowbar circuits are limited by the rate of switch on of the focus voltages. These are ramped up over several seconds. They may only be used in single shot mode.
Triggers	2 triggers (optical or electrical).
	Currently both must be of the same type.
Electrical trigger requirements	5 volts into 50Ω rising in < 5ns for both triggers.
Optical trigger sweep	Optical trigger signal input
	Wavelength 820-900 nm
	Optical power (on) -15 dBm (min), +3 dBm (max)
	Optical power (off) -30 dBm (max)
	Width (50% level) 100 ns (min), 250 ns (max)
	Rise time <2 ns
Optical trigger pre trigger	Use Broadcom HFBR-1404Z transmitter or similar.
Tube connectors	
Photo-cathode	Custom HV connector
Mesh	Custom HV connector
Lens 1	Custom HV connector
Lens 3	Custom HV connector
Corrector	Lemo ERA.00.250.CTL
Mating connector	FFB.00.250.CTAC33
Sweep drives	2 x TNC - use 90°plugs on cables.
Sweep monitors	2 x SMA - use 90°plugs on cables.
Blanking drive	Lemo PSA.00.250.CTL.C33
Mating connector	FFA.00.250.CTA.C33

2 Low voltages are used for slow turn on. There are 6 kV of zeners between the lens outputs.

6.3 CABLES AND CONNECTORS

Fielding the Scorpion-Z streak camera will require many leads. Further, as initially proposed, the streak tube was to be at one of two possible locations, the second requiring slightly longer leads for the final stage from the interface box to the tube.

The lead and connector requirements have been captured into two documents that give the details of all the connectors and leads. One document has been a collaborative effort between the user and Kentech Instruments. Further, the rack is to be used within a screened room and a set of leads from the rack to the screened room wall will be needed. These are included in the two documents but are not part of the deliverables with this device. The connections on the outside of the screened room that go to the tube are the same as those on the rack unit. This means that the system can be tested without such leads although there are timing issues for the "MCP off" signal, the blanking trigger and the sweep waveforms.

Figure 3 on page 15, Table 1 on page 16 and Table 2 on page 17 give the details of the connectors and leads required. There are a few points to note:

1. For the phosphor monitor to work there need to be two connections to the phosphor. Some Max module heads have this as standard, one either side of the tube. For Max modules with a single connection, a suitable "T" piece/connection could be used to make a second connection but this would not give a true continuity test.
2. The phosphor monitor circuit in each of the interface boxes is an RC network that will deliver the phosphor voltage into a 1MΩ load at the end of a long cable. Consequently this can be used either for pulsed or DC mode of the phosphor with a ~2000:1 division ratio. See Figure 14 on page 34.
3. The system can check the continuity of the phosphor connection by measuring the current in DC mode. This only works if there is a resistive load to ground at the phosphor. The monitor circuit provides this. If the monitor circuit is not connected to the phosphor no continuity test can be made.
4. Note that the cabling for the phosphor is 75Ω, cable except that from the monitor circuit to the scope, which is 50Ω. The 75Ω is used for reduced capacitance. During pulsed mode the charge stored in the pulser is shared between the source and the load. Keeping the load capacitance small results in a higher voltage available on the load.
5. The lengths of cables for the MCP drive, blanking trigger and sweep leads are all preset so that the signals arrive at the tube at the correct times with respect to each other. In particular the sweep leads are in foam dielectric cable. This has a faster propagation rate than the other cables and consequently the ramp waveforms are delayed w.r.t. the other signals.

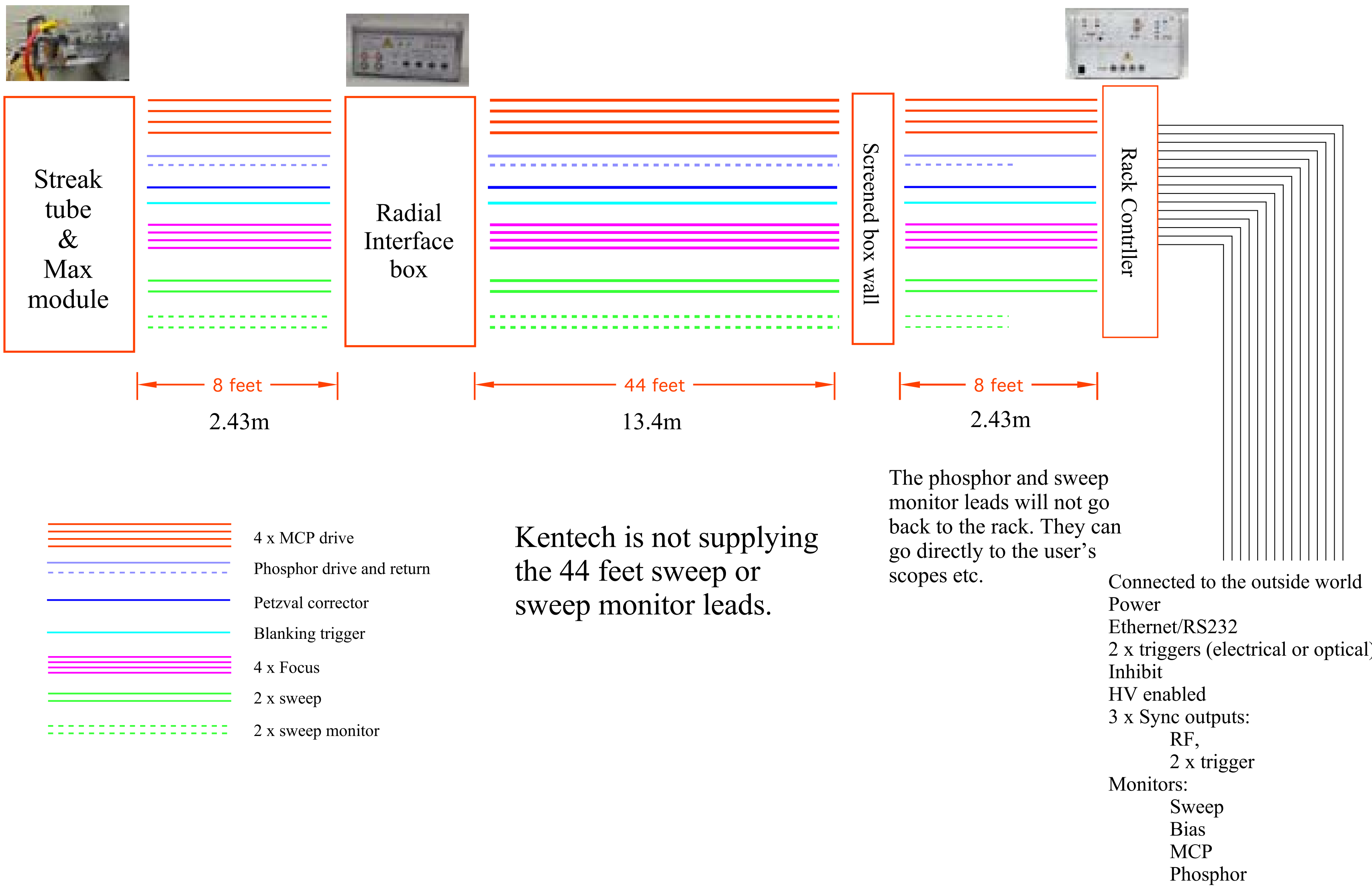


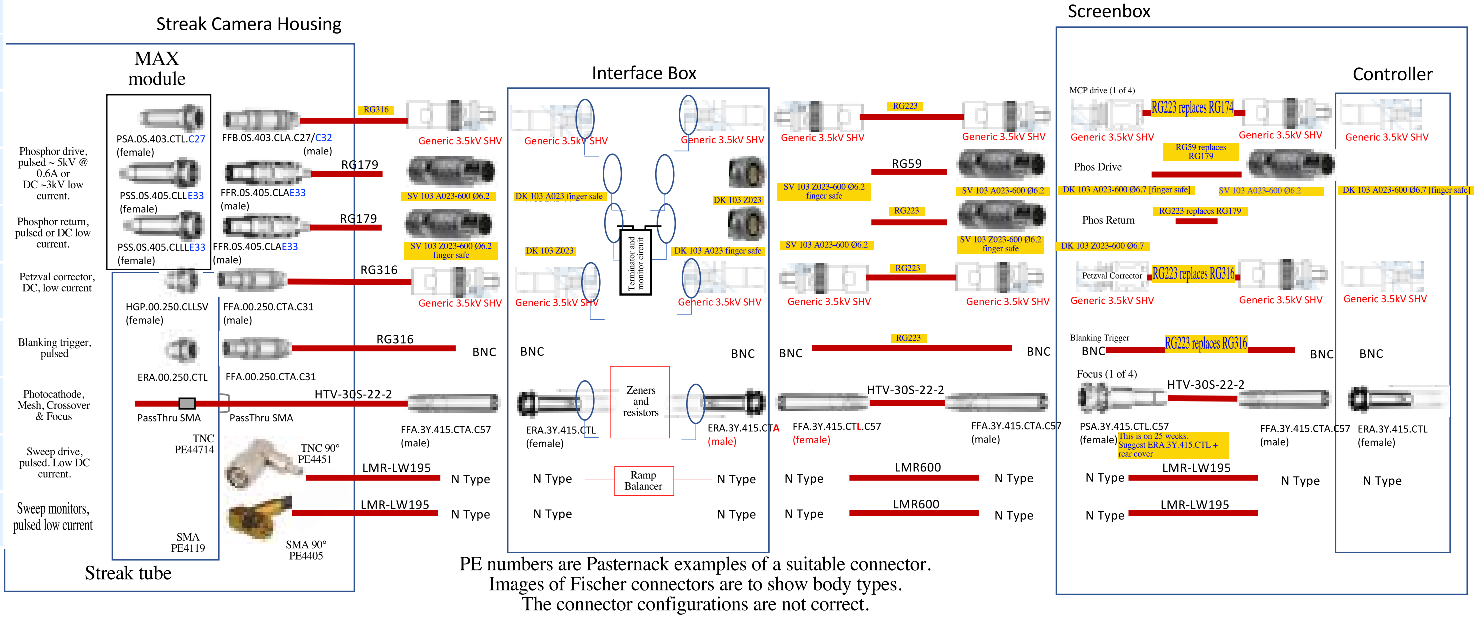
Figure 2 General wiring diagram showing the major blocks and cables

Updated 12th January 2023
by AKLDB Kentech.

Cables and connectors between the rack controller and the streak tube, with the rack controller inside a screened box.

		Maximum ratings	
Qty		V	I
4	Generic SHV	1kV	100μA
1	Lemo & Fischer	5kV	100 μA
1	Lemo & Fischer	5kV	100μA
1	Lemo & Generic SHV	1kV	5mA
1	BNC & Lemo	LV	
4	Lemo & Custom	15kV	5mA
2	Generic TNC	1.5kV	
2	Generic SMA	LV	

Stored energy
<10J for each output



	Interface box - Streak tube		Screened box - interface box	Rack to screened box
Radial (boat)	2.44m = 8 feet		13.4m = 44 feet	2.44m = 8 feet
Axial (axial package)	6.1m = 20 feet		13.4m = 44 feet	2.44m = 8 feet
Scope (provider)	Kentech		Kentech	SNL

Figure 3 Cables and connectors from the rack to the streak tube

Scorpion leads and box connectors

						(blue)	Supplied	
						(pink)	Will be required	
High Voltage leads and connectors (15kV focus supplies)								
Based on one rack system, and 2 interface boxes at different locations. Tube connectors not indicated.								
Item	**Kentech part No.**	**QTY**	**use**	**Cable**	**Length of cable [feet]**	**Length of cable [m]**	**Left connector (nearer tube)**	**Right connector (nearer rack)**
1	0070-0161-001	4	Rack to Screened Room wall	HTV-305-22-2	8	2.438	PSA.3Y.415.CTL.57 used ERA.3Y.415.CTL + custom rear cover	FFA.3Y.415.CTA.57
2	0070-0161-002	4	Radial Control box to Tube	HTV-305-22-2	8	2.438	SMA in house HV	FFA.3Y.415.CTA.C57
3	0070-0161-003	4	Axial Control box to tube	HTV-305-22-2	20	6.096	SMA in house HV	FFA.3Y.415.CTA.C57
4	0070-0161-004	4	Screened room to radial interface box	HTV-305-22-2	44	13.411	FFA.3Y.415.CTA.C57	FFA.3Y.415.CTL.C57
5	0070-0161-005	4	Screened room to axial interface box	HTV-305-22-2	44	13.411	FFA.3Y.415.CTA.C57	FFA.3Y.415.CTL.C57
6		12	Rack and Interface box output					ERA.3Y.415.CTA
7		2	Interface box input					ERA.3Y.415.CTL
Petzval Corrector								
8	0070-0162-001	1	Rack to screened room wall	RG223 (replaces RG174)	8	2.438	Bulkhead jack SHV Pasternack PE44093 or similar	SHV Pasternack PE4194 or similar
9	0070-0162-002	1	Screened room to Radial interface box	RG223	44	13.411	SHV Pasternack PE4194 or similar	SHV Pasternack PE4194 or similar
10	0070-0162-003	1	Screened room to Axial interface box	RG223	44	13.411	SHV Pasternack PE4194 or similar	SHV Pasternack PE4194 or similar
11	0070-0162-004	1	Radial interface box to tube	RG316	8	2.438	FFA.00.250.CTA.C31	SHV Pasternack PE4498 or similar
12	0070-0162-005	1	Axial interface box to tube	RG316	20	6.096	FFA.00.250.CTA.C31	SHV Pasternack PE4498 or similar
13		1	Rack and Interface box output					SHV Pasternack PE4239 or similar
14		4	Interface box input & output					SHV Pasternack PE4239 or similar
Scorpion-Z blanking trigger								
15	0070-0163-001	1	Rack to screened room wall	RG316	8	2.438	BNC bulkhead jack PE4106 or similar	BNC plug for RG316
16	0070-0163-002	1	Screened room to Radial interface box	RG223	44	13.411	BNC plug for RG223+ BLUE STRAIN RELIEF	BNC plug for RG223+ BLUE STRAIN RELIEF
17	0070-0163-003	1	Screened room to Axial interface box	RG223	44	13.411	BNC plug for RG223	BNC plug for RG223
18	0070-0163-004	1	Radial interface box to tube	RG316	8	2.438	FFA.00.250.CTA.C29Z + GMB:00.028.DA (BLUE STRAIN RELIEF)	BNC plug for RG316 + BLUE STRAIN RELIEF
19	0070-0163-005	1	Axial interface box to tube	RG316	20	6.096	FFA.00.250.CTA.C31	BNC plug for RG316
20		1	Rack output	RG316				BNC bulkhead jack PE4106 or similar
21		4	Interface box input & output	RG316				BNC bulkhead jack PE4106 or similar
Sweep Drive								
22	0070-0164-001	1	Rack to screened room wall Positive	LMR-195	8	2.438	N type bulkhead jack PE44528 red strain relief	N type PE4329 red strain relief or similar
23	0070-0164-002	1	Rack to screened room wall Negaitive	LMR-195	8	2.438	N type bulkhead jack PE44528 black strain relief	N type PE4329 black strain relief or similar
24	0070-0164-003	1	Screened room to Radial Interface box Positive	LMR-600	44	13.411	Pasternack EZ-600-NMC-2-D or similar	Pasternack EZ-600-NMC-2-D or similar
25	0070-0164-004	1	Screened room to Radial Interface box Negative	LMR-600	44	13.411	Pasternack EZ-600-NMC-2-D or similar	Pasternack EZ-600-NMC-2-D or similar
26	0070-0164-003	1	Screened room to Axial Interface box Positive	LMR-600	44	13.411	Pasternack EZ-600-NMC-2-D or similar	Pasternack EZ-600-NMC-2-D or similar
27	0070-0164-004	1	Screened room to Axial Interface box Negative	LMR-600	44	13.411	Pasternack EZ-600-NMC-2-D or similar	Pasternack EZ-600-NMC-2-D or similar
28	0070-0164-005	1	radial Interface box to tube Positive	LMR-195	8	2.438	Pasternack red strain relief TNC 90° PE4678 or similar	N type PE4329 red strain relief or similar
29	0070-0164-006	1	Radial Interface box to tube Negative	LMR-195	8	2.438	Pasternack black strain relief TNC 90° PE4678 or similar	N type PE4329 black strain relief or similar
30	0070-0164-007	1	Axial Interface box to tube Positive	LMR-195	20	6.096	Pasternack TNC 90° PE4678 or similar	N type PE4329 or similar
31	0070-0164-008	1	Axial Interface box to tube Negative	LMR-195	20	6.096	Pasternack TNC 90° PE4678 or similar	N type PE4329 or similar
32		2	Rack output	RG402				Pasternack PE44707 or similar
33		8	Interface boxes input & output	RG402				Pasternack PE44707 or similar

Table 1 Scorpion-Z cables and connector details part 1

Item	Kentech part No.	QTY	use	Cable	Length of cable [feet]	Length of cable [m]	Left connector (nearer tube)	Right connector (nearer rack)
Sweep monitor								
34	0070-0165-001	1	Rack to screened room wall Positive	LMR-195	8	2.438	PE44528	N type PE4329 or similar
35	0070-0165-002	1	Rack to screened room wall Negative	LMR-195	8	2.438	PE44528	N type PE4329 or similar
36	0070-0165-003	1	Screened room to Interface box Positive	LMR-600	44	13.411	Pasternack EZ-600-NMC-2-D or similar	Pasternack EZ-600-NMC-2-D or similar
37	0070-0165-004	1	Screened room to Interface box Negative	LMR-600	44	13.411	Pasternack EZ-600-NMC-2-D or similar	Pasternack EZ-600-NMC-2-D or similar
38	0070-0165-005	1	Interface box to radial tube Positive	LMR-195	8	2.438	SMA 90°plug + red strain relief	N type PE4329 + red strain relief or similar
39	0070-0165-006	1	Interface box to radial tube Negative	LMR-195	8	2.438	SMA 90°plug + black strain relief	N type PE4329 + black strain relief or similar
40	0070-0165-007	1	Interface box to axial tube Positive	LMR-195	20	6.096	SMA 90°plug + black strain relief	N type PE4329 + red strain relief or similar
41	0070-0165-008	1	Interface box to axial tube Negative	LMR-195	20	6.096	SMA 90°plug + black strain relief	N type PE4329 or similar
42		8	Interface boxes input & output	RG402				Pasternack PE44707 or similar
Scorpion-Z phosphor drive								
43.000	0070-0166-001	1.000	Rack to screened room wall	RG59 not RG179	8.000	2.438	DK 103 A023-600 Ø6.7 [finger safe]	SV 103 A023-600 Ø6.2
44	0070-0166-002	1	Screened room to Radial interface box	RG59	44	13.411	SV 103 Z023-600 Ø6.2 [finger safe]	SV 103 A023-600 Ø6.2
45	0070-0166-003	1	Screened room to Axial interface box	RG59	44	13.411	SV 103 Z023-600 Ø6.2 [finger safe]	SV 103 A023-600 Ø6.2
46	0070-0166-004	1	Radial interface box to tube	RG179	8	2.438	FFR.0S.405.CLAEC33	SV 103 A023-600 Ø6.2
47	0070-0166-005	1	Axial interface box to tube	RG179	20	6.096	FFR.0S.405.CLAEC33	SV 103 A023-600 Ø6.2
48		1	Rack output (finger safe)	RG59			D 103 A023	
49		2	Interface box input				D 103 Z023	
50		2	Interface box output (finger safe)				D 103 A023	
Scorpion-Z phosphor RETURN								
51	0070-0166-006	1	Screened room wall to scope room wall	RG223	8	2.438	DK 103 Z023-600 Ø6.7 [finger safe]	Flying lead
52	0070-0166-007	1	Radial interface box to Screened room wall	RG223	44	13.411	SV 103 A023-600 Ø6.2 [finger safe]	SV 103 Z023-600 Ø6.2 [finger safe]
53	0070-0166-008	1	Screened room to Axial interface box	RG223	44	13.411	SV 103 A023-600 Ø6.2 [finger safe]	SV 103 Z023-600 Ø6.2 [finger safe]
54	0070-0166-009	1	Radial interface box to tube	RG179	8	2.438	FFR.0S.405.CLAEC33***	SV 103 Z023-600 Ø6.2** [finger safe]
55	0070-0166-010	1	Axial interface box to tube	RG179	20	6.096	FFR.0S.405.CLAEC33***	SV 103 Z023-600 Ø6.2** [finger safe]
56		2	Interface box input				D 103 Z023	
57		2	Interface box output				D 103 A023	
Scorpion-Z MCP								
58	0070-0167-001	4	Rack to screened room wall	RG223 (replaces RG174)	8	2.438	SHV Pasternack PE44080 or similar	SHV Pasternack PE4194 or similar
59	0070-0167-002	4	Screened room to Radial interface box	RG223	44	13.411	SHV Pasternack PE4194 or similar	SHV Pasternack PE4194 or similar
60	0070-0167-003	4	Screened room to Axial interface box	RG223	44	13.411	SHV Pasternack PE4194 or similar	SHV Pasternack PE4194 or similar
61	0070-0167-004	4	Radial interface box to tube	316 (replaces RG1	8	2.438	FFB.0S.403.CLAC27	SHV Pasternack PE44093 or similar
62	0070-0167-005	4	Axial interface box to tube	RG316 (replaces RG174)	20	6.096	FFB.0S.403.CLAC27	SHV Pasternack PE44093 or similar
63		4	Rack output	RG316			SHV Pasternack PE44093 or similar	
64		16	Interface box input & output	RG316			SHV Pasternack PE44093 or similar	
Scorpion-Z HV ENABLED LEAD								
65	0070-0168	1	Rack to user	’ro MP002342 [2 c	9.842	3.000	Unterminated	FFA.0S.302.CLAC32
66		1	Rack output					ERA.0S.302.CLL
Scorpion-Z INTERLOCK LEAD								
67	0070-0169	1	Rack to user	RG174	9.842	3.000	BNC plug for RG174	FFA.00.250.CTA.C27
68		1	Rack output					ERA.00.250.CLL
Scorpion-Z internal loop though trigger leads								
69	0070-0183	3	Rack internal loop through leads	RG316		0.084	Lemo FFA.00.250.CTAC31	Lemo FFA.00.250.CTAC31

Table 2 Scorpion-Z cables and connector details part 2

6.4 FUNCTIONALITY

The camera has several modes of operation but the important points to note are the electronic features that are present. These include the following:

1. Focussing for checking that the image on the cathode is in focus.
2. Flat fielding, for measuring the relative sensitivity of various parts of the detector system. The image of the cathode can be swept slowly across the detector.
3. Sweep modes
4. Sync. modes
5. Cathode blanking; the cathode to mesh voltage can be short circuited to blank the camera at the end of the sweep to stop large electron fluxes entering the camera. This is fairly fast, ~ tens of ns.
6. Crowbarring. The Focus voltages can all be reduced to near zero at the end of a sweep to protect the cathode and mesh from breakdown. This is slower than blanking, ~100 µs. The high voltage supplies are turned off when the crowbar fires to stop the voltage rising again as the crowbar switch turns off.
7. Electrical or optical triggering
8. Full-Frame Gating (FFGt) mode. Also referred to as Blankety Blank mode (BB mode).

Whilst in principal the system can do any combination of the various functions listed above, many will need further programming to implement. These are straightforward procedures but need to be done at the factory.

7. OVERALL DESCRIPTION

7.1 MECHANICS OF THE STREAK TUBE

The streak tube is a vacuum component. It should be kept clean, particularly on the surfaces exposed to the vacuum. Wear suitable gloves if possible when working on the streak tube.

The main vacuum interface is about halfway down the tube at the anode. Behind the anode is the drift tube and mounted along side this are the two connector boxes, one of which contains the blanking circuit. The blanking circuit short circuits the cathode and mesh (extraction grid) when triggered, effectively shuttering the tube. This is a fairly fast circuit, (tens of ns).

The connector boxes may be removed or partially removed to make fitting of a sensor module easier. See section 7.2.3 on page 22

The tube needs to be fitted with a photocathode and an extractor grid (mesh). The tube is supplied fitted with a LLNL supplied photo cathode pack which also accommodates a facility to mount a fibre optic fiducial system. As supplied the fibre optic fiducial cable is not installed as this makes packaging for shipping difficult.

When operating without the FO fiducial system the FO feed through needs to be plugged to seal the vacuum. The feed through is supplied with the plug fitted.

7.2 FITTING A MAX MODULE

The Max module is attached to the drift tube with four M5 bolts that screw from the tube and into the MAX module. In order to fit the bolts it will be necessary to remove the connector boxes. It is hard to fit a connector box with the fiducial fibre optic cable in place. Consequently the order of assembly should be:

1 Remove the connector boxes
2 Set the position of the scraper inside the drift tube.
3 Fit the sensor
4 Refit the connector boxes.
5 Fit the Fibre Optic fiducial assembly if required.

7.2.1 REMOVING THE CONNECTOR BOXES

Each connector box is held in position with four M3 screws. Remove the screws from one box then ease the box backwards and upwards (slightly) to miss the rear flange. Note that there are two high voltage leads entering the box from the streak tube. These are a little fragile as they are made from steel free RG402 cable. Each lead has a brass contact soldered to the end. This may catch on the edge of the hole as the box is withdrawn. Do not force it, but wriggle it if necessary. Each cable is fitted with a spring and a brass or aluminium alloy washer. Make sure these are in place before refitting the box.

7.2.2 SET THE POSITION OF THE SCRAPER INSIDE THE DRIFT TUBE.

The scraper ring (previously circular but now rectangular) prevents electrons that are highly deflected from bouncing of the drift tube wall and hitting the sensor.

The scraper ring position has been set to be suitable with a MAX module but may need resetting to make it suitable for the particular sensor that the user fits to the tube. The best way to find the optimum position is to use 3D modelling of the tube and sensor and look for relevant beam paths from the deflection plates to the sensor plane. Allow a little margin to avoid vignetting. A STEP file of the tube will be included with the tube data. The relevant dimension to measure in the model is the axial distance from the output face of the scraper to the output face of the drift tube where the sensor will be mounted. This should be set up before the sensor is mounted. The position is easily changed by loosening the four screws in the output face of the scraper and pulling or pushing the ring in the drift

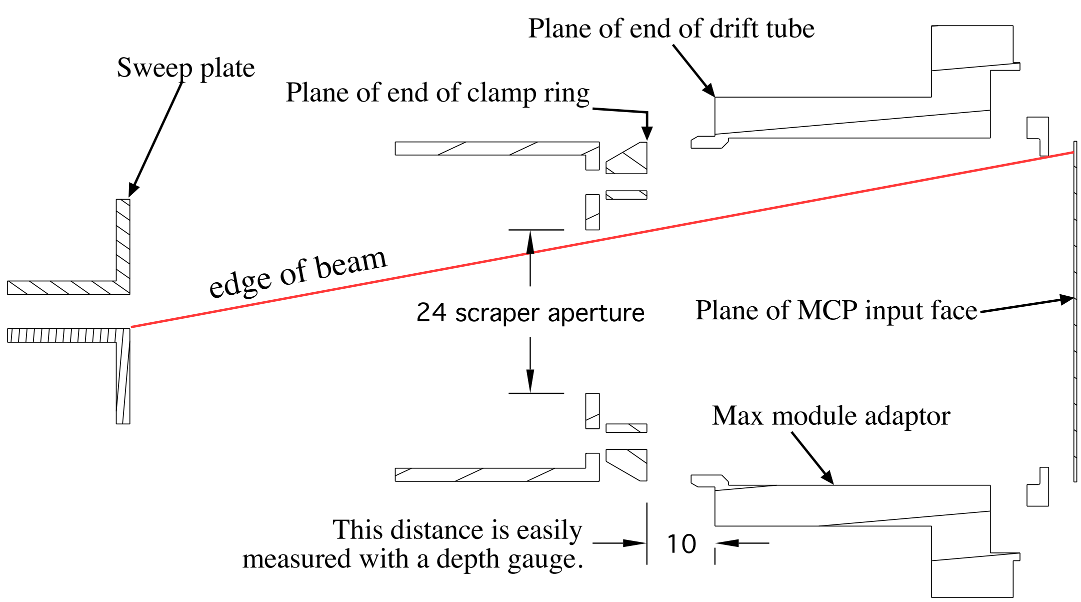


Figure 4 Schematic showing the axial position of the scraper.
The drift tube is omitted for clarity.

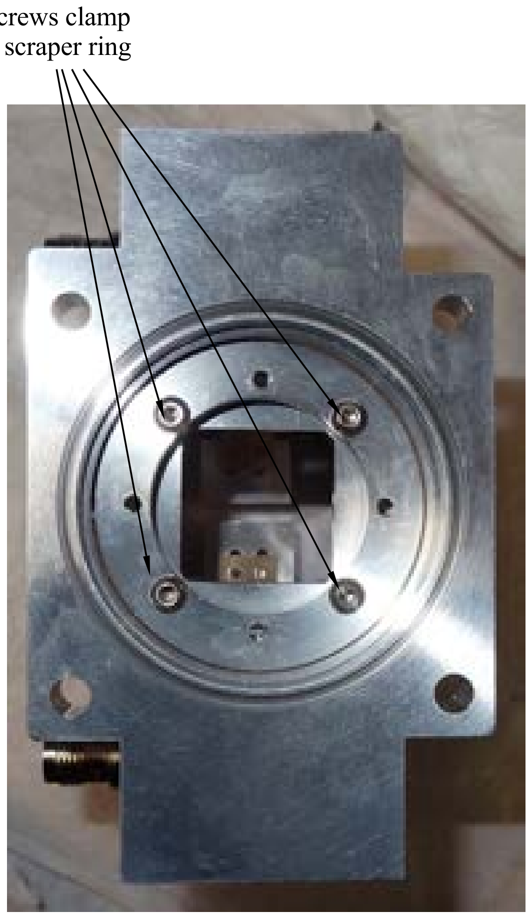


Figure 5 Scraper ring mounting.
View into rear end of streak tube before fitting the sensor. The scraper ring can be loosened and moved.
If necessary it can be mounted in the reverse direction using the second set of threaded holes.
There is no forced alignment of the orientation. this should be set by “eye” or measured.

tube to get the position correct. A vernier depth gauge will allow one to set it quite accurately and also square in the tube. Note also that the orientation w.r.t. the sensor should be retained. The fitted scraper aperture is 24 mm square. Different aspect ratio scraper rings are easily accommodated by replacing one aluminium alloy piece. This is left to the user, but we are happy to help. Note that the scraper

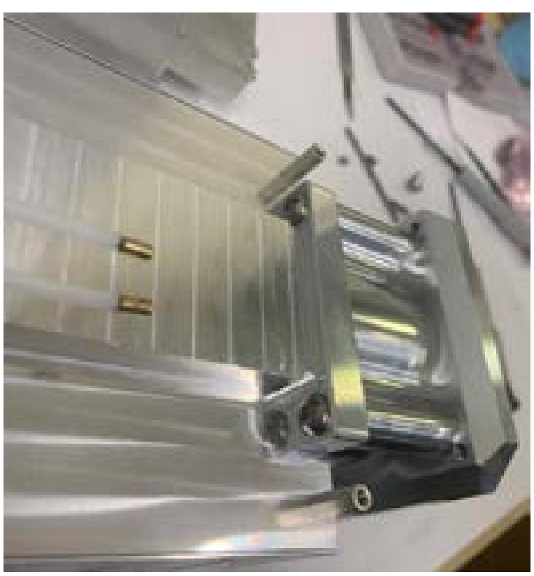


Figure 6 Mounting the Max Module adaptor.

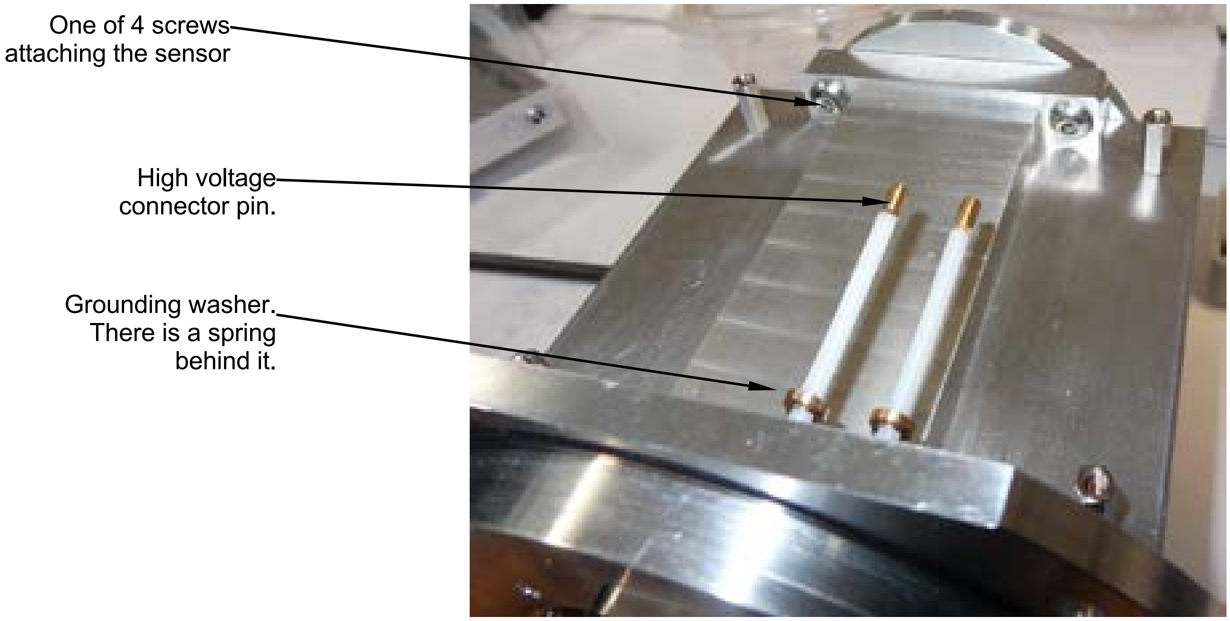


Figure 7 Access to the camera mount holes

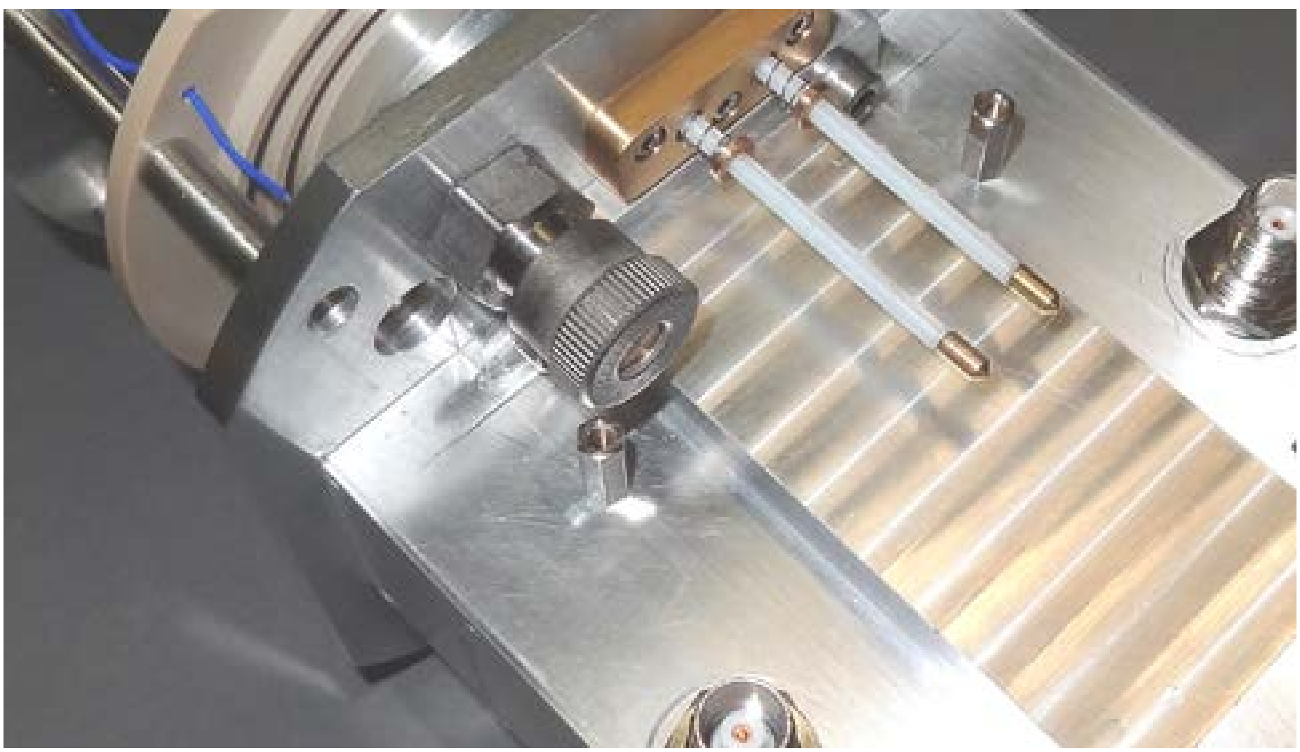


Figure 8 With the connector boxes removed
Take care not to damage the four high voltage leads or to lose the washers and springs. Check that the brass end connections are in good order and well soldered to the cables. Note that these cables have copper inner conductors and are not as robust as most semirigid cables.

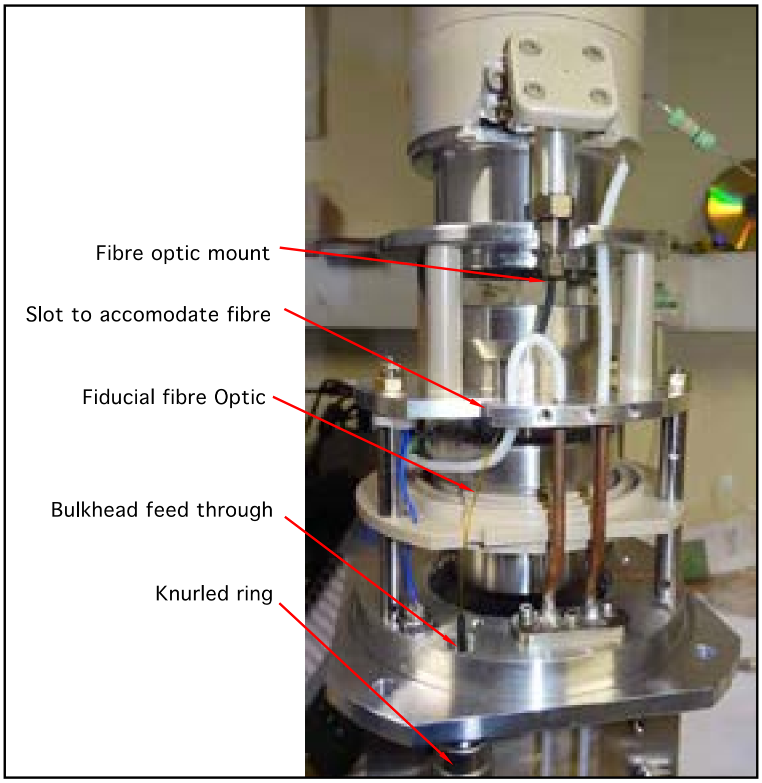


Figure 9 The fiducial fibre optic should be threaded very carefully through the Swage fitting and up to the photocathode pack.
There is a slot in the grounded central lens to retain the fibre. Do not bend the fibre excessively. If you are unhappy about fitting it this way, loosen the photocathode pack and raise it as necessary to assist fitting the fibre.
Tighten the swage fitting to achieve a vacuum seal on the fibre assembly.

assembly can be fitted either way around (w.r.t. the tube axis) with the clamp assembly either side of the scraper ring. Use which ever suits the application best.

7.2.3 FIT THE SENSOR

Kentech Instruments only has experience of fitting a phosphor or a MAX module. To fit a Max module four M5 screws are fitted through the holes shown in Figure 5 on page 20. They are mounted from the tube towards the Max module adaptor. Ensure that the ”O” ring is fitted in the end of the drift tube.

The Max module is then attached to the adaptor. Again be ensure the “O” ring is fitted between the adaptor and the Max module. It is necessary to remove the cable supports of the max module in order to access the mount holes. Once the Max module is fitted the cable mounts and clamps can be refitted.

7.2.4 REFIT THE CONNECTOR BOXES

This is the reverse process of removing them. Be careful not to bend the high voltage connections coming out of the tube. These are difficult to replace and quite fragile as they are made from steel free semi rigid cable. Each connector box is held in place by 4 x M3 cap head screws.

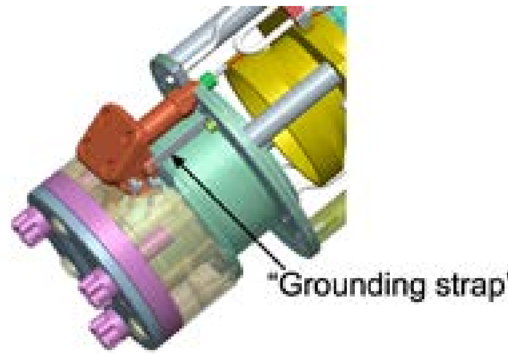
7.2.5 FIT THE FIDUCIAL FIBRE OPTIC

The fibre optic fiducial is supplied by LLNL and is easily fitted to the streak tube before insertion into the vacuum system. Be aware that the fibre is fragile and should not be bent excessively. Also the tip must not be chipped.

1. Remove the knurled ring at the fibre optic vacuum feed through.
2. Remove the brass blocking piece.
   Keep this as it is useful to block up the hole for vacuum tests without the fibre fitted.

3 Make sure the "O" ring is still in place and slightly greased (Krytox™ XHT-ACX silicone vacuum grease). Carefully thread the fibre through the bulkhead hole and feed the tip into the Fibre optic mount near the cathode. The fibre should fit in the slot in the grounded electrode. There should be enough space to fit the fibre without removing the connector box. It is difficult to refit the connector box with the knurled ring in place. The user may find that fitting the connector box after the fibre is OK.

4 Note that there is a "grounding" strap on the mirror of the FO fiducial system. It is not actually grounded as it connects to the Lens 1 element which is typically at ~11kV, however, it is important not to have pieces of metal in the tube assembly that are not connected to a specific potential. If left unconnected they can charge up via sprayed charge and then break down to some other element. On this build of Scorpion-Z the fiducial system was not fully implemented. The mirror is missing. Consequently the "grounding" strap has nothing to connect to. However, it is still fitted.



7.3 CONNECTIONS

There are 15 or 16 leads from the interface box to the streak tube assembly.

7.3.1 CONNECTING THE STREAK TUBE TO THE INTERFACE BOX

The following needs to be connected to the streak tube:

1 Two sweep leads.
TNC plug to 90°TNC plug at the tube end. The sweep will be towards the positive sweep cable.

2 Two Sweep monitor leads, SMA.

3 Blanking drive lead from the head unit to the "Fast Blanking Box"

4 Petzval corrector lead.

5 Focussing high voltage leads.
These four leads, cathode, mesh, lens1 (Crossover) and lens3 (Focus) are fixed into the high voltage module at the sockets marked. The ends that fit into the streak tube should be treated carefully. Each has a brass contact soldered onto its end. This engages in a spring loaded contact in the female connector. The leads use SMA clamping screws to hold them in place. If removing these leads do not pull hard, undo the SMA nuts and slowly remove the lead. If it catches wriggle it rather than pulling hard.
Note that there are a similar set of connections between the connector boxes and the streak tube. The tube is supplied with these connected. The boxes will need to be removed to access the screws that hold the sensor on the rear of the tube. When refitting the boxes make sure the brass washers and springs on the leads from the streak tube are not lost. Also make sure the leads are not bent significantly. In the event that one of the brass contacts becomes detached from its cable it is a little hard to repair.

7.3.2 CONNECTING THE MAX MODULE TO THE INTERFACE BOX

The following needs to be connected:

1. 4 MCP drive leads
2. Phosphor leads 1 or 2 depending upon the Max module type.

7.3.3 CONNECTING THE INTERFACE BOX TO THE RACK UNIT

This has 13 connections. In addition there are 2 sweep and possibly a phosphor monitor that may go back to the screened box in which the rack unit sits. These 3 are not connected to the rack unit.

7.3.4 CONNECTING THE RACK UNIT TO THE OUTSIDE WORLD

There are the following connections from the rack unit to the outside world. Some are essential, others are for diagnstics or alternative modes.

1. power lead - rear panel - IEC connector
2. comms lead, either Ethernet on RJ45 or RS232 on a 9 way DIN connector.
3. 2 triggers, pretrigger for the MCP and Phosphor ON and a sweep trigger. Currently the unit is configured so that they must both be either electrical or optical, not one of each.
4. Inhibit/enable. This is an input, short to enable the unit
5. HV enabled, this is an output. 2 pins are shorted when the high voltages are enabled.
6. Control module monitors, RF, MCP & phosphor ON trigger, sweep trigger.
7. Sweep module monitors, bias and sweep.
8. Max module driver, MCP and phosphor.

8. RADIATION HARDENED TECHNOLOGY

Scorpion-Z is designed to run in a high neutron radiation environment. The damage done by neutrons to electronics is different from that done by radiation in space. Many electronic components fail (even space rated ones) from fusion generated neutron damage. However, two groups of components have been found that are useful, the first group contains components that can withstand the neutrons and a second group that can survive neutrons if the power is not ON. The fast blanking switch uses components from the first group. The rack controller should be far enough away that neutrons are not an issue. The interface box contains only passive components that have been found to be resistant to neutrons.

9. STREAK CAMERA OPERATION

This section describes the general use of the X-ray streak camera. It assumes that the system is assembled as above and that the user has full control of the software, see section 14 on page 44

9.1 VACUUM REQUIREMENTS

The streak tube can only be used under a reasonable vacuum. The tube is not pumped but relies on the vacuum of the chamber it is connected to, in order to pump the tube. Care should be taken not to slow the pumping rate significantly with apertures and filters etc. For normal use with a phosphor the pressure should be below 10^{-4} mBar. For thin cathode to grid (mesh) spacers (under 2 mm) pump to under 10^{-5} mBar. If a Max module is fitted the user should use the recommendations of the supplier but generally lower is better. Our testing was done at ~ 10^{-6} mBar. When the max module is first pumped

Figure 10 Front panel of the rack unit

Figure 11 Rear panel of the rack unit
The EEPROM write protect button is at top right

after installation it is good not only to pump it for a long time (a few days) but also to apply the phosphor voltage gradually. With our testing we used a high impedance insulation tester with a current trip to check the phosphor breakdown voltage. Applying the voltage appears to cause gas to be emitted from the surfaces and it takes several attempts to get the hold off voltage high enough for operation.

9.2 PRINCIPAL OF OPERATION

The X–rays to be investigated, are incident on the photocathode and produce photoelectrons. The photoelectrons are imaged by the focussing electrodes, passing through the hole in the anode and form an image on the sensor module at the end of the streak tube. With a slit in front of the photocathode an image of the slit is formed on the phosphor. This image is swept across the phosphor by a ramp potential applied to deflection plates situated just beyond the anode hole. Position along the photocathode is magnified nominally by a factor of ~1.2 when used with a standard Kentech phosphor. The direction normal to this corresponds to time. There is an image inversion in the electron optics.

9.3 THE ELECTRON OPTIC FOCUSSING

Before the high voltage focussing supply is switched on the vacuum tube must be at a suitably low pressure, see section 12 on page 35. In order to obtain higher time resolution it will become necessary to increase the extraction field to >3 $kVmm^{-1}$ and under these conditions we recommend that the pressure be below 10^{-5} mBar. The extraction field can be adjusted without changing the voltages or focus by changing the spacer between the cathode and the extraction grid. If the unit is used at too high a pressure, electrical breakdown may occur which can damage the photocathode and/or extraction grid. There are many possible values of voltages that give focussed images and their values will depend upon the required magnification and the position of the sensor. It is up to the user either to experiment or preferably to simulate the electron lens to decide upon suitable values. The cathode is nominally at -14 to -15 kV and users should be aware not to place metallic objects near to the front end of the tube. As supplied the focus voltages are set to a set of values that gives a reasonably good focus on a Max module. The spatial resolution of the Max module is not as good as a standard phosphor.

Focussing is achieved most easily with the camera unswept and with a gold on quartz resolution cathode used in place of a normal one. This cathode is then illuminated with UV and the image of it focussed on the detector. The software has a mode of operation for doing this.

The cathode should be set to ~15 kV and then the other three high voltage potentials adjusted for good focus and desired magnification. The Petzval corrector voltage should also be set to give good spatial resolution at the image edges. Two further conditions need to be met. Firstly the voltage on Lens 1 (crossover) should be more negative than the mesh voltage. this ensures that any photoelectrons emitted by the mesh cannot arrive at the detector. Secondly it is also necessary that the cross over point be near the anode and sweep plates. By looking at the vignetting of the image of the cathode it is possible to see roughly when this condition is met. The software allows a voltage increment to be added to the existing voltage, the increment can be made negative to reduce the voltage. The camera is supplied with a software interface intended to be controlled through the IBC. If it is necessary to control the camera with a terminal then the unit can be placed into debug mode. In this mode focussing can be performed without the IBC. There is a **tweakfocus** command to aid adjusting the voltages more easily.

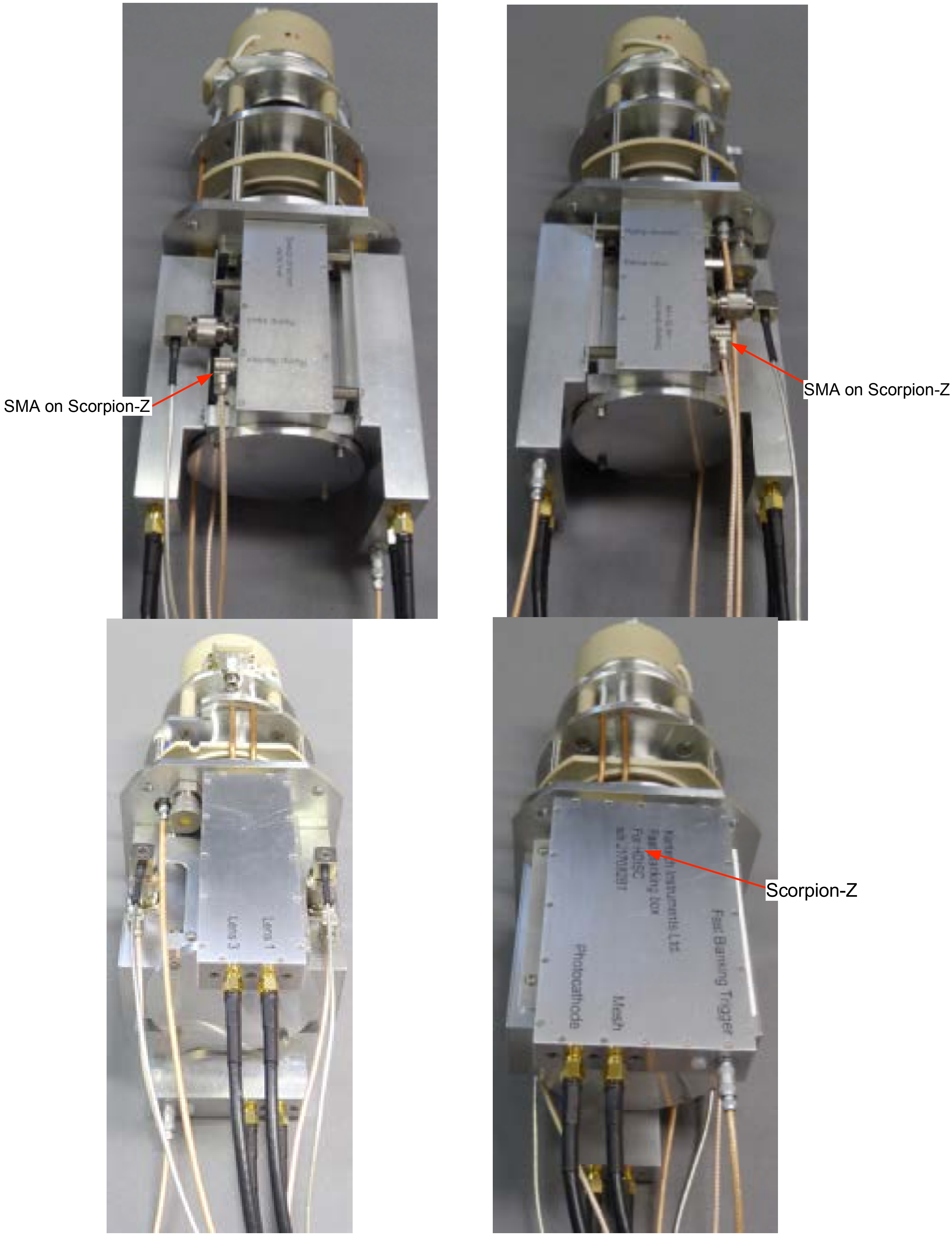


Figure 12 Four views of the tube showing the connections
The tube shown is an HDISC tube. The labels indicate the differences for a Scorpion-Z tube.

9.4 CATHODE BLANKING

The unit is fitted with the option of fast photocathode blanking. This is achieved by short circuiting the cathode and mesh potentials with a high voltage switch. The switch is located in the one of the connector boxes attached to the side of the drift tube, see Figure 12 on page 28.

The box contains several high voltage FETs that are repeatedly triggered by a signal from the rack unit. The trigger signal is sent to arrive at the end of the sweep.

The blanking switch is vulnerable to short circuits that are not current limited. To improve the chances of the switch surviving breakdowns there are series current limiting resistors. However, if there is a breakdown to ground between the switch and the resistors the switch is not protected. It is therefore necessary to be very carefully with the insulation between the blanking circuit and the resistors. This is well protected at the time of shipping but if the cathode assembly is changed it is important that careful attention is paid to this issue.

9.5 CROWBAR

The unit is also fitted with a crowbar. This short circuits the cathode to mesh in the focus supply for long enough to turn off the supply. Normally this would be used in conjunction with the fast photocathode blanking.

The blanking and crowbarring operate in single shot mode as it is necessary to turn off the focus unit to stop the voltages recovering. In repetitive mode they do not operate.

10. THE RACK ELECTRONICS

The rack electronics consists of 4 main modules:

1. The control module
2. The sweep module
3. The Max module driver
4. The high voltage (HV) module

The first three of these are removable modules mounted at the top of the rack. The HV module is fixed in place in the lower half of the rack.

10.1 THE CONTROL MODULE

The control module deals with the user interface, the triggering and the ramp and delay generation. It accepts two triggers, the first switches on the MCP and phosphor of the Max module if either or both is in gated mode. The second trigger is for the ramp generator. The MCP off, fast blanking and crowbar are all generated internally at the end of the ramp with suitable delays so that the signals arrive at the streak tube at the relevant times with the cables provided or specified.

10.2 SWEEP MODULE

The sweep unit provides bias voltages as well as the ramp voltages to deflect the image. The bias voltage sets the start position of the sweep, normally off screen. It also sets the operation point of the ramp. The bias voltages have been preset to the optimum values for best sweep linearity. The system is capable of storing up to 16 sweep settings.

The sweep unit has several modes of operation, see Figure 25 on page 45. These enable the user to do the following:

1. nothing
2. normal sweep
3. normal sweep with modified start position for timing
4. flat fielding/focussing, a slow sweep for calibrating the area sensitivity of the sensor or focussing the tube.
5. Full-Frame Gating (FFGt) mode (Blankety blank)

A sweep monitor is provided for each plate. A fraction of the sweep signal to each plate is available to monitor the sweep signal see Figure 13 on page 32 . The sweep can be made to run in either direction by swapping the sweep leads around. Time will run from the negative to positive sweep connection.

10.2.1 RATE LIMIT

The sweep unit has a hardware rate limit of 5Hz but the system is optimised for single shot use and at rates above 1Hz there may be some instability in the waveform.

The system is set up for use with the specified cables. It will drive cables of other lengths. However, if the round trip time of the sweep cables is less than the sweep duration some reflections may be present. These can be eliminated by careful setting up of the AWG sweep data but this needs to be done for the specific configuration used. Note also that the timing of the blanking and MCP OFF signals need to be tied to the end of ramp time at the sweep plates. This is discussed at 12.1 on page 35.

The bias voltages have the opposite polarity to the ramp voltages. As a convention the positive bias is the voltage on the sweep plate fed with the positive ramp and the negative bias the voltage fed to the plate that receives the negative ramp. Note that in flat fielding the bias voltages go from very negative to very positive on the positive plate and vice versa on the negative plate. During normal operation it is important that the potential at the centre of the sweep plates is close to zero otherwise the tube focussing can be degraded.

10.3 SWEEP GENERATION

Scorpion-Z uses a sweep circuit that was developed for the RSCE project at LLNL. This uses an arbitrary waveform generator and an amplifier to deliver very controlable ramps over a wide timescale range. This allows the user to compensate for waveform degradation in the long sweep cables. In addition the whole ramp waveform is easily movable within the arbitrary waveform record to accommodate delays. One feature that this system can offer is for changes in the sweep speed to be made about the screen centre, the screen edge or in principle about any other point. Ramps with variable rates or perhaps two linear rates are also possible. The ramp output can be delayed by moving the arbitrary waveform data within the output buffer. This is a fairly coarse delay of ~ 400ps. In addition there is a fine delay to cover the 400ps steps.

The arbitrary waveform is generated in the control module and fed to the sweep module where it is amplified and then split into a positive and negative ramp. The bias voltages are also added to each of the outputs. The RF monitor on the control module is a copy of the signal that is fed to the sweep module.

10.4 THE MAX MODULE DRIVER

The Max module driver is based upon the SPIDER intensifier module. This was designed to drive either a Max module or a normal image intensifier. The image intensifier mode is not supported on Scorpion-Z.

10.5 FULL FRAME IMAGING MODE (BLANKETY BLANK BB MODE)

A full frame imaging mode has been added for help with calibration of imaging sensors. This is also called Blankety Blank mode (BB mode). In this mode the negative sweep plate is grounded via a 100Ω resistor. The positive sweep plate can be switched between 0 volts and approximately 1400V in response to a trigger with the system in the relevant mode. The MCP & Phosphor trigger input should be used. This is DC coupled in this mode (it is normally AC coupled) and enables the user to drive the BB mode at the desired rate and dwell times. This mode can be enabled in focus/flat field mode in the ENERGIZE state.

BB mode is only available as a Level 3 command.

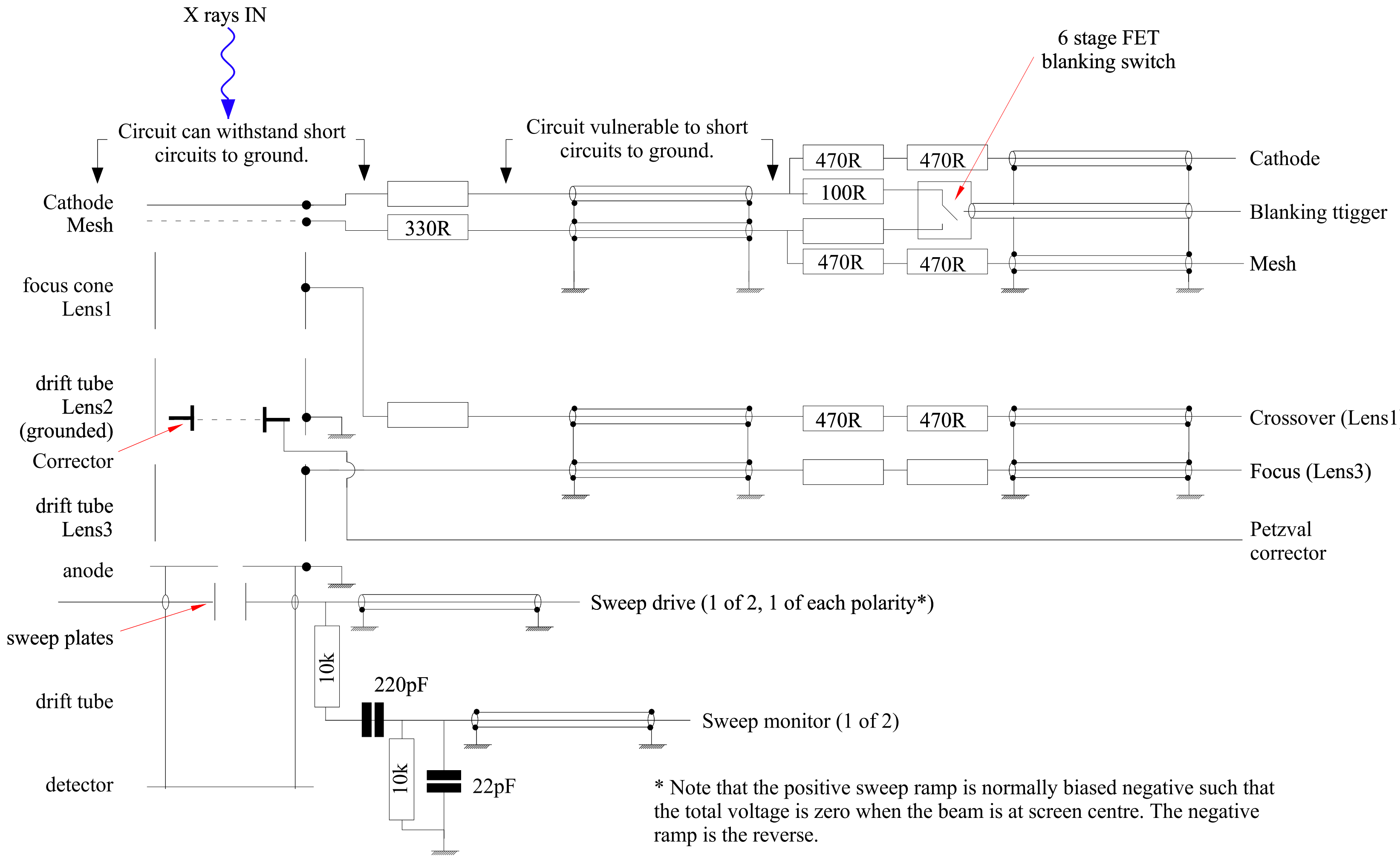


Figure 13 Tube wiring and blanking box

11. USING THE CAMERA

11.1 MAGNETIC FIELDS

The electron optics are prone to image displacement under the influence of stray magnetic fields. To remove this effect a mumetal screen, which fits around the spool tube will probably be needed. This is similar to the DISC mumetal screen and is supplied by the user.

NOTE

The use of screws of magnetic materials in or near the photocathode assembly can give rise to image displacement. If it is necessary to replace screws ensure that they are of unplated brass or nonmagnetic stainless steel. The use of nickel (magnetic) plated brass screws has not been found to cause problems but we would advise against it. Similarly the residual magnetic field from stainless steel screws generated in the screw manufacturing process has not been found to be a problem.

The cables carrying the focus potentials to the electrostatic lens have copper inner conductors.

11.2 CATHODE AND MESH ASSEMBLY

The unit is delivered with a user supplied LLNL type cathode pack rather than the standard Kentech one. This facilitates easy removal of the cathode and mesh and also integrates with a fibre optic fiducial system.

11.3 FOCUS VOLTAGES

During testing the camera has been focussed with a standard Kentech phosphor placed at the standard distance from the sweep plates and anode. The system has 4 adjustable focus voltages plus the Petzval corrector. Whilst this facilitates zooming for use on a variety of sensors it means that there will be many focus conditions.

The following voltages produced a good focus on the Max module supplied for testing.

VPC	VME	VCR	VFO	VPE
15000	10616	10254	10286	900

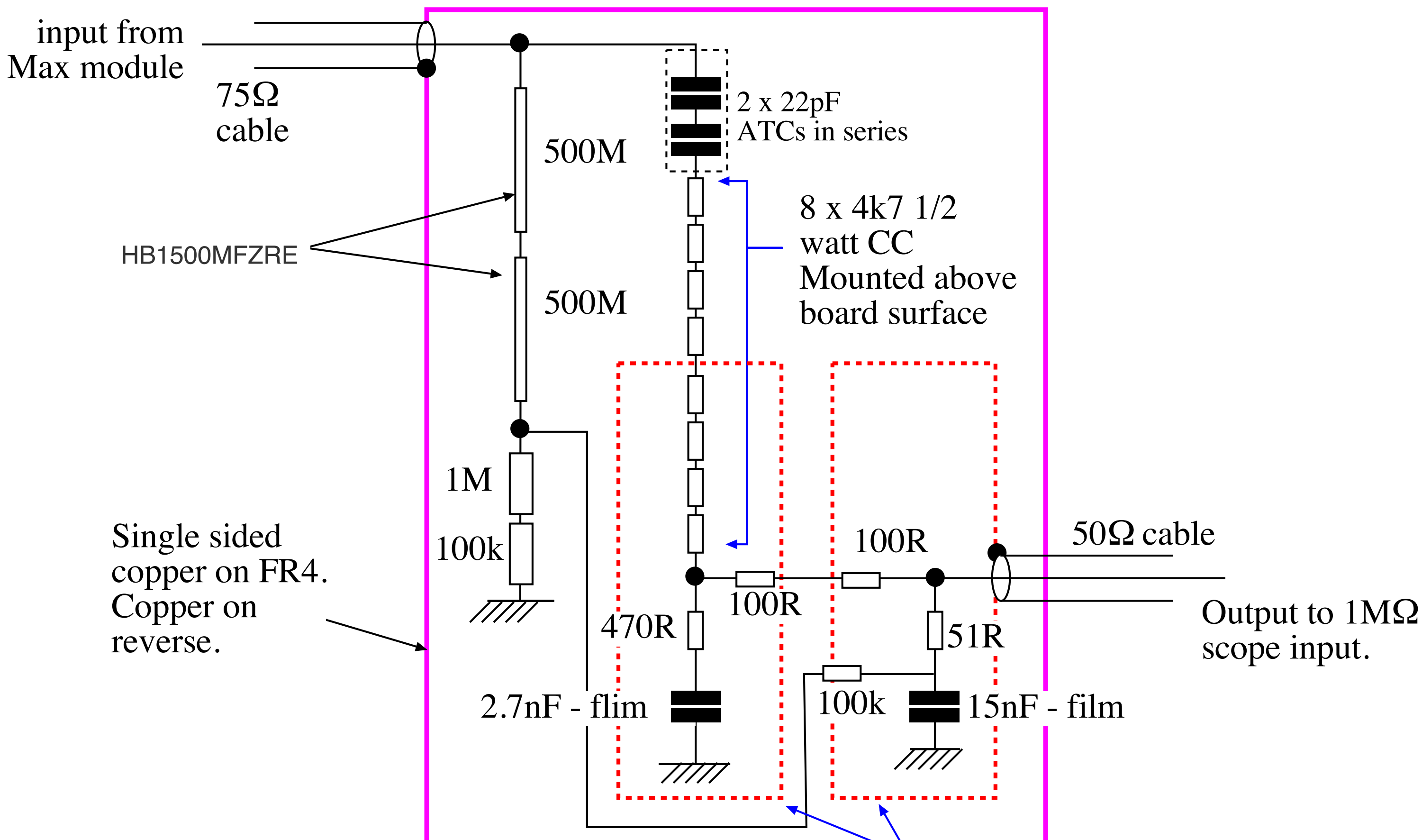
We recommend simulating the camera electron optics and calculating the optimum focus voltages for the particular configuration to be used. This has proved very accurate. The 3D model of the tube will be provided for this.

11.4 DEFLECTION SENSITIVITY

With the voltages set as above and onto the standard Kentech phosphor, the defection sensitivity was ~ ±18 V/mm. I.e. the sweep plates require each to be at 18 volts (one positive and one negative to displace the image by 1 mm). Reducing the focus voltages proportionally by a factor 14/15 (i.e. cathode at -14 kV) gives a deflection sensitivity ~ 17 V/mm.

11.5 CROWBAR AND BLANKING

The blanking switch, mounted on the tube, shorts the cathode to mesh. The crowbar switch shorts the cathode to ground and also pulls the other lenses to ground via the zener chains that limit their difference voltages. There is no current trip on the focus power supply. In single shot mode the software turns



Scorpion-Z Interface box phosphor monitor

Designed to drive a 1MΩ scope input.
DC 2000:1 division ratio.
AC and DC coupled.

Figure 14 The phosphor monitor circuit located in each interface box.

off the focus supply at trigger time. In repetitive mode neither the blanking nor the crowbar switch is triggered. The delays for triggering the blanking and crowbarring are fixed in hardware.

12. INITIAL POWER-UP

It is necessary for the interlock to be set before the focus voltages can be turned on. It is intended that this be connected to relay contacts on a vacuum gauge. The focussing supply must not be turned on if the pressure is higher than 10^{-4} mBar. At extraction fields greater than ~1.5 kvmm^{-1} (~3 mm spacer) it may be necessary to obtain a better pressure. We recommend that the camera first be timed and set up with a low extraction field (3 mm spacer between the cathode and mesh). Once the system is operating satisfactorily at this field the spacer can be reduced and the vacuum improved. Note that the pressure in the cathode to mesh gap is what is important, not that at some distance from the cathode.

When the power is first applied a small breakdown may occur as a result of absorbed gas being released under the influence of high electric fields. Note that the focus unit is set up to come on slowly. This has been found to help with breakdown problems.

It is recommended not to leave the camera powered up for long periods, e.g. while waiting for shots. An unexpected rise in the chamber pressure due to accidental venting or possibly pump failure could result in the destruction of the cathode and/or the extraction grid as the breakdown voltage falls in higher pressure gas.

12.1 PROCEDURE FOR TIMING THE STREAK CAMERA

In general the trigger signal should be timed so that it coincides with the X–ray signal on the photocathode, with allowance made for:

- i the flight time of electrons from the cathode to the sweep plates (approximately 1.7 ns)
- ii the time delay from triggering the control unit to the photocathode image reaching the middle of the screen. This time depends very much on the sweep speed in use and the distance from the rack electronics to the head and the set up of internal delays.
- iii the flight time of photons from the plasma to the cathode
- iv the relative timing of the electrical trigger and the start of the event at the target.

The Scorpion-Z streak tube is mounted a significant distance from the electronics. Consequently the timing has to take into account the various delay in the cabling. Further, there are 3 signals that need to arrive at the tube at the appropriate time, the ramp, the blanking trigger and the MCP off drive. The MCP on and Phosphor on are relatively slow and easily timed. These are linked to the other trigger input on the control module, labelled MCP and Phosphor ON. This needs to be triggered about 15 to 30 μs before the event.

The ramp needs to arrive at the tube next and then the Blanking trigger and MCP off need to arrive at the end of the ramp. However, the specified ramp cables use a foam dielectric which has a fast propagation velocity, whilst the other two signals are on solid dielectric. Consequently for a fast ramp, the blanking and MCP off signals have to be launched from the rack earlier than the ramp. The ramp needs then to be delayed so that it arrives at the correct time. With slower ramps the other two signals has to be delayed. A result is that the minimum trigger delay for the system is determined by the timing of the other two signals not by the ramp generator. The relative timing of all these signals is set up with a combination of delay cables and delay calibrations in the sweep records, see 14.13 on page 69.

11 of the 16 sweep records have been configured prior to shipment. The cables lengths used were exactly as prescribed in the updated Statement of Work and mirrored in Figure 3 on page 15. If there are any significant departures from this cabling then the timings may have to be reconfigured.

The timing of the MCP off signal is easy to determine as this is applied directly to the Max module and so should appear at the Max module 1.4ns after the end of the ramp. This allows for the time it takes the photoelectrons to move from the deflection plates to the Max module.

The timing of the ramp should be such that the event (assumed to be of very short duration) arrives at screen centre. So the photoelectrons representing the event need to be at the deflection plates at the time the sweep reaches screen centre. It takes around 1.5 ns for the electrons to move from the photocathode to the deflection plates.

The timing of the blanking pulse should be such that it arrives at the photocathode 1.5ns before the sweep ends. In practice it is not a very fast switch. The time the gate pulse takes to move from the blanking switch to the photocathode is around 1.5ns. The delay in the switch will be several ns and the rise time of the switch at least 10 ns. How accurately these need to be timed depend upon the type of event and how important post event blanking is.

If the streak tube is not fitted with an extraction grid or photocathode, then it is possible to run the focus potentials at atmospheric pressure. In this situation one can place a scope probe near the cathode and pick up the blanking signal. Do not run the Max module at atmospheric pressure.

It may be possible to pick up the blanking switch firing at the switch, possibly with its cover removed.

12.1.1 TRIGGER LOOP THROUGH CABLING

Three of the trigger signals are looped through connections on the hidden panel behind the front panel. This can help with diagnosing faulty triggering but it is also used to set the relative delays to the triggers for the fast blanking and the MCP off signals. These signals need to be nearly synchronous at the streak tube but there is significantly more delay in the MCP off pulse generation. These two signals are driven from the same trigger source. Consequently their relative delay has been fixed by careful setting of the length of the trigger loop through leads on the panel hidden behind the front panel.

See Figure 15 on page 37.

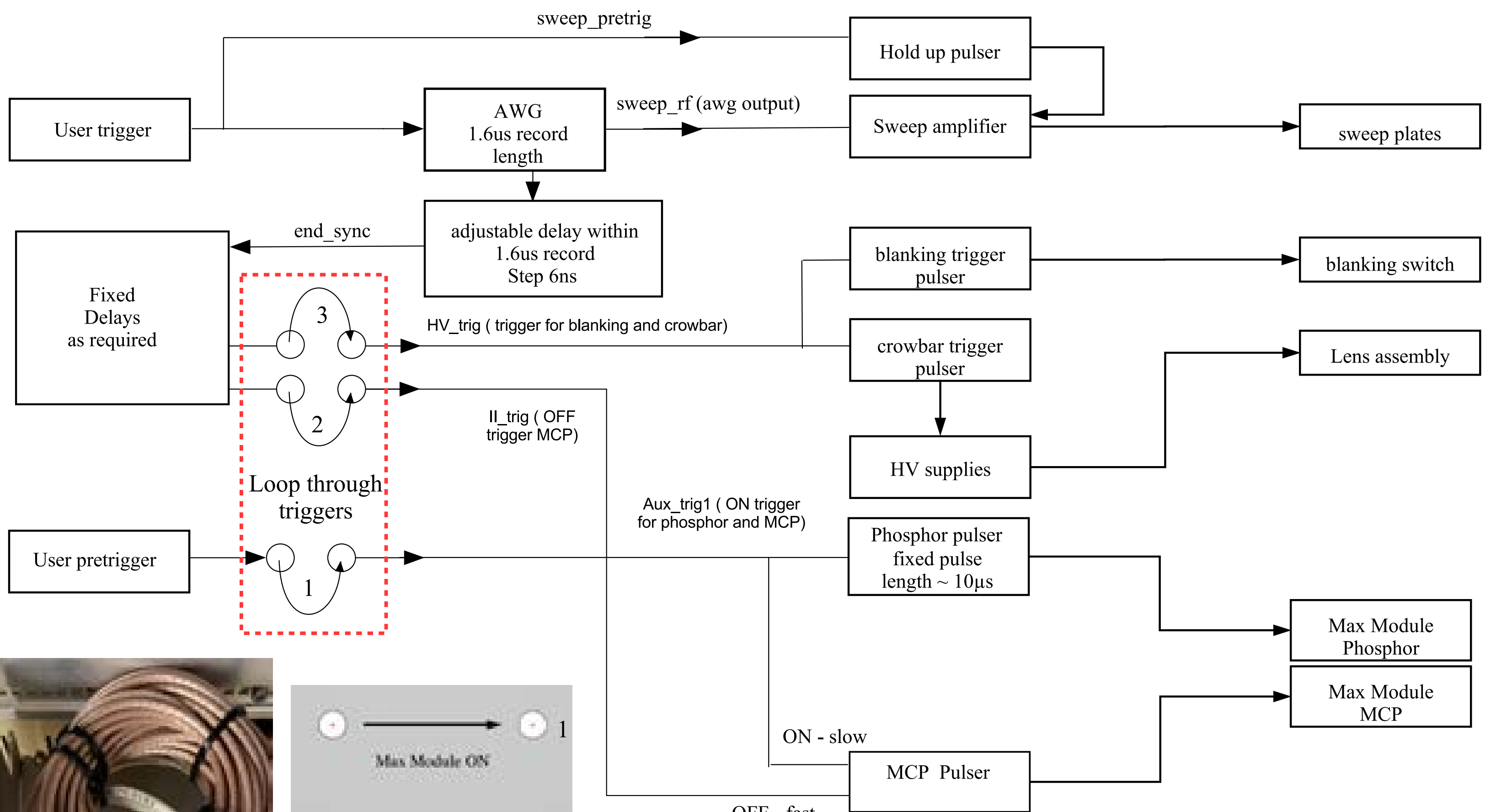
12.1.2 DELAY MODES

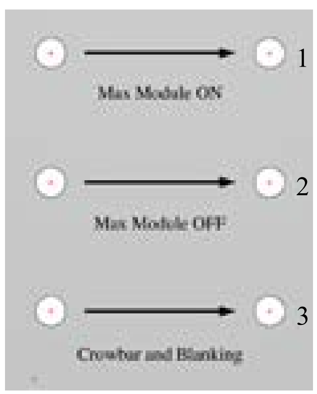
Scorpion-Z has several delay modes. One is such that the sweep rate can be changed and the timing to screen centre is unchanged. This enables the user to expand the time base about screen centre rather than the ramp start position. Whilst this may be useful in some instances it does require that the trigger delay for fast sweeps is necessarily long. There is also a delay mode whereby the time base expands about the screen edge or ramp start. Such modes have different delays to screen centre but are similar to conventional streak camera behaviour. The timing of the blanking and MCP off pulses is linked to the end of ramp and these will move with the change in sweep speed.

12.2 SWEEP TIMING DATA

The figures over the next few pages indicate of the timings of the different signals including the Ramp hold up pulser which is internal to the ramp generator and extends the period for which the ramp voltages stay high at the end of a sweep, so stopping retrace. Without this hold up pulser the time the ramps stays high will depend upon the capacitance of the cables to the sweep plates and consequently the length of the sweep cables.

Scorpion-Z timing diagram





The Crowbar & Fast blanking needs a significant delay so that the arrival time of the fast blanking trigger at the tube matches the arrival time of the MCP off signal.
The loop through triggers can also be used for investigating triggering issues.

The arrival time at the streak tube of the MCP off and the Fast blanking can be made synchronous by adjusting the length of the loop through triggers in the rack electronics.

The delay between the receipt of the fast trigger and the emitting of the blanking pulse will depend upon the cabling to the streak tube, the sweep speed and the position of the sweep data in the AWG record. This is calibration data that is stored along with the sweep data.

Figure 15 Scorpion-Z timing flow diagram

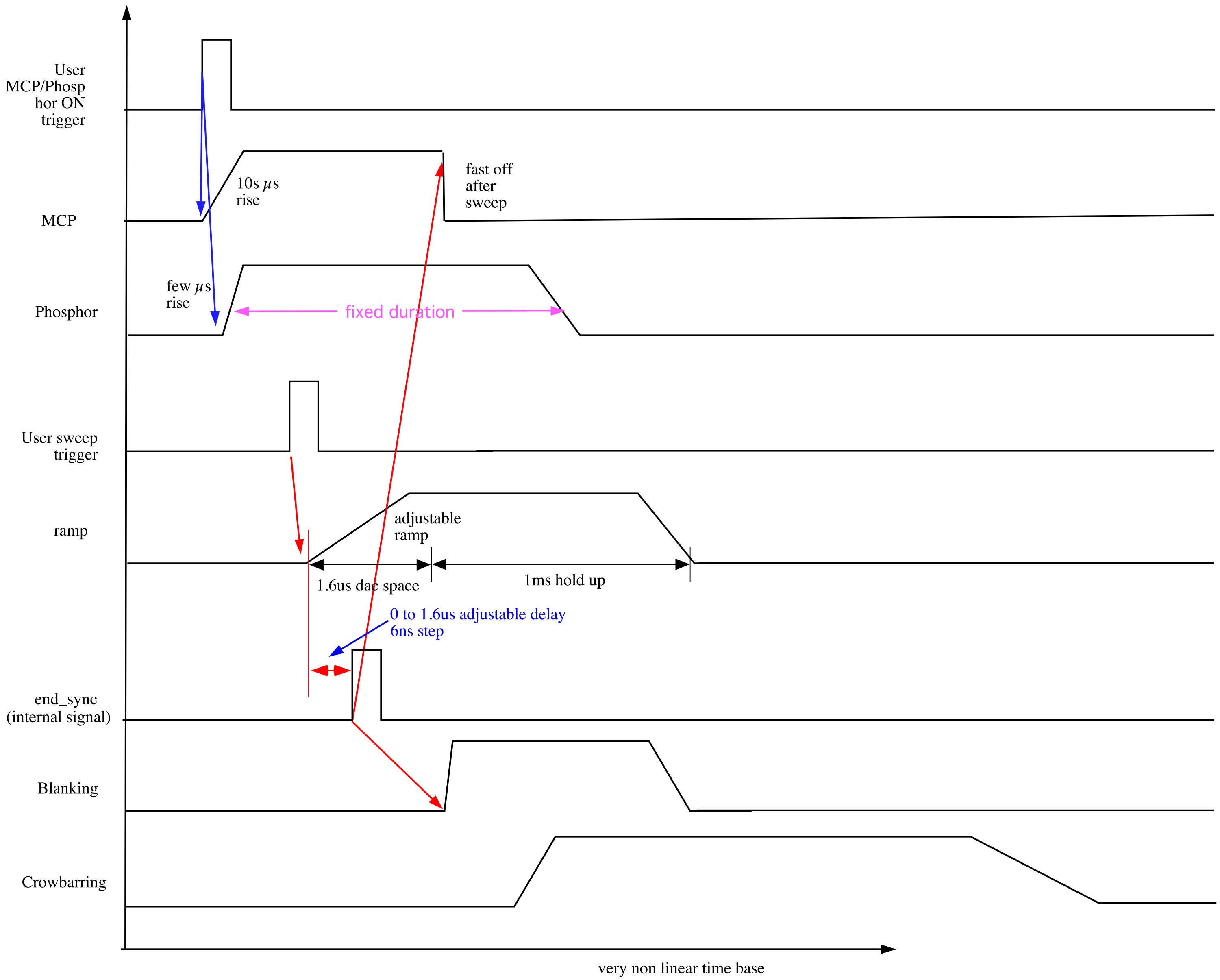


Figure 16 Scorpion-Z timing graph

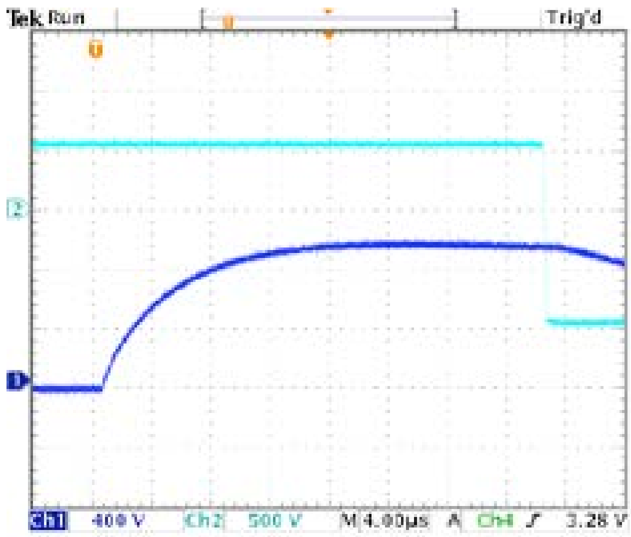


Figure 17 Ramp (upper) and Phosphor (lower) at 4µs/div

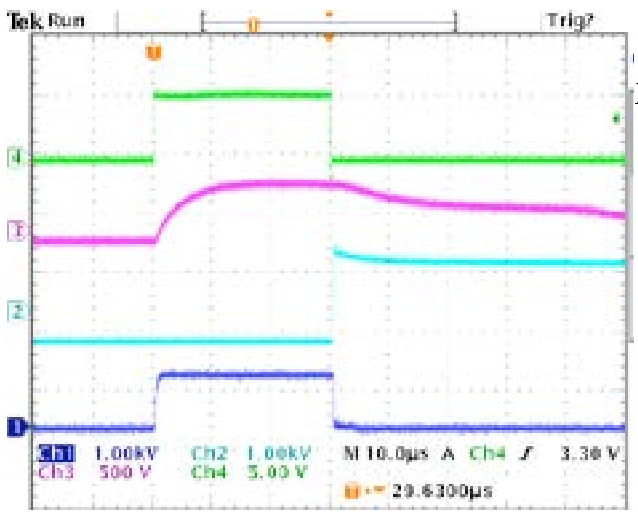


Figure 18 Trigger, Phosphor, Ramp and MCP OFF Top to bottom.
The trigger signal here is indicative of the two triggers. The rising edge represents the first trigger that turns the MCP ON and Phosphor ON and the trailing edge represents the second trigger that drives the ramp, MCP OFF

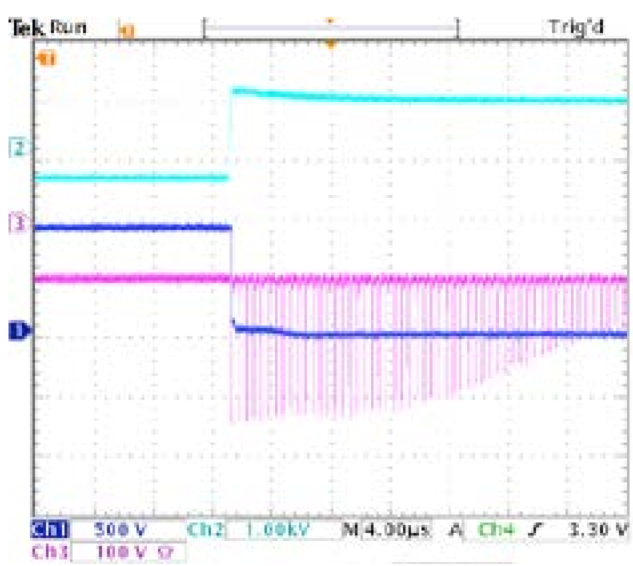


Figure 19 Ramp, MCP OFF and blanking Top to bottom.
This shows the approximate simultaneity of the three signals at this time scale. The blanking trigger is a burst of pulses that repeatedly triggers the AC coupled blanking switch to keep it on.

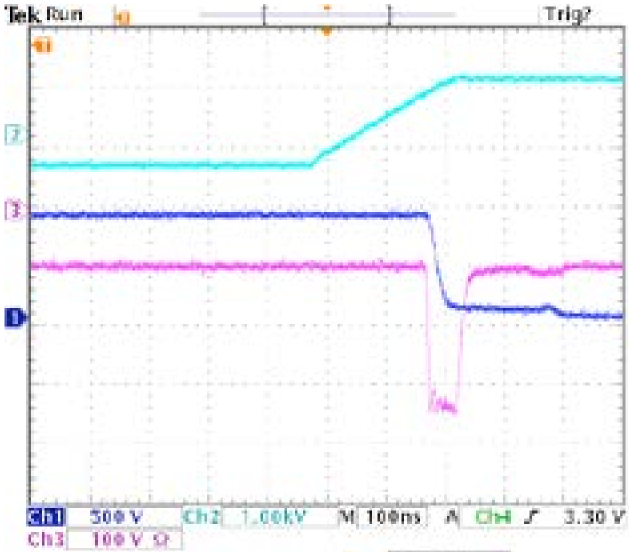


Figure 20 Sweep 0, MCP OFF, and blanking from top to bottom.
This shows the timing of the signals at the end of the cabling, near the streak tube. It sows the timing of the end of ramp wrt the other two signals.

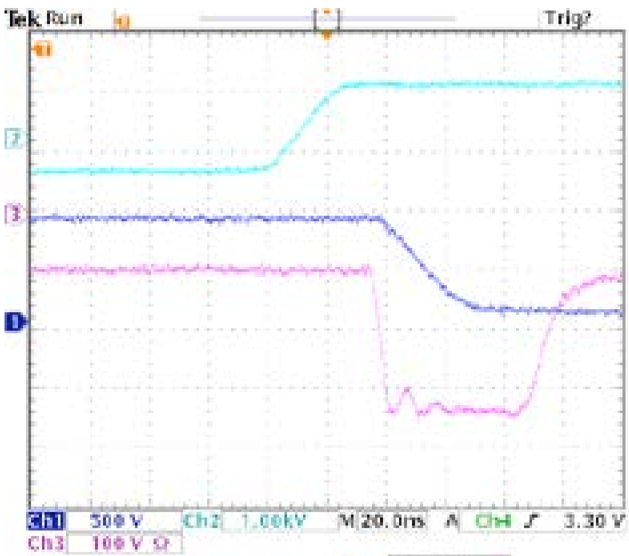


Figure 21 Sweep 5, MCP OFF, and blanking from top to bottom.
This shows the timing of the signals at the end of the cabling, near the streak tube. It sows the timing of the end of ramp wrt the other two signals.

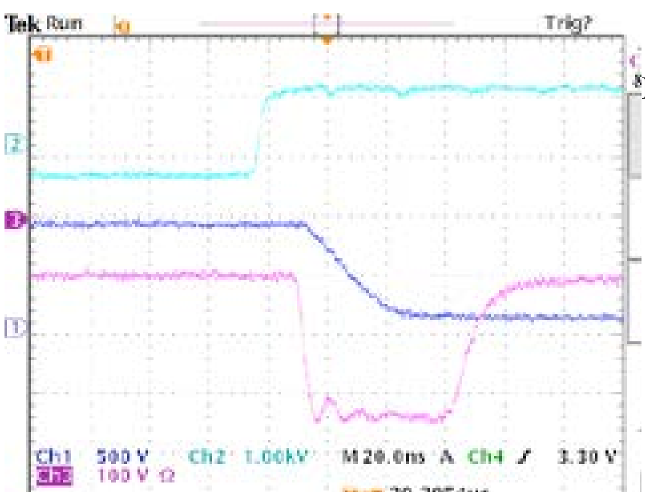


Figure 22 Sweep 10, MCP OFF, and blanking from top to bottom.
This shows the timing of the signals at the end of the cabling, near the streak tube. It sows the timing of the end of ramp wrt the other two signals.

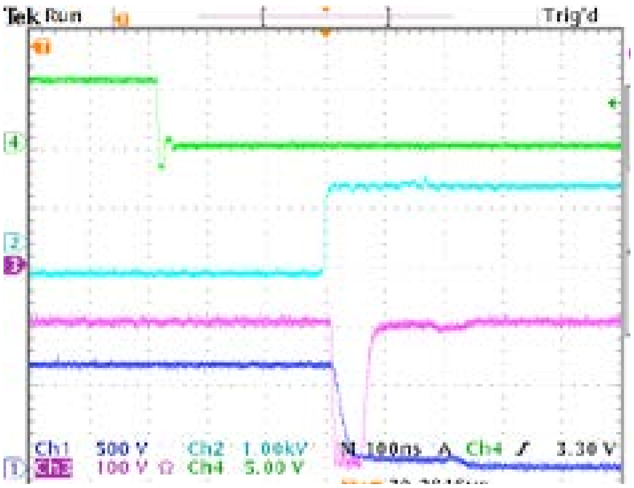


Figure 23 Sweep trigger, sweep 10, Blanking trigger and MCP OFF from top to bottom.
The trigger is shown here negative going but it actually positive going.
This shows the timing of the signals at the end of the cabling, near the streak tube. It shows the timing of the end of ramp wrt the other two signals.
This shows the trigger delay of ~ 285ns.
Much of this is the length of the cables.

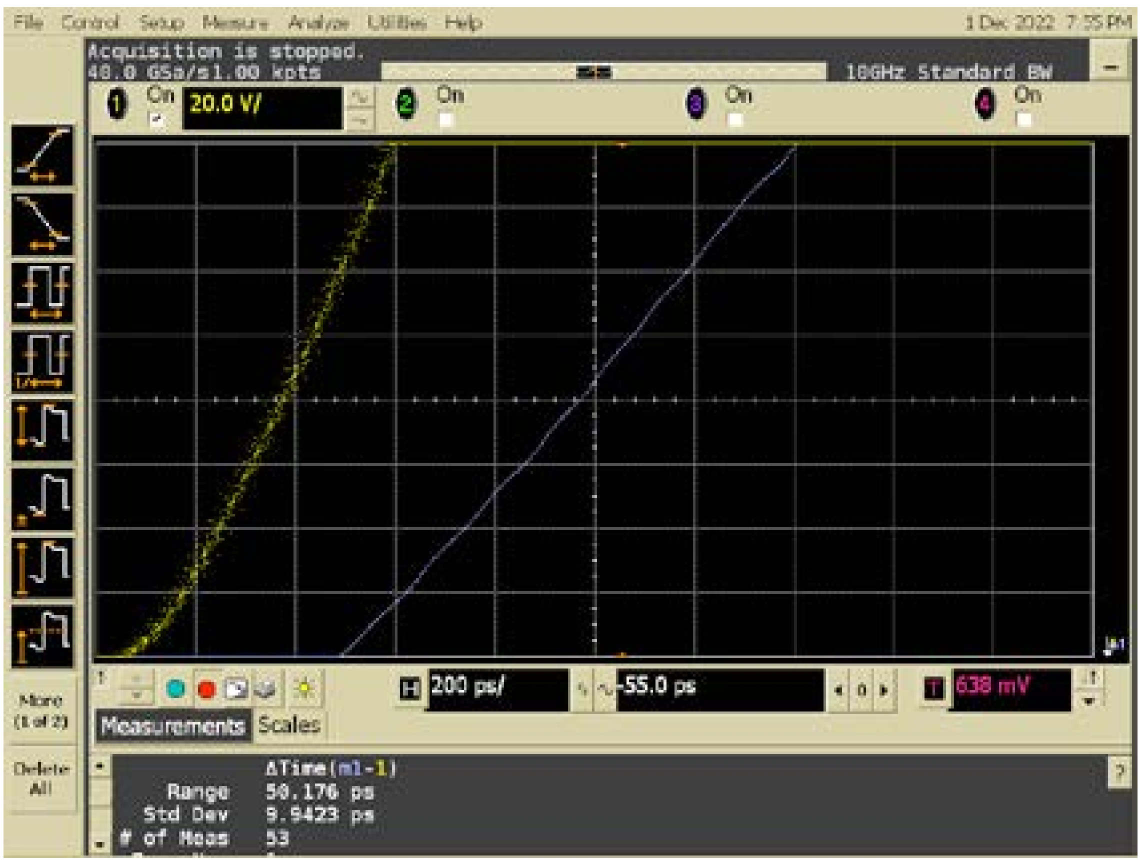


Figure 24 The trigger jitter of sweep 10 (the fastest) with delays set to minimum SD is ~ 9.9 ps

12.3 TESTS

The electron optics may be tested with either a DC X–ray source or a DC UV source, such as a mercury vapour lamp with quartz envelope. However, for optimum focus, the wavelength should match that to be used in the experiment as this affects the electron energy distribution of the photoelectrons. With an x-ray photocathode, the emitted electrons are secondary, i.e. generated by primary photoelectrons hitting the cathode structure and releasing several new electrons. For a UV photocathode the primary photoelectrons are used. It so happens that there is some similarity between the distribution of the electrons from a UV cathode and a gold x-ray one at 8keV, the peaks of the distribution are both at ~ 1.2eV. The electrons produced by x-rays have a longish tail going to higher energies. A suitable test resolution cathode should be used. LLNL and Kentech have designed these jointly and can offer advice.

A typical mercury vapour lamp operating 200 mm from the cathode will give a bright image on an intensified image. With suitable cathodes and reduced lamp to cathode spacing, it is possible to obtain moderately bright images without an intensification. Remember that the cathode is at -15 kV and that the lamp is probably grounded. It is possible to melt plastic substrate cathodes with some types of UV lamp. Also the UV output from UV lamps usually increases significantly as they warm up. UV light emitting diodes are coming on the market and may also be suitable. We have not yet tested any.

The focus potentials are changed with level 2 and 3 software commands.

With the DC source, the focus should be set for optimum image quality. The four potentials are interdependent and the optimum image quality is obtained by iterating between the various settings. The position of the crossover should also be close to the hole in the anode. If it is not, vignetting will occur. This is obvious when focussing the camera. Note that vignetting can occur if the crossover is either too far or too near the cathode. A suitable mid position must be found and this will be with the cross over roughly at the anode. This will ensure that the cross over is near the sweep plate assembly.

Stray magnetic fields may displace the image slightly. A mumetal screen may be adequate to remove this. Otherwise the magnetic field will have to be eliminated.

12.4 POSSIBLE FAULTS

12.4.1 NO DC IMAGE

Focussing unit not on or vacuum interlock not set.

Insensitive cathode.

Bad connections to cathode/mesh assembly.

Short circuit between mesh and cathode.

Breakdown of high voltage feed.

12.4.2 BAD FOCUS.

Poor connections to cathode/mesh.

Old/damaged cathode.

Poorly mated high voltage connector.

Fault in bias/sweep supply. (Confirm by disconnecting the sweep circuit completely, which should restore focus).

Focus voltages have drifted (unlikely).

Photocathode and mesh not normal to camera axis.

Image is due to x-rays going straight through the tube and exciting the phosphor. Check that no image is present with the focussing unit switched off. If necessary block the direct X-ray path.

12.4.3 NO STREAKED IMAGE.

Sensor triggering at wrong time, possibly from noise.

Sweep unit triggering at wrong time from noise.

Sweep feeds incorrectly connected.

Inadequate trigger signal causing jitter.

12.4.4 SPURIOUS BLOBS OF LIGHT.

Breakdown in chamber.

Pressure too high. Check vacuum and perform initial power up test.

Breakdown on shot. Plasma or target debris getting into electron optics. Is front of re-entrant vessel adequately screened? It is wise to restrict the front aperture as much as possible and cover the X–ray line of sight with as thick a filter as will transmit the desired X–rays. Use the blanking and crowbarring options.

12.4.5 REDUCED SWEEP SPEED COMBINED WITH POSSIBLE LOSS OF FOCUS

Bad connection of one sweep lead. This reduces applied voltage ramp but also fails to a maintain zero potential in drift tube, hence affecting the focus.

12.4.6 JITTER PRESENT IN IMAGE.

Inadequate or irreproducible trigger signal. The electronics has a jitter of about 20 ps SD. It is necessary to provide a good and stable trigger source for the electronics. This may well not be easy but is left to the user. Kentech can advise about solutions to trigger problems but the subject is too wide for a discussion here.

N.B. Poor connections to the mesh or cathode will often result in an apparent drift in the focussing as the electrodes charge up.

13. PHOTOCATHODES

The cathode materials normally recommended for X–ray use are often heavy metal salts of iodine or bromine, or gold, but for high time resolution the energy spread from gold is too great. We recommend the use of potassium bromide or potassium iodide. Transfer the Photocathodes, if supplied, to an evacuated desiccator as soon as possible after receipt.

14. SOFTWARE INTERFACE

14.1 INTRODUCTION

The software used in Scorpion-Z uses a Forth operating system running on an M3 Cortex microprocessor in the rack control module. The program is stored in EEPROM and can be upgraded by a simple drag and drop process if the "Service only" USB port on the front panel is connected to a PC.

There are several modes for several different functions of the system. These are most easily understood by reference to Figure 25 on page 45. Within this figure the core operating states of the system can be appreciated along with how the system moves from one state to another and some of the operations and parameters that can be selected at each stage.

14.2 COMMAND LEVELS

There are three levels of commands:

Level 1 is for day to day use with a set up system.

Level 2 is for setting up the tube focus, timing and performing flat field tests.

Level 3 is for setting up system behaviour and sweep waveforms.

Levels 1 and 2 use a defined protocol with a strictly limited vocabulary and format of command and response. This is designed for easy interfacing with a suitable interface program. See section 14.10 on page 50.

Level 3 runs in "debug" mode. Here the system uses the Forth interpreter and replies with "OK" after commands are entered.

14.3 SOFTWARE VERSIONS AND SERIAL NUMBERS

The Level 3 command **scnz.hardware** should produce the following response:

SW version = 0
HV module # = 1
SW module # = 1
TC module # = 1
Job no. = 2104091

14.4 NON VOLATILE MEMORY

There are many parameters that need to be stored in non volatile memory. These include the basic calibration data for the various measurement systems, the system behaviour when certain conditions are encountered, the user parameters for use with a particular streak tube, etc.

There are two EEPROMs available to the user but only one should generally be adjusted. The other is in the HV module and this should not be changed unless the user is very clear about what they are doing. It is possible to do serious damage to a streak tube and possibly to the Rack control system if the parameters in there are changed inappropriately.

The second available EEPROM is in the Control module. Some information stored in this is unlikely to need changing frequently and so is protected by a write enable control. The control button is on the rear panel of the rack unit above the power inlet. It is not labelled.

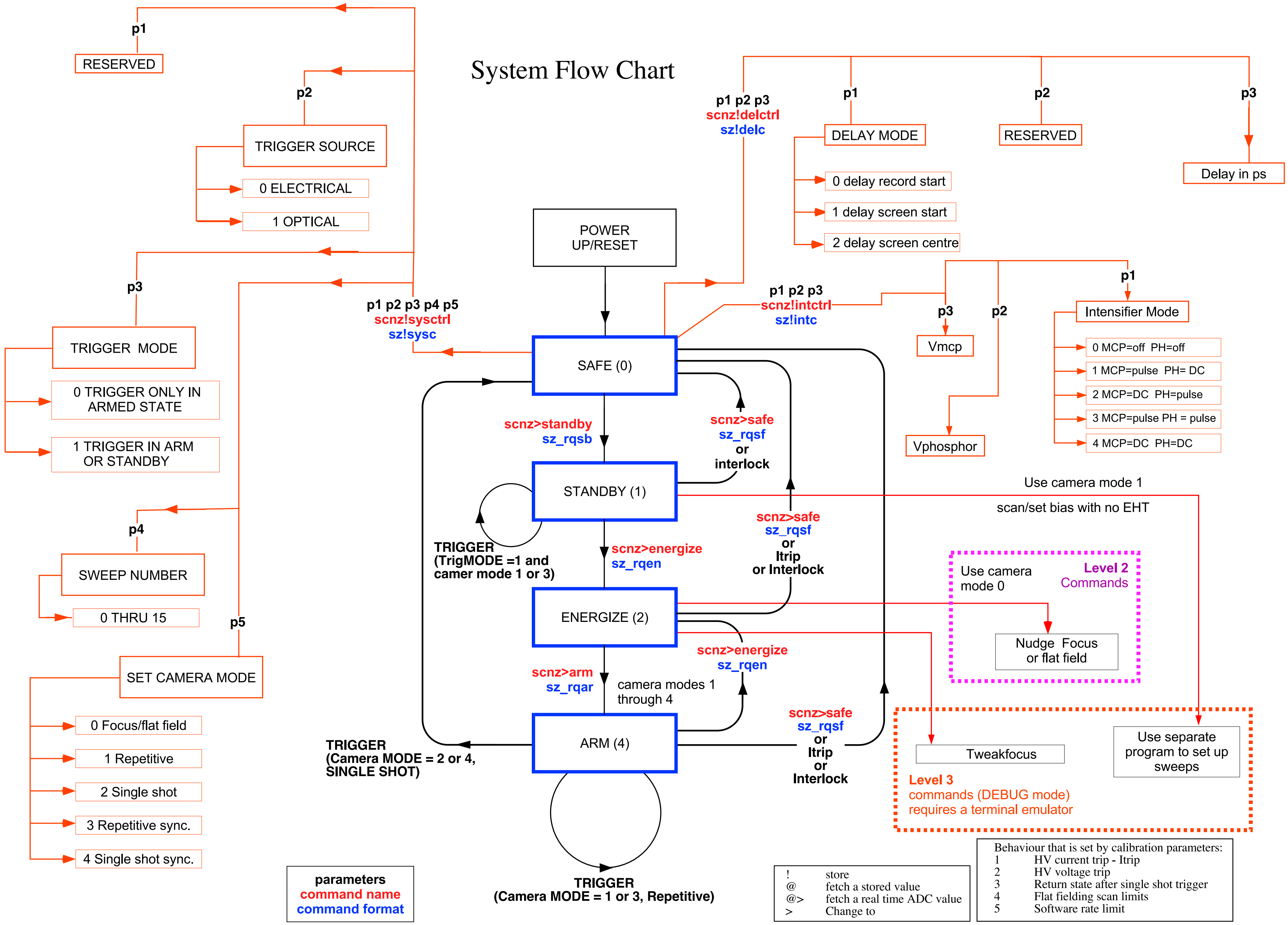


Figure 25 Flow diagram for set up and operation in single shot and repetitive modes.

Other parameters such as ramp waveforms may need more regular changing and are not write protected. The commands for saving the system state to the EEPROMs are in the sections below where it will also be indicated whether the write enable button needs to be depressed during the write cycle. See section 14.18 on page 83.

14.5 OPERATING STATE

There are four defined system operating states. These are:-

i. SAFE
The sweep pulser and sweep bias are off.
The focus supplies are inhibited and all HV control adcs set to zero.
Triggering is disabled

ii. STANDBY
The sweep pulser is ON but the biases are OFF..
The focus HV is inhibited and all control adcs set to zero[3].
The requested sweep data is loaded into the waveform buffer.
Triggering is disabled or enabled depending on the trigger mode.

iii. ENERGISE
The sweep pulser and sweep bias are ON
The focus HV supplies are ON and set to the requested focus values.
Triggering is disabled

iv. ARM
The sweep pulser and sweep bias are ON
The focus module HV supplies are ON
Triggering is enabled.

14.6 SYSTEM OPERATIONAL VARIABLES

The operation of the Scorpion-Z system in the above operating states is also influenced and controlled by the operational variables. Operational variables are volatile and will have default values unless correctly configured after a reset or power cycling. See Figure 25 on page 45.

The following parameters are set with the command **scnz!sysctrl,** see section 14.10 on page 50.

1	Reserved	
2	Trigger Source	Defines the trigger source
3	Trigger Mode	Defines the trigger behaviour
4	Sweep#	Selects a set of sweep data
5	Camera Mode	Defines the operating mode

14.6.1 TRIGGER SOURCE - PARAMETER 2

The trigger source flag selects either electrical or optical triggering.

Trigger Source	Behaviour
0	Both trigger inputs electrical - default
1	Both trigger inputs optical

3 In addition the unit will be in the STANDBY state after ENERGIZE has been requested but the high voltages have not yet reached their steady state. The HV active LEDs will flash as the voltages are ramped up.

14.6.2 TRIGGER MODE - PARAMETER 3

The trigger mode determines the behaviour of the trigger in the STANDBY operating state.

This allows the operation of the ramp generator and sweep bias to be checked without applying the focus voltages to the streak tube.

Trigger Mode	Behaviour
0	Trigger enabled in ARMED state only
1	Trigger enabled in ARMED and in STANDBY - default

14.6.3 SWEEP NUMBER - PARAMETER 4

The sweep data is stored in EEPROM in an area known as the sweep table. This is divided into 16 sweep records numbered 0 through 15. Each entry in a sweep record consists of the sweep waveform and a set of sweep control data. The sweep table has the capacity for 16 different data sets (records) (0 through 15), each set defining one sweep speed. The sweep control data includes a set of focus voltages, i.e. there is a independent set of voltages for each sweep#. The focus voltages need to be stored with the sweep data as the deflection sensitivity is dependent on them. The focus voltages may be slightly dependent upon the sweep speed due to dynamic defocussing In addition each sweep # includes a set of bias voltages for both normal and sync. operation.

The default sweep number at power on is 0.

14.6.4 CAMERA MODES - PARAMETER 5

The camera mode defines the mode of operation of the Scorpion-Z system.

There are five modes (0 through 4), a focus mode, 2 normal modes and 2 synchronisation modes:-

0 Focus/Flat field mode in which the focus of the streak tube may be check and modified, The focus supplies are operative but the fast sweep pulser is inhibited.

1 Repetitive (OPERATE) mode in which the camera may be repetitively triggered when armed.

2 Single shot (OPERATE) mode in which the camera may be triggered once after arming.

3 Repetitive SYNC mode in which the sweep starts on screen and in which the camera may be repetitively triggered when armed.

4 Single shot SYNC mode in which the sweep starts on screen and in which the camera may be triggered once when armed.

Note that there is no reduced scan mode set up although in principal this is possible.

Mode#	Mode
0	Focus/Flat field
1	Repetitive - default.
2	Single shot
3	Repetitive Sync
4	Single shot Sync

14.7 DELAY CONTROL

The following delay control parameters are set with command **scnz!delctrl**, see section 14.10 on page 50. This takes 3 parameters:

1. Delay mode - which point in the sweep record is used to set the sweep delay
2. Reserved
3. Sweep delay - the amount of delay.

14.7.1 DELAY MODE - PARAMETER 1

The delay mode defines the point of the sweep waveform that is delayed by the sweep delay

Delay Mode#	Behaviour
0	delay record start
1	delay screen start
2	delay screen centre

Note that sweep waveforms are stored in EEPROM with minimum delay (i.e. at the beginning of the sweep record) and the delays are then increased if necessary to accommodate the delay mode. Delays of the ramps are achieved by moving the ramp data within the waveform buffer (the section of RAM to where the waveform record is downloaded). This gives 400 ps resolution. In addition there is 400 ps of fine analogue delay. These two delay systems are integrated into the delay commands and are transparent to the user.

If mode 2 is chosen and a repetitive event is timed to screen centre at a slow sweep, then the sweep speed can be increased and the event will remain at screen centre. One can zoom in on the event. Note, however, that the trigger delay will be long as it has to accommodate the slowest sweep speed.

14.7.2 SWEEP DELAY - PARAMETER 3

This specifies the sweep delay to be applied in picoseconds. The range is 0 through 1,600,000ps.

14.8 MAX MODULE CONTROL

The Max module is controlled with the command **scnz!intctrl**, see section 14.10 on page 50. This command takes 3 parameters:

1. Intensifier mode
2. Phosphor voltage
3. MCP voltage

14.8.1 INTENSIFIER MODE PARAMETER 1

There are 5 modes for the Max module set by parameter 1:

0. MCP off, Phosphor off
1. MCP pulsed, Phosphor DC
2. MCP DC, Phosphor pulsed
3. MCP pulsed, Phosphor pulsed
4. MCP DC, Phosphor DC.

14.8.2 PHOSPHOR VOLTAGE, PARAMETER 2

This can take a value from 0 through 5500

14.8.3 MCP VOLTAGE, PARAMETER 3

This can take a value 0 though 900.

14.9 POWER UP SEQUENCE

After power cycling or a reset, the rack control module leaves the system in the SAFE state.

The results of this process should be read using the following two commands:

1. The rack controller hardware status read command **scnz@hardware**. This will return the software version number, the HV module serial number, the sweep module serial no., the control module serial no., and the Kentech job number. The state of the system can be verified with the Scorpion-Z status read command **scnz@status.**

A change of state can be requested by the IBC/user. The current, requested states are returned by **scnz@status** along with change of state activity.

This is not useful for normal operation of the system but it can be useful to read it for diagnostic purposes. After the power up sequence, the system state should eventually be SAFE. At this point there is no focus high voltage supply to the tube and the trigger is disabled.

The IBC/user should now set the operational variables using the Level 1 commands **scnz!sysctrl** and **scnz!delctrl**

scnz!sysctrl sets: Sweep#, Trigger Mode, Camera Mode, Trigger Source

scnz!delctrl sets Delay Mode and Delay

14.10 LEVEL 1 OPERATIONAL COMMANDS

For day to day use with a set up system.

There are two sets of commands names shown below. Remote control of the instrument should use the truncated form shown in blue below, all of which use the control protocol used on hDISC etc.

Commands shown in red are available in DEBUG mode only, they do not use the protocol as they are intended for an engineer to type. They are included because the names are less cryptic than the remote control forms, so I hope are an aid to understanding.

The following conventions are used in the command names:

!	store a value
@	fetch a stored value
@>	fetch a real time ADC value
>	hange to
0	reset

Name **scnz>safe**
Explanation Request system change to SAFE state
Format **sz_rqsf**
returned value 1 r1 0 => command completed, -1 => unable
Notes Will execute in STANDBY, ENERGIZE, ARMED states

Name **scnz>standby**
Explanation Request system change to STANDBY state
Format **sz_rqsb**
returned value 1 r1 0 => command completed, -1 => unable
Notes Will execute in SAFE state
This command clears interlock latches

Name **scnz>energize**
Explanation Request system change to ENERGIZE state
Format **sz_rqen**
returned value 1 r1 0 => command completed, -1 => unable
Notes Will execute in STANDBY state
This command clears current trip latches

Name **scnz>arm**
Explanation Request system change to ARMED state
Format **sz_rqar**
returned value 1 r1 0 => command completed, -1 => unable
Notes Will execute in ENERGIZE state
This command clears trigger latches

Name	**scnz!sysctrl**
Explanation	store system control settings
Format	**p1 p2 p3 p4 p5 sz!sysc**
parameter 1	p1 = reserved
parameter 2	p2 = Trigger source 0 = electrical 1 = optical
parameter 3	p3 = Trigger mode 0 = trigger in ARM only 1 = trigger in ARM or STANDBY
parameter 4	p4 = Sweep# 0 thru 15
parameter 4	p5 = Camera mode 0 = focus/flat field 1 = repetitive 2 = single shot 3 = repetitive sync 4 = single shot sync
returned value 1	r1 0 => command completed, -1 => unable

Notes   Will execute in SAFE state

Name	**scnz@sysctrl**
Explanation	read back system control settings
Format	**sz@sysc**
returned value 1	r1 = reserved
returned value 2	r2 = Trigger source 0 = electrical 1 = optical
returned value 3	r3 = Trigger mode 0 = trigger in ARM only 1 = trigger in ARM or STANDBY
returned value 4	r4 = Sweep# 0 thru 15
returned value 5	r5 = Camera mode 0 = focus/flat field 1 = repetitive 2 = single shot 3 = repetitive sync 4 = single shot sync

Notes   Read back of values set with sz!sysctrl

Name	**scnz!delctrl**
Explanation	store delay control settings
Format	**p1 p2 p3 sz!delc**
parameter 1	p1 = delay mode 0 = delay record start 1 = delay screen start 2 = delay screen centre
parameter 2	p2 = reserved
parameter 3	p3 = delay in ps 0 thru 1 600 000
returned value 1	r1 0 => command completed, -1 => unable

Notes   Executes in SAFE state
0 = command completed, -1 = unable
Returns unable in STANDBY, ENERGIZE and ARM
When setting up a new sweep speed, the three delays need to be set in the sweep table for the new sweep record.

Name	**scnz@delctrl**
Explanation	read back delay control settings
Format	**sz@delc**
returned value 1	r1 = delay mode 0 = delay record start 1 = delay screen start 2 = delay screen centre
returned value 2	r2 = reserved
returned value 3	r3 = delay in ps 0 thru 1 600 000

Notes   Read back of values set with sz!delctrl

Name	**scnz!intctrl**
Explanation	store intensifier control settings
Format	**p1 p2 p3 sz!intc**
parameter 1	p1 = intensifier mode 0 = MCP off, Phosphor off 1 = MCP pulsed, Phosphor DC 2 = MCP dc, Phosphor pulsed 3 = MCP pulsed, Phosphor pulsed 4 = MCP dc, Phosphor DC
parameter 2	p2 = phosphor voltage (V) 0 thru 5500
parameter 3	p3 = mcp voltage (V) 0 thru 900
returned value 1	r1 0 => command completed, -1 => unable

Notes   Executes in SAFE state
0 = command completed, -1 = unable
Returns unable in STANDBY, ENERGIZE and ARM

Name	**scnz@intctrl**
Explanation	read intensifier control settings
Format	**sz@intc**
returned value 1	r1 = intensifier mode 0 = MCP off, Phosphor off 1 = MCP pulsed, Phosphor DC 2 = MCP dc, Phosphor pulsed 3 = MCP pulsed, Phosphor pulsed 4 = MCP dc, Phosphor DC
returned value 2	r2 = phosphor voltage (V) 0 thru 5500
returned value 3	r3 = map voltage (V) 0 thru 900

Notes Read back of values set with sz!delctrl

Name	**scnz@status**
Explanation	Read status
Format	**sz@stat**
returned value 1	r1 = machine state 0 = SAFE 1 = STANDBY 2 = ENERGIZE 4 = ARM r2 = requested state 0 = SAFE 1 = STANDBY 2 = ENERGIZE 4 = ARM r3 = remote task activity 6 = changing to STANDBY 7 = changing to ENERGIZE 9 = changing to ARM 12 = idle r4 =trigger latch 0 = not triggered -1 = triggered r5 = current trip latch 0 = ok -1 = tripped r6 = reserved r7 = interlock latch 0 = ok -1 = interlock compromised r8 = reserved

Notes The trigger latch signal is the logical OR of:
sweep trig input latch
MCP trig input latch
HV module internal trigger latch

Intensifier module internal ON trigger latch
Intensifier module internal OFF trigger latch
More detail is returned by scnz@trigger

The current trip latch signal is the logical OR of
cathode current trip latch
mesh current trip latch
focus current trip latch
crossover current trip latch
phosphor current trip latch
mcp current trip latch

Notes More detail is returned by scnz@trip

Name	**scnz@trigger**
Explanation	Read trigger latches
Format	**sz@trig**
returned value 1	r1 = Sweep user trigger input latch 0 = not triggered -1 = triggered r2 = MCP user trigger input latch 0 = not triggered -1 = triggered r3 = HV module internal trigger latch 0 = not triggered -1 = triggered r4 = Intensifier module internal ON trigger latch 0 = not triggered -1 = triggered r5 = Intensifier module internal OFF trigger latch 0 = not triggered -1 = triggered r6 = reserved

Name	**scnz0trigger**
Explanation	Reset all trigger latches
Format	**sz0trig**
returned value 1	r1 0

Notes Trigger latches also cleared by scnz>armed sz_rqar

Name **scnz@trip**
Explanation Read current trip latches
Format **sz@trip**
returned value 1 r1 = cathode current trip latch
0 = ok
-1 = tripped
r2 = mesh current trip latch
0 = ok
-1 = tripped
r3 = focus current trip latch
0 = ok
-1 = tripped
r4 = crossover current trip latch
0 = ok
-1 = tripped
r5 = phosphor current trip latch
0 = ok
-1 = tripped
r6 = mcp current trip latch
0 = ok
-1 = tripped

Name **scnz0trip**
Explanation Reset current trip latches
Format **sz0trip**
returned value 1 r1 0 => command completed, -1 => unable
Notes Trigger latches also cleared by scnz>energise sz_rqen

Name **scnz@interlock**
Explanation Read interlock status
Format **sz@intk**
returned value 1 r1 = interlock input, true = open circuit, false = closed circuit = ok (to operate)
r2 = reserved
r3 = interlock latch, true = tripped, false = ok
Notes Interlock latches also cleared by scnz>standby sz_rqsb
Interlock input must be close circuited to allow operation.
Open circuit halts operation.

Name **scnz0interlock**
Explanation Reset interlock latch
Format **sz0intk**
returned value 1 r1 0 => command completed, -1 => unable

Name	**scnz@hardware**
Explanation	Read hardware status
Format	**sz@hrdw**
returned value 1	r1 = Kentech job number from rack controller
	r2 = trigger control unit serial no. (0 thru 15)
	r3 = sweep unit serial number (0 thru 15)
	r4 = HV unit serial number (0 thru 15)
	r5 = software version
	r6 = reserved
	r7 = reserved
	r8 = reserved

Name	**scnz@>temp**
Explanation	Read measured remote temperatures
Format	**sz@>tmp**
returned value 1	r1 = Processor module T1 (degrees C)
	r2 = Processor module T2 (degrees C)
	r3 = Sweep module T1 (degrees C)
	r4 =HV unit T1 (degrees C)
	r5 = HV unit T2 (degrees C)
	r6 = reserved
	r7 = reserved
	r8 = reserved

Name	**scnz@>Vtube**
Explanation	Read measured sweep tube voltages
Format	**sz@>vtb**
returned value 1	r1 = Petzval (V)
	r2 = Cathode (V)
	r3 = crossover (V)
	r4 = focus (V)
	r5 = mesh (V)
	r6 = Negative bias (V)
	r7 = Positive bias (V)
	r8 = reserved

Name	**scnz@>Itube**	
Explanation	Read measured sweep tube currents	
Format	**sz@>itb**	
returned value 1	r1 = reserved	
	r2 = cathode	(0 thru 4095)
	r3 = crossover	(0 thru 4095)
	r4 = focus	(0 thru 4095)
	r5 = mesh	(0 thru 4095)
	r6 = reserved	
	r7 = reserved	
	r8 = reserved	

Notes Measures load current plus current into 1.5GΩ sense resistor plus crowbar bias current on the photocathode.
The current read values are not calibrated. Leakage currents may be significant with long lengths of cabling. The main thing is to check that they are not very high and do not change significantly.

Name **scnz@>int**
Explanation Read intensifier monitor ADCs
Format **sz@>int**
returned value 1
r1 = Phosphor output voltage, in volts
r2 = MCP1 output voltage, in volts
r3 = MCP2 output voltage, in volts
r4 = MCP3 output voltage, in volts
r5 = MCP4 output voltage, in volts
r6 = Phosphor current, in µA
r7 = MCP current, in µA
r8 = reserved

Name **scnz@>1diag**
Explanation Read measured diagnostics
Format **sz@>1dia**
returned value 1
r1 = 24V supply current in mA
r2 = 12V supply current in mA
r3 = Hold up pulser supply (V)
r4 = Sweep pulser supply (V)
r5 = reserved
r6 = DAC rate count
r7 = reserved
r8 = reserved

Name **scnz@>2diag**
Explanation Read measured diagnostic voltages
Format **sz@>2dia**
returned value 1
r1 = reserved
r2 = reserved
r3 = reserved
r4 = reserved
r5 = reserved
r6 = EHT ref monitor
r7 = reserved
r8 = reserved

Notes EHT (Extra High Tension) 10 volt ref. is used in the focus supply feed back circuit. This is a monitor of it for trouble shooting.

Name **scnz@>3diag**
Explanation Read measured diagnostic voltages
Format **sz@>3dia**
returned value 1 r1 = 22V unregulated monitor
r2 = 24V input monitor
r3 = Blanking supply monitor
r4 = Bias psu1 monitor
r5 = Bias psu2 monitor
r6 = reserved
r7 = reserved
r8 = reserved

Name **scnz@>4diag**
Explanation Read measured diagnostic voltages
Format **sz@>4dia**
returned value 1 r1 = MCP psu voltage
r2 = MCP 1M voltage
r3 = Phosphor psu
r4 = reserved
r5 = reserved
r6 = reserved
r7 = reserved
r8 = reserved

Notes The psu measures the voltage directly at the output of the MCP power supply. The 1M voltage is after a 1MΩ resistor which is from where the MCP circuit is fed. Any difference in the voltages gives the current through the 1MΩ resistor. This is mainly for trouble shooting.

Name **scnz@1swpctrl**
Explanation Read sweep control table part 1
Format **sz@1swc**
returned value 1 r1 = swp_eof
r2 = swp_hu_f
r3 = swp_step
r4 = swp_lhs_ps
r5 = swp_cen_ps
r6 = swp_bias
r7 = swp_sync
r8 = reserved

Notes These parameters are a function of the sweep#
They are set up and stored in eeprom with sweep waveform

Name **scnz@2swpctrl**
Explanation Read sweep ctrl table part 2
Format **sz@2swc**
returned value 1 r1 = swp_Vcathode

r2 = swp_Vcrossover
r3 = swp_Vfocus
r4 = swp_Vmesh
r5 = swp_Vpetzval
r6 = reserved
r7 = reserved
r8 = reserved

Notes These parameters are a function of the sweep#
They are set up and stored in eeprom with sweep waveform

Name	**scnz@wfmblock**
Explanation	Read block of 16 samples from AWG buffer
Format	**sz@wfmb**
parameter 1	p1 = block number (0 thru 255)
returned value 1	r1 = sample value from address p1 x 16 + 0
	r2 = sample value from address p1 x 16 + 1
	r3 = sample value from address p1 x 16 + 2
	r4 = sample value from address p1 x 16 + 3
	r5 = sample value from address p1 x 16 + 4
	r6 = sample value from address p1 x 16 + 5
	r7 = sample value from address p1 x 16 + 6
	r8 = sample value from address p1 x 16 + 7
	r9 = sample value from address p1 x 16 + 8
	r10 = sample value from address p1 x 16 + 9
	r11 = sample value from address p1 x 16 + 10
	r12= sample value from address p1 x 16 + 11
	r13= sample value from address p1 x 16 + 12
	r14 = sample value from address p1 x 16 + 13
	r15 = sample value from address p1 x 16 + 14
	r16 = sample value from address p1 x 16 + 15

Notes This data is the data in the AWG waveform buffer generating the current sweep waveform.

It is a function of the sweep# and the user delay and delay mode. It is basically the data in the waveform table for the current sweep# in eprom but is right shifted to give the required coarse delay in 400ps steps.

14.11 LEVEL 2 COMMANDS TO ADJUST THE FOCUS & FLAT FIELD

Commands to adjust the focus of the system in situ and executing flat field measurements.

Name	**scnz_focus**
Explanation	Setup camera focus condition
Format	**p1 sz_fcus**
parameter 1	p1 = bias voltage for focus, range -800V to +800V
returned value 1	r1 0 => command completed, -1 => unable

Notes Will execute only in focus/flatfield mode

Name	**scnz_flatarm**
Explanation	Arm the camera system in flat field mode
Format	**p1 sz_farm**
parameter 1	p1 = pause in ms per step for flat field
returned value 1	r1 0 => command completed, -1 => unable

Notes Will execute only in focus/flatfield mode
Restores sweep bias to flatfield start condition

Name	**scnz_flattrig**
Explanation	Trigger the camera system in flat field mode
Format	**sz_ftrg**
returned value 1	r1 = sweep bias voltage on termination
returned value 2	r2 0 => command completed, -1 => unable

Notes Will execute only in focus/flatfield mode
This command will not send a return value for several seconds until the Flat field sweep has terminated. It will terminate prematurely if any further serial character is received.

Name	**scnz_incvcathode**
Explanation	add an increment to the cathode voltage
Format	**p1 sz_+vpc**
parameter 1	p1 = voltage increment, range +/-1000V
returned value 1	r1 = revised cathode voltage setting
returned value 2	r2 0 => command completed, -1 => unable

Note Will execute only in focus/flatfield mode
Changes only the ram value, will be lost on power up unless calibration saved

Name	**scnz_incvmesh**
Explanation	add an increment to the mesh voltage
Format	**p1 sz_+vme**
parameter 1	p1 = voltage increment, range +/-1000V
returned value 1	r1 = revised mesh voltage setting
returned value 2	r2 0 => command completed, -1 => unable

Notes Will execute only in focus/flatfield mode
Changes only the ram value, will be lost on power up unless calibration saved

Name	**scnz_incvfocus**
Explanation	add an increment to the focus voltage
Format	**p1 sz_+vfo**
parameter 1	p1 = voltage increment, range +/-1000V
returned value 1	r1 = revised focus voltage setting
returned value 2	r2 0 => command completed, -1 => unable

Notes Will execute only in focus/flatfield mode
Changes only the ram value, will be lost on power up unless calibration saved

Name	**scnz_incvcrossover**
Explanation	add an increment to the crossover voltage
Format	**p1 sz_+vcr**
parameter 1	p1 = voltage increment, range +/-1000V
returned value 1	r1 = revised crossover voltage setting
returned value 2	r2 0 => command completed, -1 => unable

Notes Will execute only in focus/flatfield mode
Changes only the ram value, will be lost on power up unless calibration saved

Name	**scnz_incvpetzval**
Explanation	add an increment to the petzval voltage
Format	**p1 sz_+vpe**
parameter 1	p1 = voltage increment, range +/-1000V
returned value 1	r1 = revised petzval voltage setting
returned value 2	r2 0 => command completed, -1 => unable

Notes Will execute only in focus/flatfield mode
Changes only the ram value, will be lost on power up unless calibration saved

14.12 LEVEL 3 COMMANDS

These commands talk directly to the Forth interpreter using the Forth programming language and can be used manually with a terminal emulation program such as Hyperterminal.

A good general guide to Forth programming is Programming Forth by Stephen Pelc which is available on line in pdf format. However it is not necessary to have an in depth knowledge of Forth to use these commands.

Level 3 commands are only accessible in DEBUG mode. Debug mode is enabled/disabled using:-

+debug - change into debug mode

-debug - change into normal mode

Strictly +debug is a level 1 or 2 command but not included as it allows access to Level 3 commands and takes the unit out of the limited vocabulary mode.

In debug mode, the standard short form protocol commands can be used as in level 1 & 2 modes, but in debug mode the rack controller will also recognise the long form name of the function.

If any Forth macros are added the long form should be used.

For example the hardware status read command rc@hrdw will respond as before, but the system will also respond to the long form rc@hardware.

It will be observed that the returned parameters from rc@hardware are not formatted and printed, they are left on the data stack. The stack can be non destructively printed using the stack print command [.S] or the parameters can be printed one by one using the print command [.], which prints one parameter and drops it from the stack. Note that the returned parameters are in reverse order as the last returned parameter is at the top of the stack and will be the first one printed.

14.12.1 DECODED COMMANDS

Several of the Level 1 & 2 commands have new versions under level 3 with parameter decoding.

scnz.delctrl	scnz@delctrl	sz@delc
scnz.intctrl	scnz@intctrl	sz@intc
scnz.status	scnz@status	sz@stat
scnz.lswpctrl	scnz@lswpctrl	sz@lswc
scnz.2swpctrl	scnz@2swpctrl	sz@2swc
scnz.hardware	scnz@hardware	sz@hrdw
scnz.trip	scnz@trip	sz@trip
scnz.interlock	scnz@interlock	sz@intk
scnz.trigger	scnz@trigger	sz@trig
scnz.>temp	scnz@>temp	sz@>tmp
scnz.>int	scnz@>int	sz@>int
scnz.>ldiag	scnz@>ldiag	sz@>ldia
scnz.>2diag	scnz@>2diag	sz@>2dia
scnz.>3diag	scnz@>3diag	sz@>3dia
scnz.>4diag	scnz@>4diag	sz@>4dia
scnz.>vtube	scnz@>vtube	sz@>vtla
scnz.›Itube	scnz@>Itube	sz@>itb

These are typical responses to the commands:

scnz.delctrl
delay = 0
delaymode = record start ok

scnz.intctrl
vmcp = 0
vphos = 0
intmode = MCP> dc off Phos> dc off ok

scnz.status
interlock latch = 0
hv_itripl =0
trig_l = 0
remtask state = Idle
Requested state = Energized
Remote state = Energized ok

scnz.1swpctrl
swp_sync = -250
swp_bias = -585
swp_cen_ps = 75960
swp_lhs_ps = 15740
swp_step = 0
swp_hu_f = -1
swp_eof = 28 ok

scnz.2swpctrl
swp_Vcorr = 568
swp_Vmesh = 10962
swp_VL3 = 9923
swp_VL1 = 11404
swp_Vcath = 14997 ok

scnz.hardware
SW version = 0
HV module # = 1
SW module # = 1
TC module # = 1
Job no. = 2104091 ok

```
tweakfocus

use q and w choose param then decrement/increment with 1 2 3 4 5 6
s to save
c to copy
v to paste
z to undo paste

SW#   VPC    VCR    VFO    VME     VPE
   0  14997  11404   9923  10962    568
^^^^^

SW#   VPC    VCR    VFO    VME     VPE
   0  14997  11404   9923  10962    568
      ^^^^^

SW#   VPC    VCR    VFO    VME     VPE
   0  14997  11404   9923  10962    568
             ^^^^^

SW#   VPC    VCR    VFO    VME     VPE
   0  14997  11404   9923  10962    568
                    ^^^^^

SW#   VPC    VCR    VFO    VME     VPE
   0  14997  11404   9923  10962    568
                           ^^^^^

SW#   VPC    VCR    VFO    VME     VPE
   0  14997  11404   9923  10962    568
                                  ^^^^^
```

Figure 26 Example of how to use the tweakers **tweakfocus**.

scnz.trip
mcpitrip_l = 0
phositrip_l = 0
Xovitrip_l = 0
Focitrip_l = 0
meshitrip_l = 0
cathitrip_l = 0 ok

scnz.interlock
intlk latch = 0
intlk input = 0 ok

scnz.trigger
mmBtrig_l = 0
mmAtrig_l = 0
hvtrig_l = 0

mcptrig_l = 0
swptrig_l = 0 ok

scnz.>temp
Processor T2 = 45
Processor T1 = 48
Sweep T1 = 39
HV T2 = 45
HV T1 = 39 ok

scnz.>int
imcp = 0
iphos = 1
Vmcp4 = 0
Vmcp3 = 0
Vmcp2 = 0
Vmcp1 = 0
Vphos = 7 ok

scnz.>1diag
dacrate = 0
Vsweep = 2
Vhold = 4
12V current = 1365
28V current = 275 ok

scnz.>2diag
eht vref = 10058 ok

scnz.>3diag
biaspsu2 = 1425
biaspsu1 = 333
550v mon = 51
24V mon = 23942
22V mon = 21173 ok

scnz.>4diag
Phos_psu_mon = 51
mcp_1meg_mon = 23942
mcp_psu_mon = 21173 ok

scnz.>vtube
>vpbias = -700
>vnbias = 700
>vmesh = 10961
>vfoc = 9924
>vxov = 11403
>vcath = 14996
>vpet = 567 ok

scnz.>itube
>imesh = 1096
>ifoc = 992
>ixov = 1140
>icath = 2999 ok

14.12.2 TUBE FOCUSSING - TWEAKFOCUS

The focus voltages can be set up by putting the system into focus mode (camera mode 0) and the ENERGIZE state. The voltages may be varied using Level 2 commands.

An alternative is to use the TWEAKFOCUS Level 3 command. This command is provided to simplify the task of focusing the streak tube. With the system in the ENERGIZE (2) state and with the camera mode set as FOCUS (0) this command runs a routine to adjust the voltage outputs from the focus supply. The parameters that can be modified are the current sweep#, Photocathode voltage, SLOT 1 voltage, SLOT 2 voltage, Focus voltage and Spare voltage.

Each sweep record in the sweep table contains a set of focus voltages and they are saved to EEPROM in the sweep tables with either **n ee!swpctrl** or **n ee!sweep** where **n** is the sweep table number (0 through 15). See section 14.18 on page 83. The sweep rate will depend upon the focus voltages so it is necessary to set up the focus voltages for each sweep rate. Often the focus voltages will be unchanged between sweep speeds, so there is a function to copy the focus voltages from one sweep record to another.

To set the focus voltages the camera mode should be focus/flat field (0) and the state should be ENERGIZE. If the focussing is to be done with a static image at tube centre then the bias voltage will have to be changed to zero with the command **scnz_focus.**

TWEAKFOCUS is activated by typing TWEAKFOCUS (cr).

The following keys are used to operate the function:

W or Q changes the selected parameter be adjusted. W to the right and Q to the left.
1 or 2 decrements/increments the set value by 1
3 or 4 decrements/increments the set value by 10
5 or 6 decrements/increments the set value by 100
c or C will copy all the focus voltages of the selected sweep# to a clipboard
v or V will paste the clipboard into the focus voltages for the selected sweep#
s or S will save the parameters in the sweep control block of the selected sweep# in EEPROM
z or Z will undo the last paste operation.
ESC will exit the routine

On exit the voltages will remain as they have been adjusted, but note that this data is volatile. It will be lost if the system power is cycled or the state is moved from SAFE to STANDBY (as this will download a sweep control table from EEPROM), unless it is explicitly saved in EEPROM using s or S within the TWEAKFOCUS command. An alternative is to use **n ee!swpctrl** to save the sweep control table for the record being adjusted (record = n).

Note that this part of the EEPROM is not write protected.

On exit from TWEAKFOCUS a parameter is returned on the stack. This is 0 for success and -1 for fail. Note that in the event of a fail, the routine is exited immediately.

If TWEAKFOCUS returns a non zero value it means the system state is not in ENERGIZE, and/or the camera mode is not FOCUS.

Note that if the bias voltage is adjusted with **scnz_focus** while tweaking the focus and then the new focus voltages are saved with **n ee!sweep**, the bias voltage will not be overwritten. This is intentional as the bias voltage always has to be adjusted to focus the tube.

An example session of adjusting the focus voltages is shown in Figure 26 on page 66.

Note that a set of focus voltages is required for each sweep record, hence the copy and paste commands.

14.13 THE SWEEP TABLE DATA

The sweep table has 16 sweep records. Each sweep is represented in the EEPROM as a record of 8192 bytes. Each record contains a "sweep control table" and a "sweep waveform".

The sweep waveform which will be used by the AWG is kept as 4032 two byte sample values (11 bits used).

The remaining 128 bytes (that make up a sweep record) are used to store a block of parameters this is the "sweep control table". There is one sweep control table for each of the 16 sweeps that are stored.

Parameters in the sweep control table are:

swp_eof	- the eof sync delay in 6ns steps
swp_hu_f	- hold up pulser flag, true (-1) = enable, false (0) = disable
swp_lhs_ps	- time in ps from start of record to screen left
swp_cen_ps	- time in ps from start of record to screen centre
swp_bias	- bias in volts to use in repetitive and single shot modes
swp_sync	- bias in volts to use in repetitive sync and single shot sync modes
swp_vcath	- photocathode voltage in volts
swp_step	- sweep prebias - this shoud always be set to zero this feature proved to be unnecessary.
swp_vcr	- crossover voltage in volts
swp_vfo	- focus voltage in volts
swp_vmesh	- mesh voltage in volts
swp_vpe	- Petzval corrector voltage in volts

To set any of these parameters use the standard form, e.g. for the sweep hold up flag:

-1 swp_hu_f !

The value can also be read, e.g.

swp_hu_f @ .

Carriage returns have been omitted. The "@'"fetches the value, the "." prints it.

14.13.1 CHANGING THE SWEEP WAVEFORM

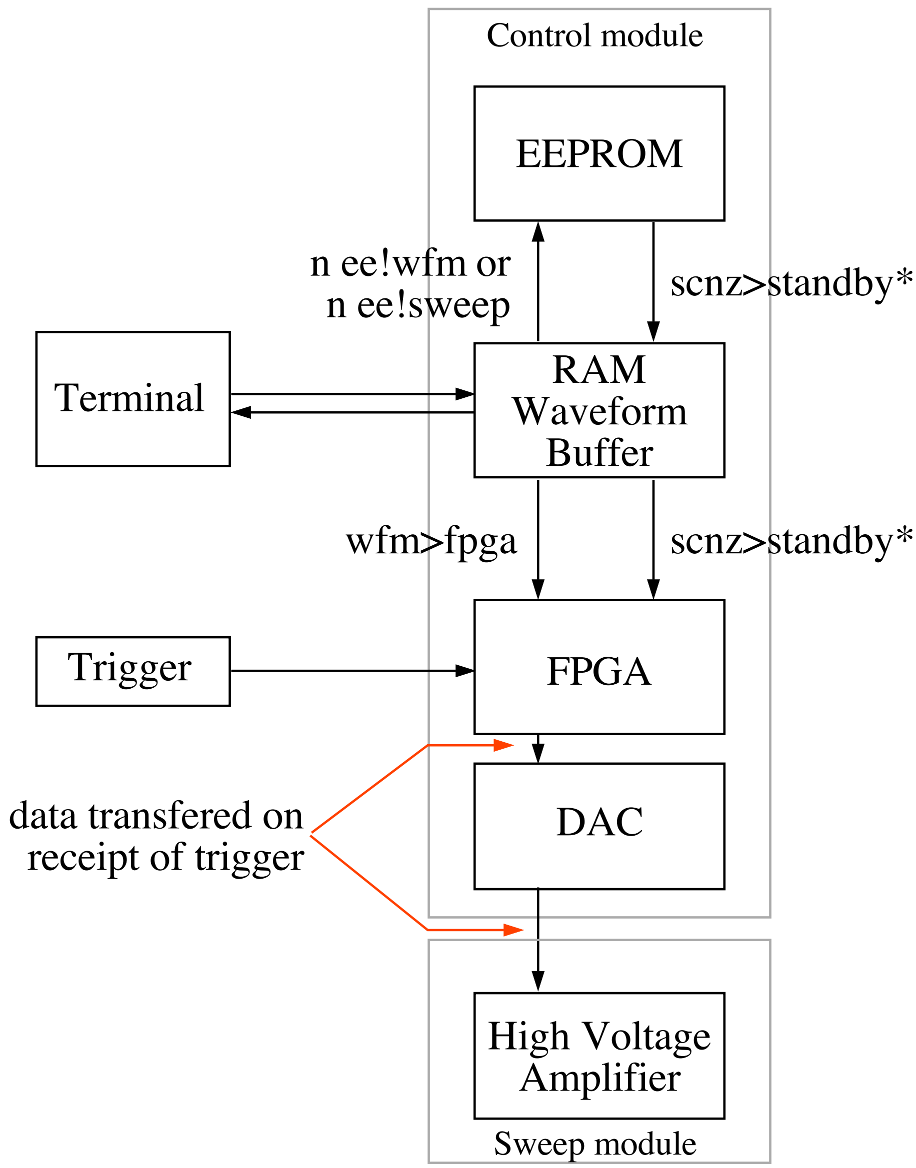
When a sweep speed is selected the sweep waveform is copied from the sweep table in EEPROM to the waveform buffer RAM in the AWG.

The waveform buffer is 4096 two byte samples long, which is longer than the 4032 sample record in the sweep table. The deficiency of samples at the end of the waveform buffer is made good by duplicating the last sample of the record in the sweep table. So this should always be enough to deflect beyond screen right.

The position of the sweep table record when copied into the waveform buffer depends on the user delay setting and the delay mode. The samples are 400ps apart, and this is used as a means to vary the coarse delay. Any deficiency of samples at the start of the waveform buffer is made good by padding with zero samples. There is a fine delay hardware function that fills in the 400ps steps. The user delay is specified in ps and the system uses the two delay modes appropriately.

The way the user delay in ps is interpreted depends on the user delay mode, see section 14.7.1 on page 48.

With trigger mode 1 selected and in camera mode repetitive, the sweep waveforms can be characterised and adjusted in the STANDBY state without high voltages present on the streak tube (other than the



* When the state is changed to standby the waveform in the EEPROM is copied to the waveform buffer. This will overwrite any changes made with “**tweak**” or “**!sample**”.
The **tweak** and **!sample** fucntions can be used in both the safe and standby states.
Note that **!sample** does not update the FGPA so if the command is executed in standby mode while viewing the waveform it will be necessary to execute the **wfm>fpga** command to see changes to the waveform.

Figure 27 The structure of the waveform generation sweep bias). The sweep waveform can be adjusted in the waveform buffer, then this can be copied to the user sweep table.

The sweep waveform should be adjusted at minimum delay. The system can add subsequently add delay to the waveform in the user sweep table relative to the sweep trigger as it copies the waveform to the AWG described above, but it can't remove delay, so the ramp data should be at the beginning of the record.

The following commands are provided to define and edit the sweep waveform:

xxx SETALL	Sets all 4096 samples in sample buffer to xxx
ZERO	Sets all samples to generate a zero waveform
+RAMP	Produces a rising linear ramp over all samples
-RAMP	Produces a falling linear ramp over all samples
xx %WFM	Scale the waveform by xx % and send to the output[4]
xx TWEAK	Interactively tweak individual samples
x n !SAMPLE	Set sample at address n (0 through 4095[3]) to x (0 through 2047[3]) (note this does not write the waveform to the FPGA)
n ?SAMPLE	Print value of sample address n
?WFM	Print the waveform buffer as a formatted list of DAC values
TXWFM	Transmit current waveform in binary from buffer to terminal
RXWFM	Receive a binary waveform from terminal to buffer.
?SUMWFM	Print the checksum of the waveform modulus 2^16
WFM>FPGA	Copy the waveform buffer to the FPGA and output to the DAC on receipt of a trigger

Note that **WFM>FPGA** is needed in conjunction with the **!SAMPLE** command. Figure 27 on page 70 shows how the data is manipulated.

Any sweep waveform set up in this way is volatile and will be lost at power down unless explicitly saved in EEPROM. Further, a change from SAFE state to STANDBY state will overwrite the waveform buffer with the data in the EEPROM at the sweep table specified by the scnz!sysctrl command. The waveform buffer can be saved to EEPROM with the command

n ee!wfm

where **n** = the sweep record to be used.

The EEPROM used for sweep data and user variables is not write protected, i.e. there is no need to operate any write protect button.

4 Note that the data has a maximum value of 2047 and is an integer. The address must be inside the permitted range. No error messages are issued for incorrect data.

14.13.2 CHANGING THE SWEEP CONTROL TABLES

The sweep control table parameters other than focus voltages should also be setup at this stage.

The 12 parameters in a sweep control table can be modified under Level 3 commands simply by saving a new value in the variable and then saving the table into the relevant sweep record with **n ee!swpctrl** where **n** is the record number (i.e. the sweep number). However, the focus voltages are more easily set up with either Level 2 commands or with TWEAKFOCUS, see section on page 64

There are also tweakers for the end of frame sync. delay.

Tweak_eof

Both take values from 0 through 255 representing 6ns steps

On launch two numbers are presented, the former is the increment and the latter the current value the parameter is set to.

Use the keys "1" & "2" respectively to decrease and increase the increment

Use the keys "3" & "4" to respectively to subtract or add the increment to the current value.

The "ESC" key will exit the routine.

The block of sweep control table parameters can be saved to EEPROM with

n ee!swpctrl

where **n** = the sweep record to be used, see section 14.18 on page 83.

The waveform and control data from the sweep table, defined by the user variable sweep# (normally set within the scnz!sysctrl command), is read by the system on transition from the SAFE to STANDBY states and used to setup the system appropriately.

14.13.3 SWEEP HOLD UP PULSER

At the end of the ramp the sweep plates will be brought back to their initial state by the bias supply. The supply has a high source impedance and so will take a long time to recharge long sweep cables. However, shorter sweep cables will recharge more quickly. There is a hold up pulser in the Sweep module that holds the voltage difference on the plates high (and in the deflected state) for ~ 1.2ms. The pulse is not equal and opposite (as the ramps are) due to loading by the sweep monitor on the sweep module that loads the positive ramp more than the negative. Imbalance after the sweep is not a important.

The hold up pulser can be enabled and disabled and there is a flag (swp_hu_f) in the sweep control table to reflect this. It should be set up in the usual way when setting up a ramp, see 14.13 on page 69**.**

14.13.4 SWEEP BIAS VOLTAGES AND SWEEP DELAYS

The above does not allow the setting of the sweep bias voltages for sweep modes (Camera modes 1 though 4). These must be explicitly set by loading the required value into the appropriate variable prior to saving the sweep control data with **n ee!swpctrl or n ee!sweep**.

The required voltages will depend on the streak tube and sweep speed. Generally the bias voltage has to be large enough to hold the start point off screen. Also if the ramp has any non linearities, then the bias voltage can be used to set the most linear part at screen centre.

The voltages have to be obtained empirically for each streak tube used.

The bias voltage used in sync. mode is often zero. This puts the sweep start at screen centre. However,, a more useful place is at the left hand side of the screen. I.e. the starting side, as this gives a longer temporal record. Sync. modes help with timing of the sweep trigger. If an undeflected image appears, the trigger was too late or absent. If no image appears the trigger was to early or no signal was received. Assuming no errors this can give a binary search procedure for the correct trigger timing. It is good practice to check for error occasionally otherwise the binary search can be lead astray.

The sweep delays also have to be set. These need to be measured for a particular sweep set up and streak tube. The delay to sweep centre is just the time it takes the ramp to get to be equal but opposite to the bias voltage, i.e. the plate voltage is zero.

If the streak tube deflection sensitivity is well known, then the time to any point on the screen can be measured and the time to screen left can be set.

14.14 NOTES ON SWEEP MODES AND DELAY - A SUMMARY

1 The ramp data for each sweep is stored in EEPROM along with several other pieces of information.

2 When a sweep speed it selected the data is copied to the sweep record but it's position within the record is set by the mode and sweep delay.

3 The mode (0,1 & 2) set the reference point (voltage) on the ramp waveform that corresponds to start, screen edge and screen centre.

This reference point is used as the point about which the sweep rate is changed. I.e. the delay to the reflerence point is the same for all sweeps.

4 However, in order for this to work for all sweeps the sweep delay (p3) muct be set to be not less than the delay to the reference point of the slowest ramp for which the facility is required.

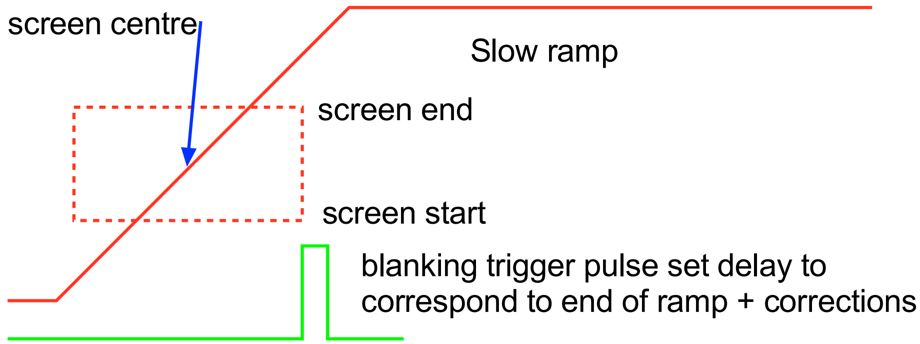
5 If the sweep delay (p3) is set smaller than that required for a slower sweep then the sweep data wil be placed as early as possible in the sweep record.

The effect of this is that for the faster sweeps the expansion about the relevant reference point wil be OK but for the slower ones the expansion point wil be earlier. This is similar to how scopes work when set to expand about centre and very slow sweeps are chosen.

6 The "expand about screen centre" and "screen edge" are left over fucntions from the RSCE projects and may not be useful/relevant to Scorpion-Z. In this case just use made 0 and it will behave like other streak cameras.

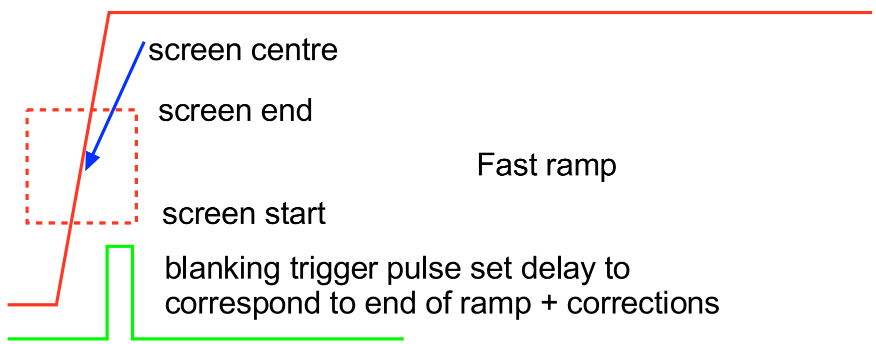
7 The blaking trigger delay is a completely separate function but is linked to the ramp data so that it is at a fixed time w.r.t. the sweep data, in particular the end of ramp time. Adjusting this delay will enable correction for long sweep cables. It is the difference in transit time over the sweep cables and the blanking trigger cable that may need correcting.

As stored in EEPROM



+ DATA

1 delay to screen centre
2 delay to screen start
3 optimum bias voltage for best linearity in operate mode
4 optimum bias for sync. mode
5 focus voltages

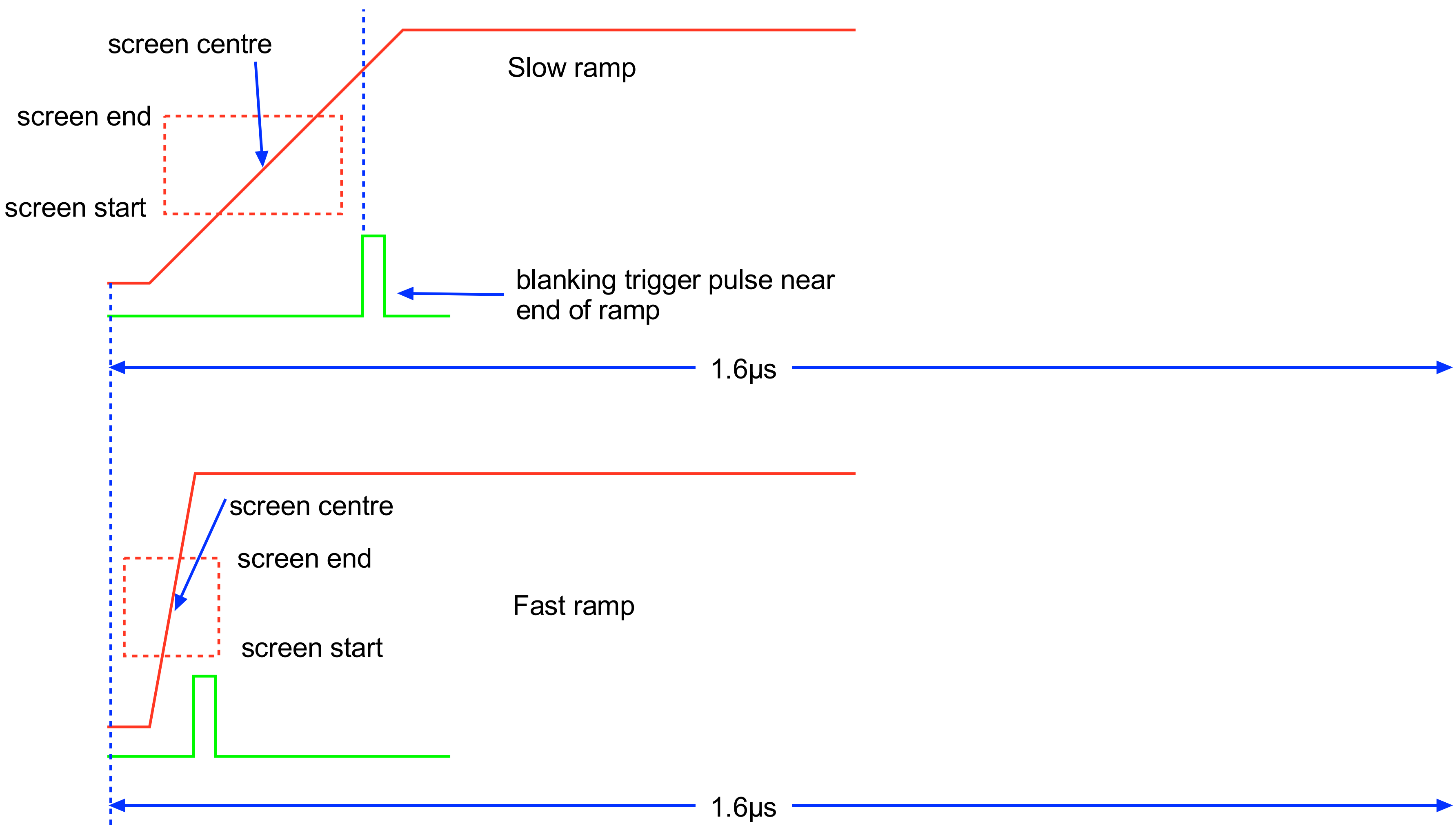


+ DATA

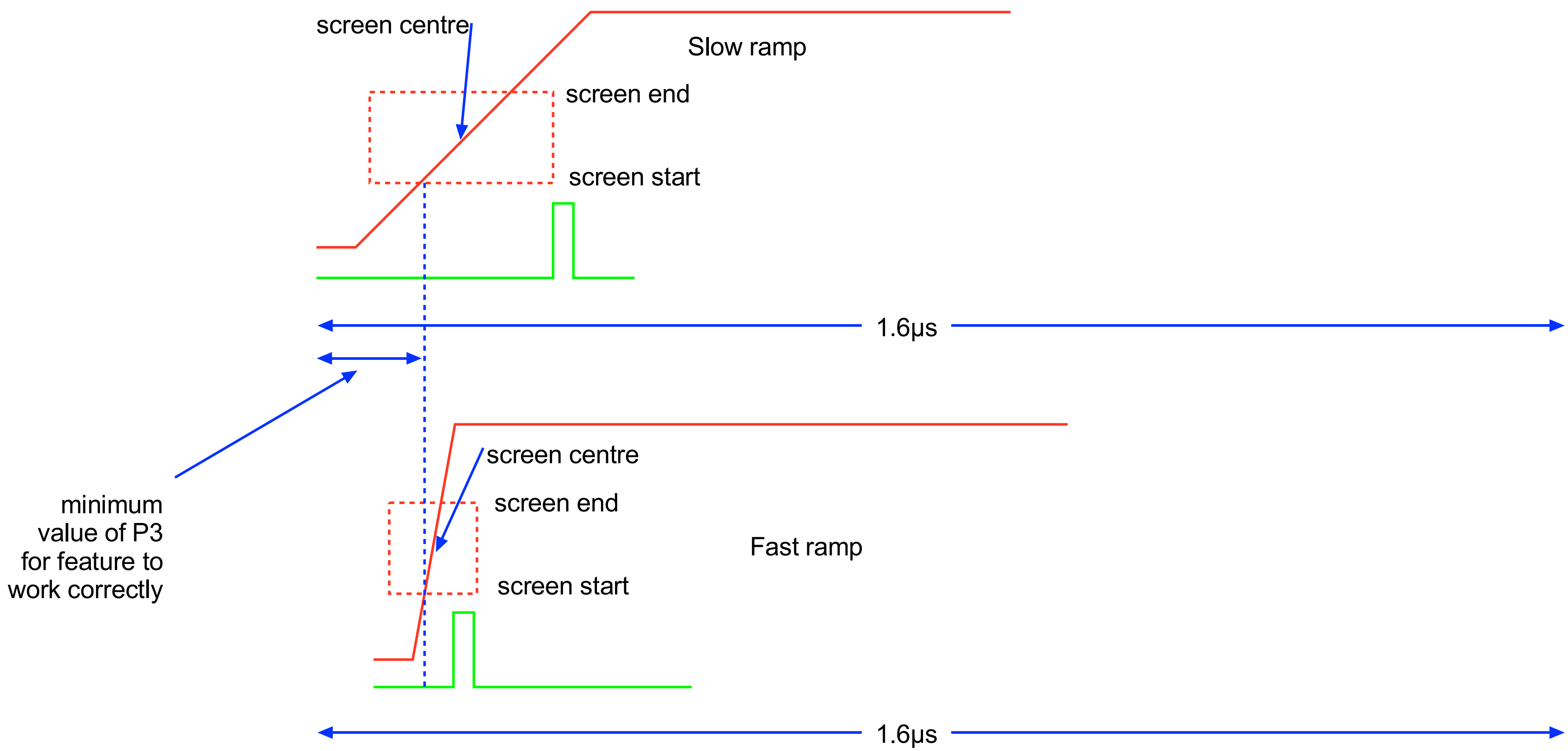
1 delay to screen centre
2 delay to screen start
3 optimum bias voltage for best linearity in operate mode
4 optimum bias for sync. mode
5 focus voltages

Note that the focus voltages have to be included as the deflection speed depends on the focus voltages. Hence the timings to screen edge and centre also depend on the focus voltages.

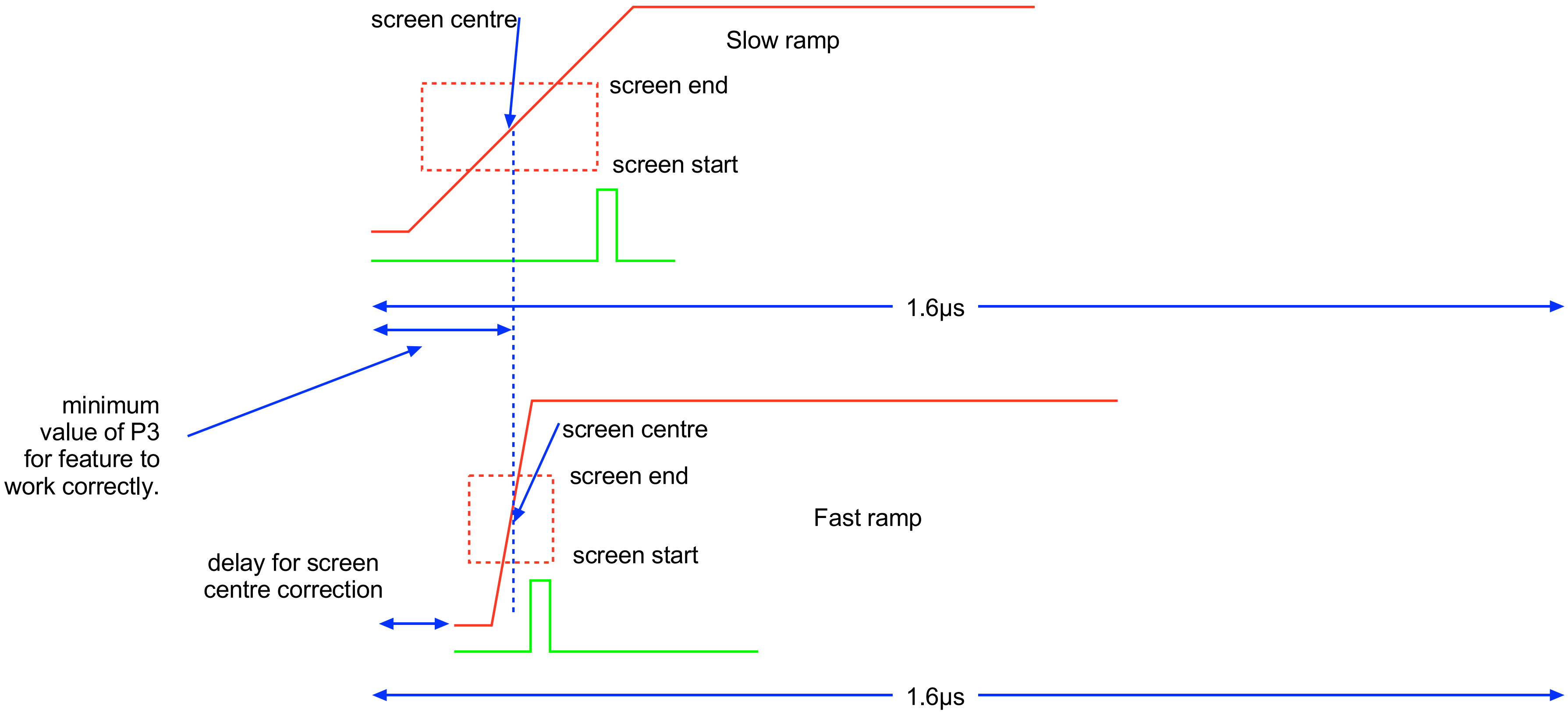
As stored in Sweep record in mode 0 (start of record) and delay (p3)=0



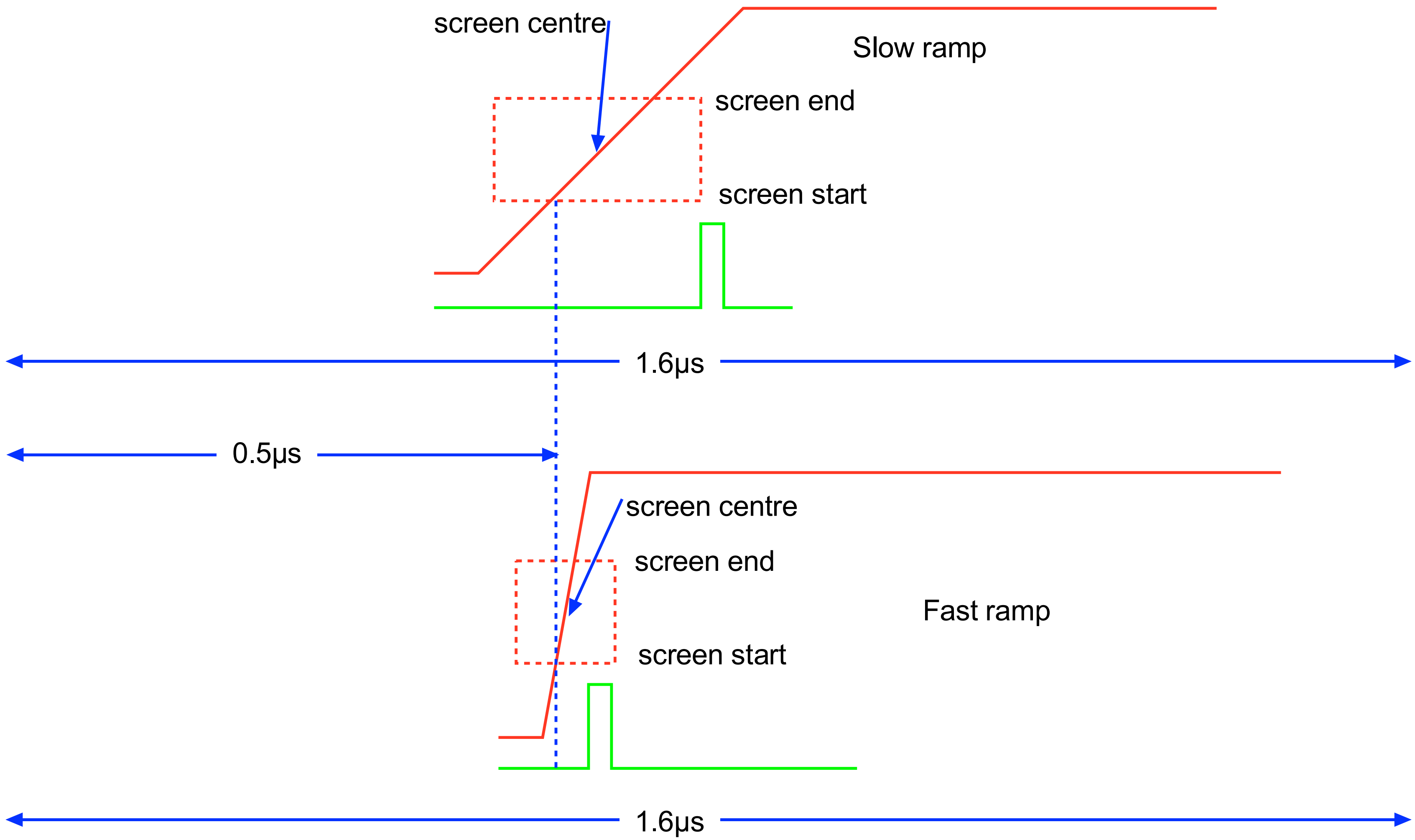
As stored in Sweep record in mode 1 (edge of detector) delay (p3) >



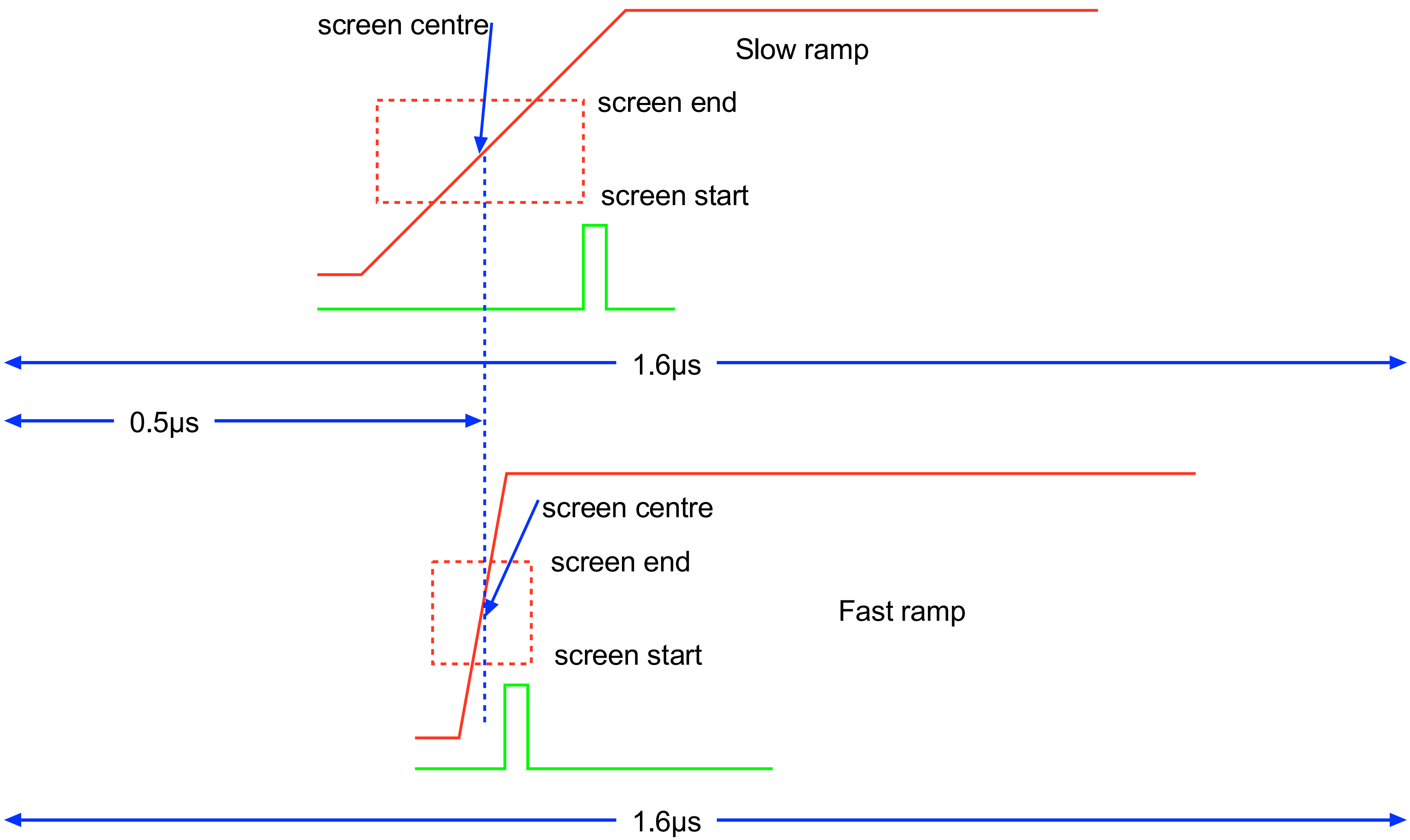
As stored in Sweep record in mode 2 (screen centre)



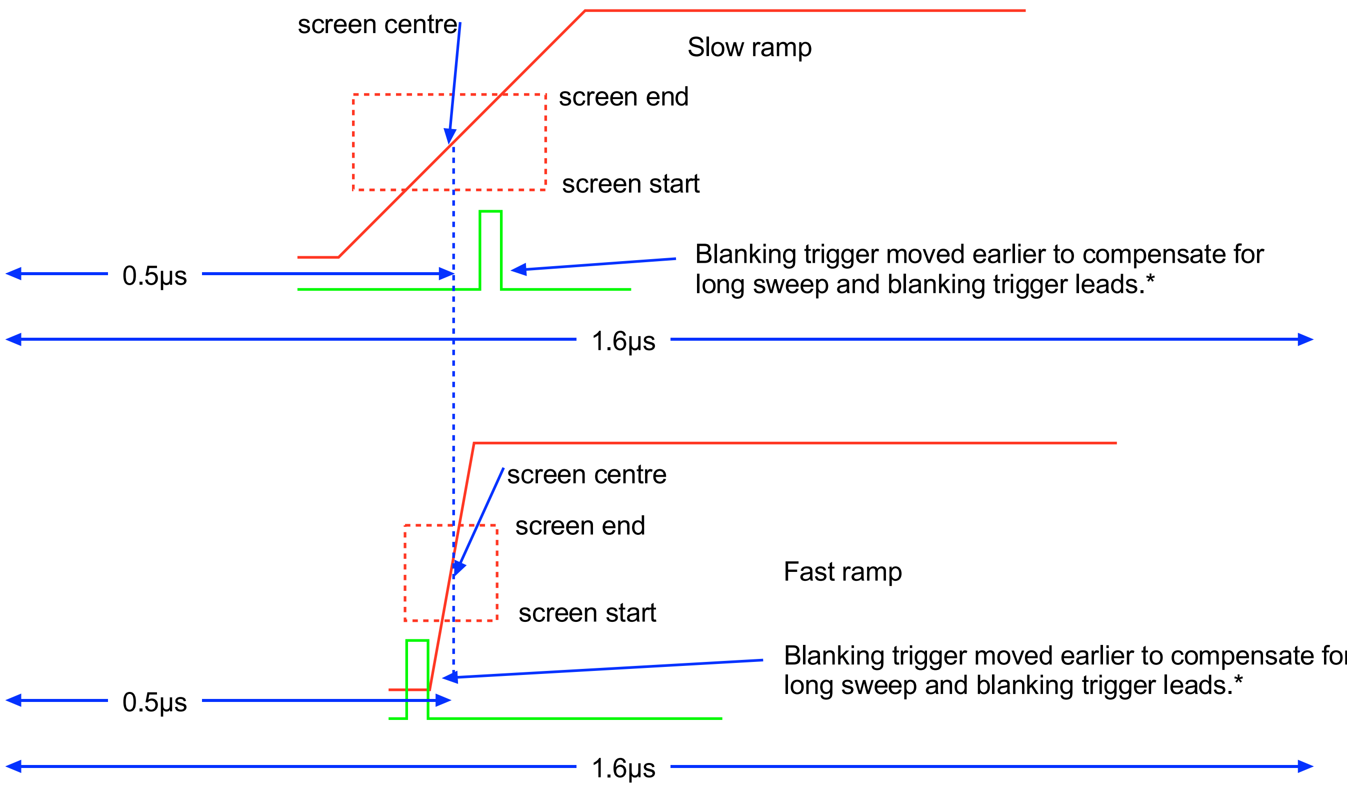
As stored in Sweep record in mode 1 (edge of detector) with delay set to 0.5μs



As stored in Sweep record in mode 2 (screen centre) with sweep delay set to 0.5μs



As stored in Sweep record in mode 2 (screen centre) with sweep delay set to 0.5μs also with blanking correction for long cables



* The propagation velocity of signals in the sweep leads is significantly faster than in the blanking trigger lead. So the longer the cables the earlier the blanking trigger has to be sent compared to the ramp so that they arrive with the blanking terigger at the end of theramp.

14.15 BEHAVIOUR CONTROLLED BY CALIBRATION VARIABLES

In the following several calibration variables may be changed. In all cases they are changed by the following procedure:

Type the following;

x variable_name ! cr

where x is the new value and there is a space before the "!" which represents "store"in Forth.

The new value is in volatile memory and should be saved to EEPROM by the appropriate ee! command.

14.15.1 FLAT FIELD RANGE

The flat field routines available under level 2 commands require the start and end bias voltages to be set. These are stored in two variables:

ffstartbias

ffendbias

The end bias must always be more positive than the start bias.

The factory default values are -700 and +700 volts respectively but these may not be suitable for all streak tubes.

The variables are changed in the usual way:

x ffstartbias ! cr

y ffendbias ! cr

Where x and y are the starting and ending bias voltages in volts (integers) in the range -800 to +800 Note that the step in the flat fielding sweep is 1 volt and the pause per step is in the range 1 to 1000 ms.

The values stored here are in volatile RAM. To save to EEPROM use the command

ee!tc_cal cr

Note that the write protect button will need depressing for this.

14.15.2 CURRENT TRIP BEHAVIOUR

There is a current trip on each of the HV outputs. The spare output current trip is only active when the "USE SPARE" link is fitted in the HV unit. (Scorpion-Z does not have a spare output.) The same trip level is applied to all outputs and is in arbitrary units 0 though 4095. The trip is enabled or disabled according to the variable

Uitrip_en

It takes values, True (-1) = enable, False (0) = disable.

There are two different levels applied, these are defined by the variables

itripl_startup
itripl_steady

itripl_startup is the value loaded for the soft start of the HV module and will be the higher of the two values.

After soft start has finished there is a programmable delay before the lower value **itripl_steady** is loaded and used. A delay is necessary as it takes time for voltages in the Gate module to stabilise.

The delay is defined in milliseconds by the variable

Tsettle

It is unlikely that they will need changing. They can be saved to EEPROM with **ee!tc_cal**, this needs the write protect button depressed.

Uitrip_en and Tsettle are in the control unit calibrationvariables and use **ee!tc_cal**. **itripl_statup** and **itripl_steady** are in the HV calibration variables and use ee!hc_cal. Both of these need the write protect button depressed to overwrite the data.

14.16 SLOW SCAN FOR FLAT FIELDING

In order to do a flat field calibration of the sensor Scorpion-Z has a slow scan mode, see "Name scnz_flatarm" on page 61 and subsequent commands.

The sequence of operations for a slow scan is (the text on the left, in red, is what is entered +cr but it is not echoed on normal mode):

safe		Make sure camera is in Safe mode
0 0 01 0 0 sz!sysc	{0 0 1 0 0 sz!sysc;0 }	Set camera mode to zero = flat field/slow scan Trigger inputs - electrical Trigger mode 1 - may not be necessary
sz_rqsb	{sz_rqsb;0 }	Request standby mode
sz_rqen	{sz_rqen;0 }	Request energise - turns on focus voltages
sz@stat	{sz@stat;**1** ;2 ;7 ;0 ;0 ;0 ;0 ;0 }	Check machine state is energised (currently not), it takes around 10 seconds for the voltages to come up.
sz@stat	{sz@stat;**1** ;2 ;7 ;0 ;0 ;0 ;0 ;0 }	re-check
sz@stat	{sz@stat;**2** ;2 ;12 ;0 ;0 ;0 ;0 ;0}	re-check - now energised.
5 sz_farm	{5 sz_farm;0 }	Arm slow scan - beam moves off screen to start position. Scan rate will be 5 ms per step
sz_ftrg;700	{sz_ftrg;700 ;0 }	Trigger slow scan - there is no response until the command completes. The bias remains at 700 volts on the positive ramp at the end of the scan (-700 on the negative ramp).

14.17 FULL-FRAME GATING, BLANKETY BLANK

This mode, described at 10.5 on page 31, can be enabled in focus mode with the Scorpion-Z in the ENERGIZE state.

scnz_+bblank - start Bblank operation
scnz_-bblank - stop Bblank operation

Both these commands return a flag on the stack,

0 = successful
-1 = unable to execute

scnz_?bblank - query state of Bblank state

14.18 SUMMARY OF COMMANDS FOR SAVING TO EEPROM

There are several commands for saving different parts of the overall calibration and set up to the EEPROMs.

The commands can only be executed in debug mode and all take the form:

ee!xxxx where xxxx defines which group of parameters is to be saved. Some have a preceding parameter, i.e. **n ee!xxx**

14.18.1 LIST OF ee! COMMANDS

To execute a write protect save the button on the rear panel should be depressed while executing the command.

ee!hv_cal	write protected
ee!tc_cal	write protected
ee!sw_cal	write protected.
ee!user	NOT write protected
n ee!swpctrl	NOT write protected
n ee!wfm	NOT write protected
n ee!sweep	NOT write protected

ee!hv_cal HV calibration data. We recommend not changing as it could result in damage to components.

ee!tc_cal For saving calibration data

ee!sw_cal Saves the sweep module calibration

ee!user This is useful for saving a set up as default that otherwise would require the execution of the control commands for the system and the delay (scnz!sysctrl & scnz!delctrl).

It saves the following parameters:

U_intmode	0 = allways off
	1 = pulsed mcp
	2 = pulsed phosphor
	3 = pulsed both
	4 = DC on
UVmcp	MCP voltage
UVphos	Phosphor voltage
Utrigmode	0 = all triggers only enabled in armed state
	1 = all triggers enabled in standby and armed
Utrigsource	0 = electrical trigger
	-1 = opto trigger
Ucammode	0 = focus/flatfield
	1 = repetitive
	2 = single shot
	3 = repetitive sync
	4 = single shot sync
Usweep#	0 through 15
Udelmode	0 = delay record start
	1 = delay screen start
	2 = delay screen centre

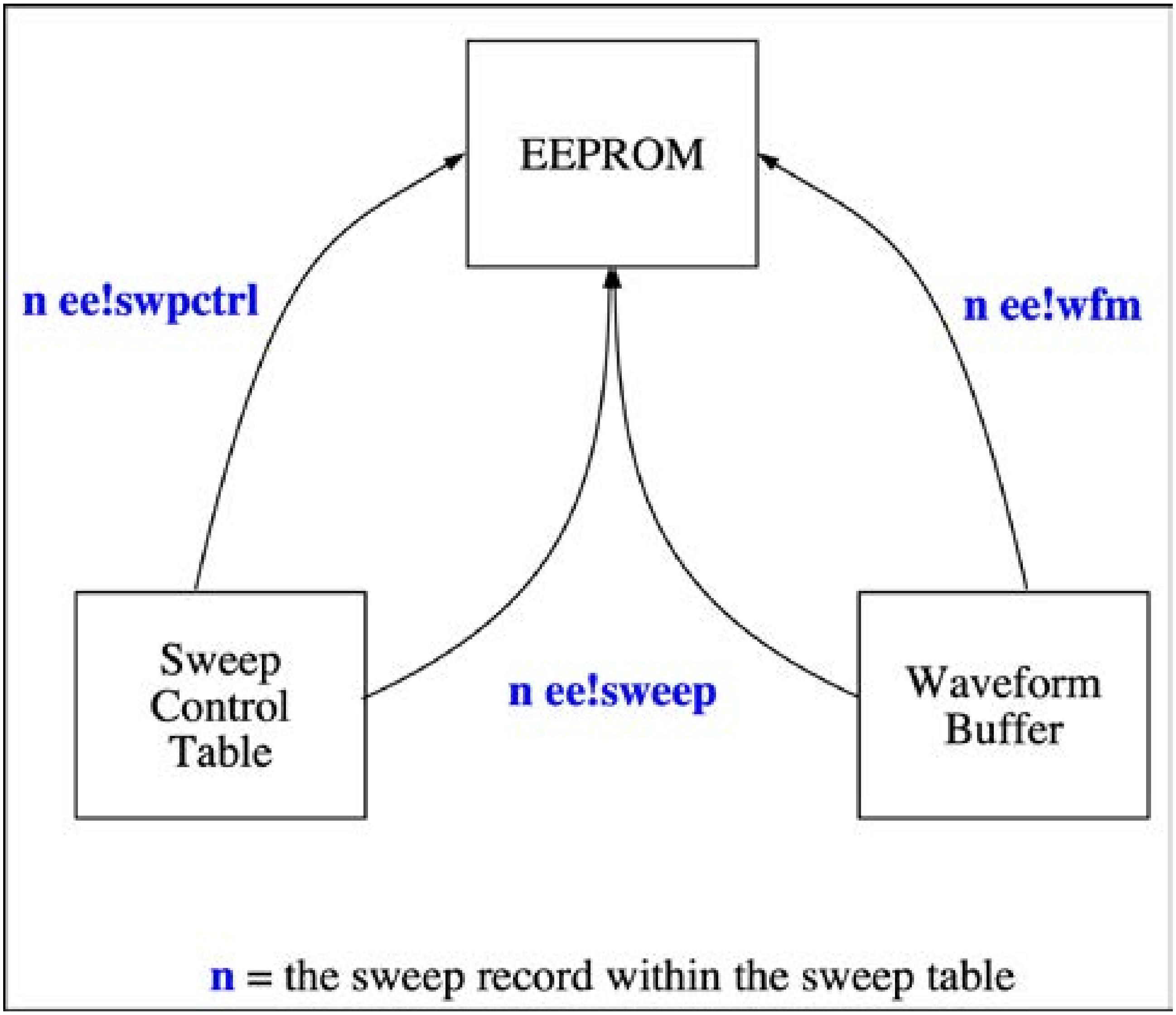


Figure 28 The commands for saving the 2 parts of a sweep record to the EEPROM

Udelay	delay in ps
n ee!swpctrl	Saves all the current sweep control table parameters to entry n (0 through 15) in the sweep table
n ee!wfm	saves the contents of the current waveform buffer to entry n (0 through 15) in the sweep table
n ee!sweep	saves all the current sweep data to entry n (0 through 15) in the sweep table i.e. it does **n ee!swpctrl** and **n ee!wfm**

These three commands are show in Figure 28 on page 84

15. MAINTENANCE, REPAIR AND REFURBISHMENT

The tube may require occasional cleaning if the x-ray source deposits significant debris on the tube. Solvent cleaners are recommended. Pump down times after such cleaning may take somewhat longer.

All parts of the tube (as supplied) are easily replaceable although damage to the 4 high voltage feeds will require some careful work.

We recommend that no repair, other than the replacement of the photocathode and/or extraction grid (mesh), of the tube be carried out with the fiducial fibre optic in place.

Repair or replacement of the wiring to the extraction grid (mesh) and photocathode should be done in the knowledge that the blanking circuit is vulnerable to breakdown at certain points, see Figure 13 on page 32. Insulation should not be compromised at these vulnerable points.

Always take care removing the two connector boxes as a failure of the vacuum feed through cable (see Figure 7 on page 21, is a significant repair.

16. TUBE PERFORMANCE IN STATIC TESTING

The streak tube was focussed using UV light onto a gold on quartz resolution photocathode. The photocathode is specifically designed to help focus this tube and has been designed by a collaboration of LLNL and Kentech staff. The photocathodes are manufactured by Luxel in Washington State.

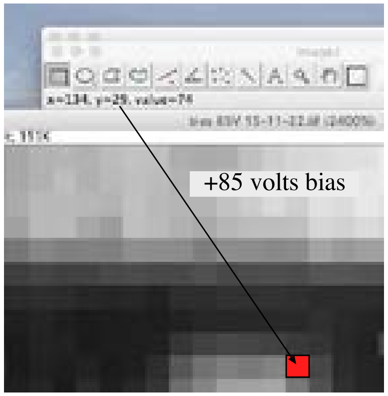
Focussing was first carried out using a Kentech phosphor. A fibre optically coupled CCD camera was used to record the images. However, this only had an 18 mm FO input. Further the FO input was a taper to match an 18mm input format to a smaller CCD chip. Consequently the sensitivity near the edges of the input face is reduced as the fibre are longer and more curved. The illumination of the photocathode is also quite non uniform as it is necessary to mount the UV lamp close to the photocathode to get enough signal.

The images are, however, adequate to check the focus and the magnification as a function of position along the length of the photocathode.

Focussing was then carried out using the supplied Max module. There was no obvious difference in the optimum focus voltages. The axial position of the MCP input face is 0.76mm off the phosphor detection surface according to the 3D modelling.

The spatial resolution achieved with the max module is significantly worse than with a simple phosphor.

Some results are shown in Figure 29 on page 88 and Figure 30 on page 89.

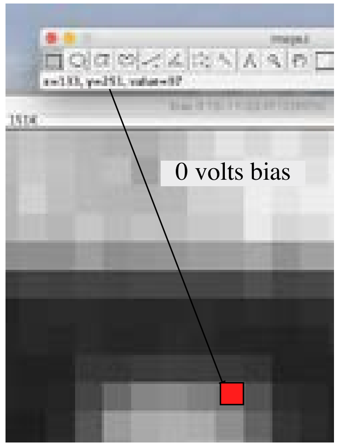


deflection to left

251-29=222 two binned pixels = 85 volts
444 pixels = ±85 volts
(i.e. both plates driven to 85 volts)
94.538 pixels/mm from calibration of sensor (15-11-22)
Gives 444/94.538/85 mm/volt
Gives 18.098 volts/mm

Tube focus conditions:

```
Vpc =     -14.997 kV
Vmesh =   -10.962 kV
VL1 =     -11.404 kV
VL3 =      -9.923 kV
Vcor =     -0.568 kV
```

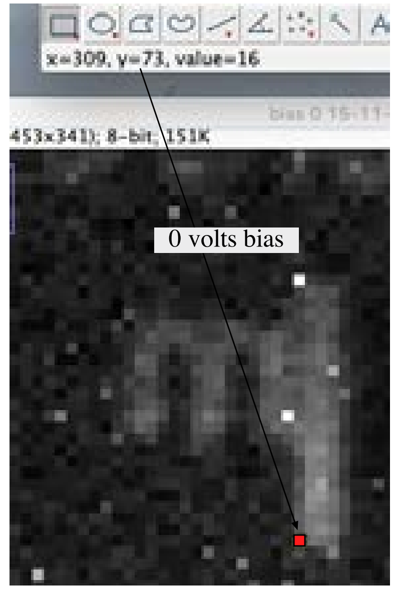


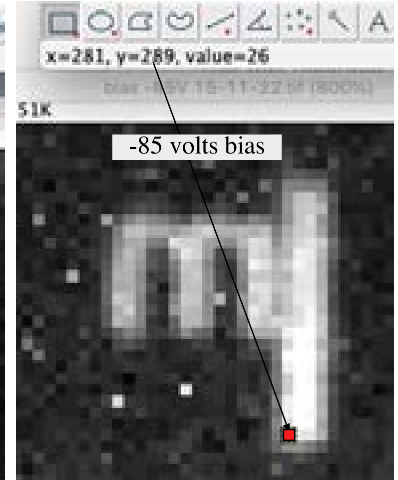
deflection to right

289-73=216 two binned pixels = 85 volts
432 pixels = ±85 volts
(i.e. both plates driven to 85 volts)
94.538 pixels/mm from calibration of sensor (15-11-22)
Gives 432/94.538/85 mm/volt
Gives 18.601 volts/mm

Tube focus conditions:

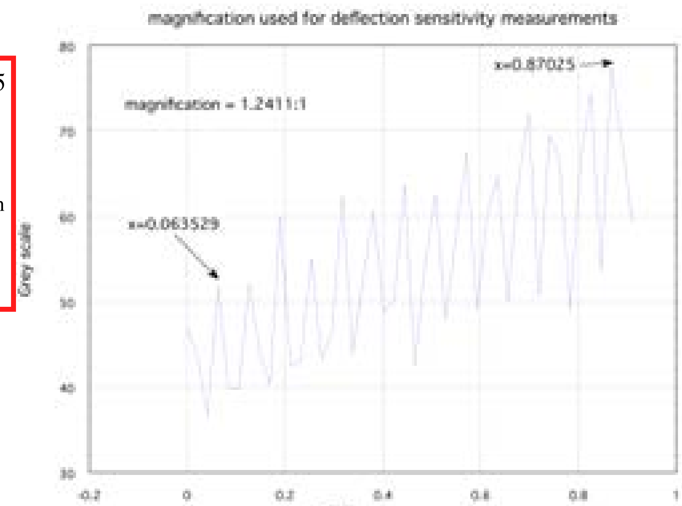
```
Vpc =     -14.997 kV
Vmesh =   -10.962 kV
VL1 =     -11.404 kV
VL3 =      -9.923 kV
Vcor =     -0.568 kV
```





Average deflection = 18.35 volts/mm
with
magnification = 1.2411:1

Total volts needed for deflection across a 38 mm window = ± 697.3 volts.
I.e. 1,394.6 volts across the plates.



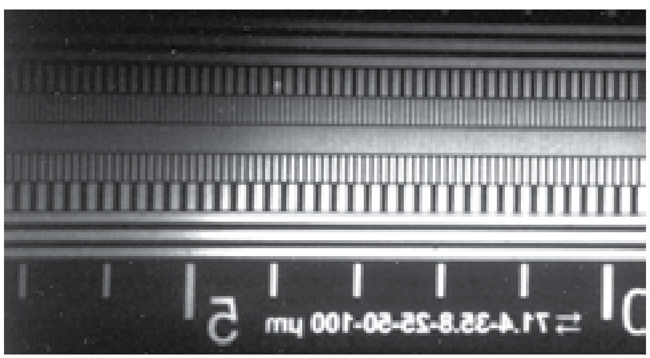
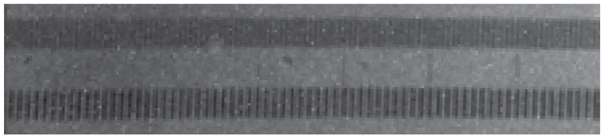
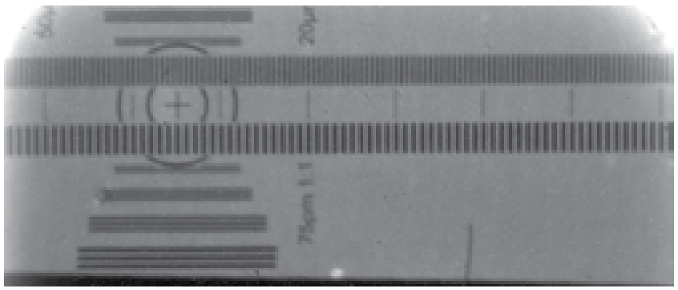
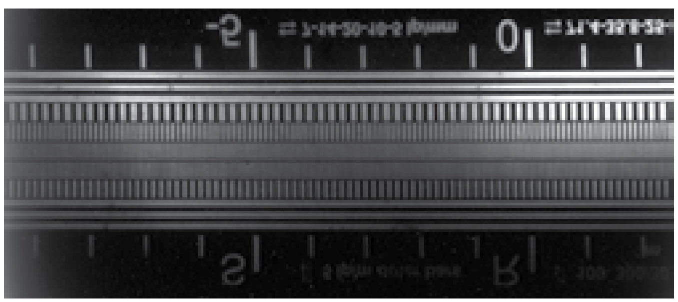
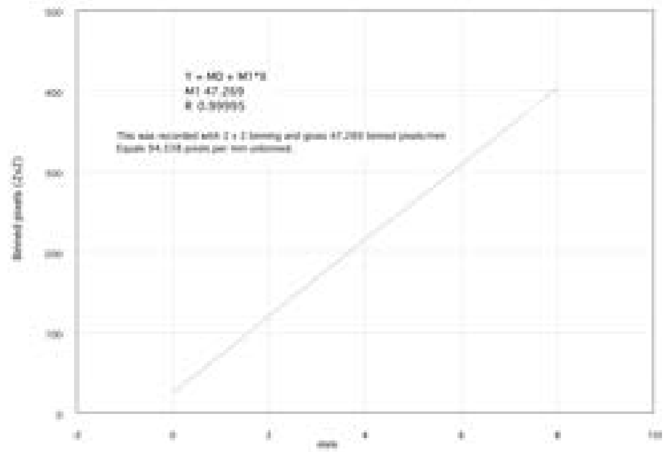


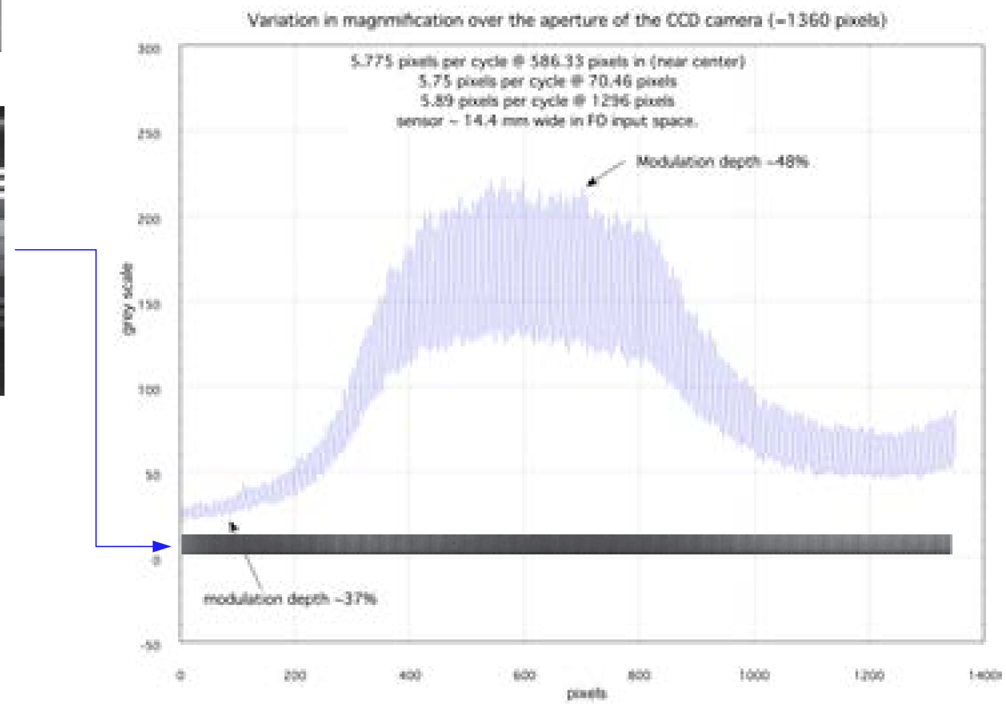
Figure 29   Data for the measurement of deflection sensitivity.











Variation of the magnification along the slit direction with position over a 13 mm range. 5.75 pixels per cycle to 5.89 pixels per cycle.

Figure 30 Variation in magnification along the slit.

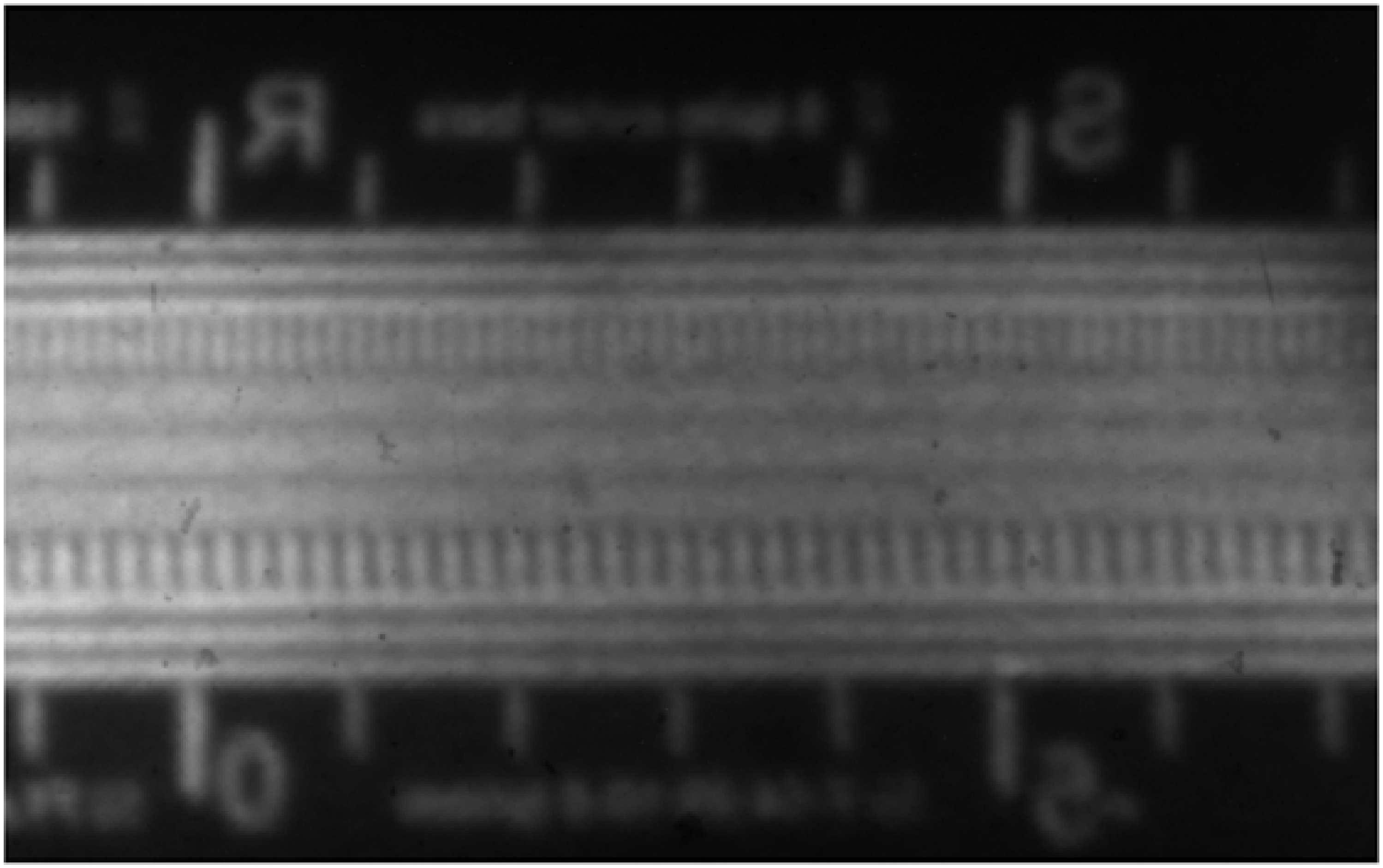


Figure 31   Focussing with the Max module.

17. SWEEP DATA

One the following 6 pages are shown 11 stored ramps numbered 0 through 10. The scope traces also show the calculated limits of the sweep range on the tube. These limits are obtained by measuring the tube deflection sensitivity and assuming a 39 mm active window.

During ramp setup the voltage about witch the ramp is most linear is measured and this is used to set the bias voltage for the particular ramp. Then the time to screen centre is measured so that the expand about screen centre function can be implemented.

The ramp data, the bias voltage, the focus voltages and the delays to screen edge and screen centre are stored in a sweep record.

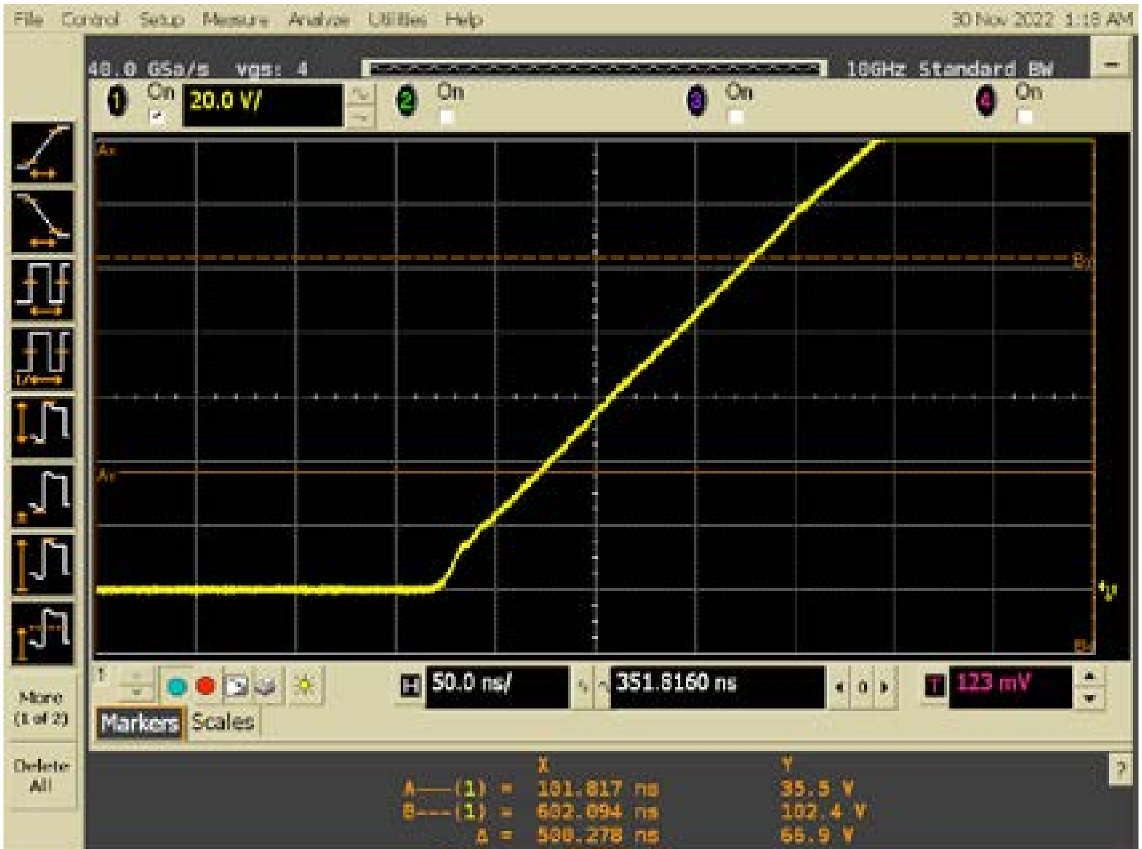


Figure 32 Sweep 0

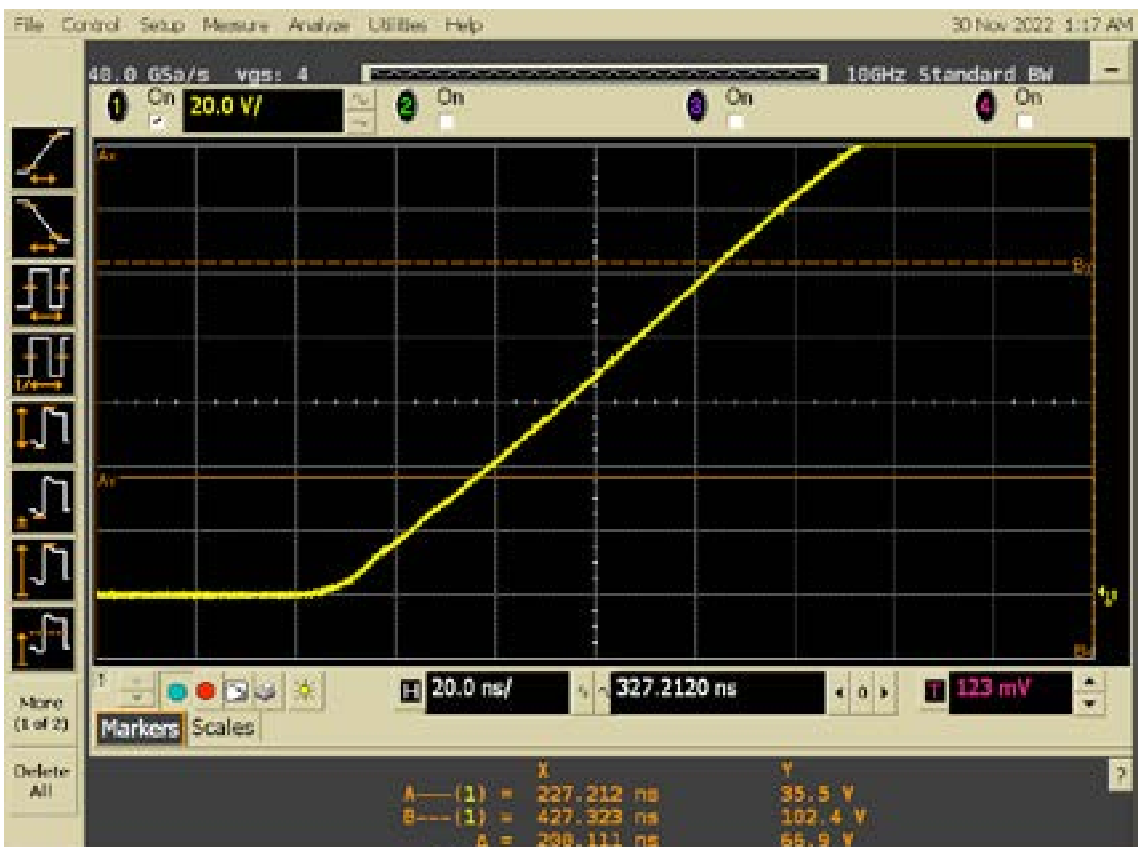


Figure 33 Sweep 1

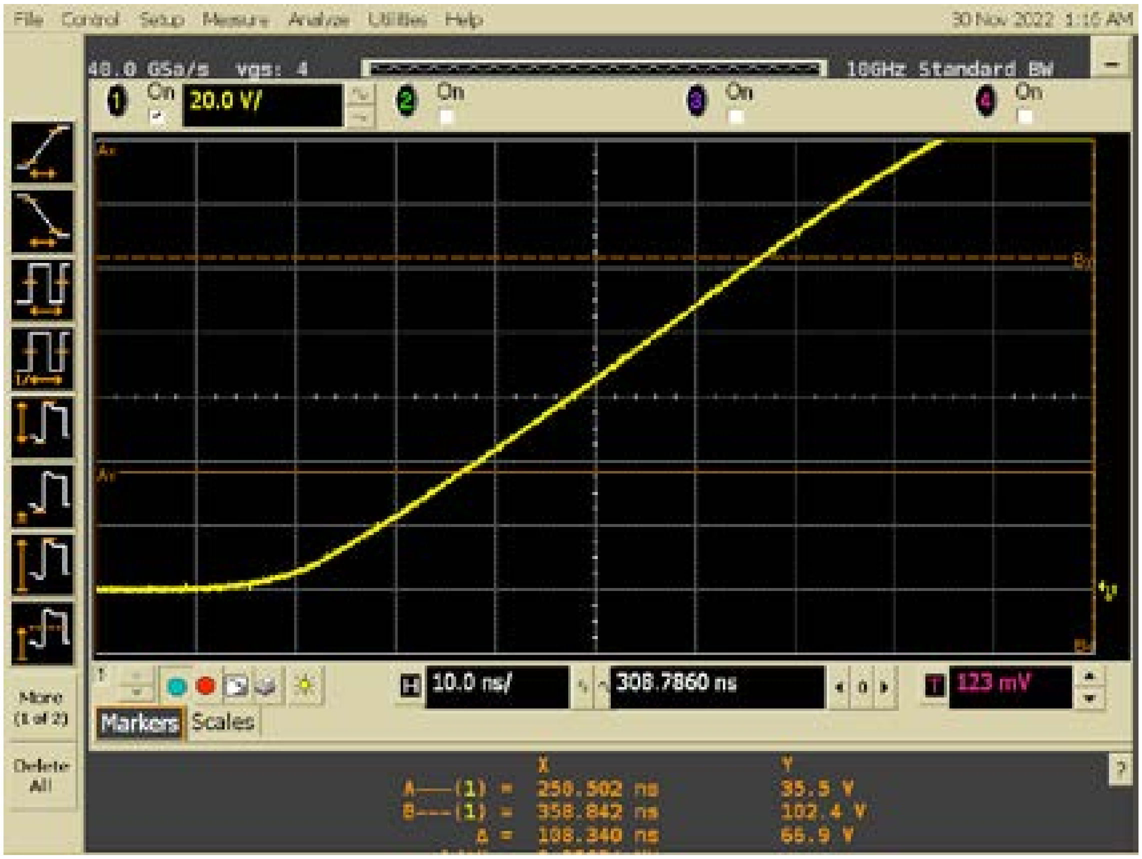


Figure 34 Sweep 2

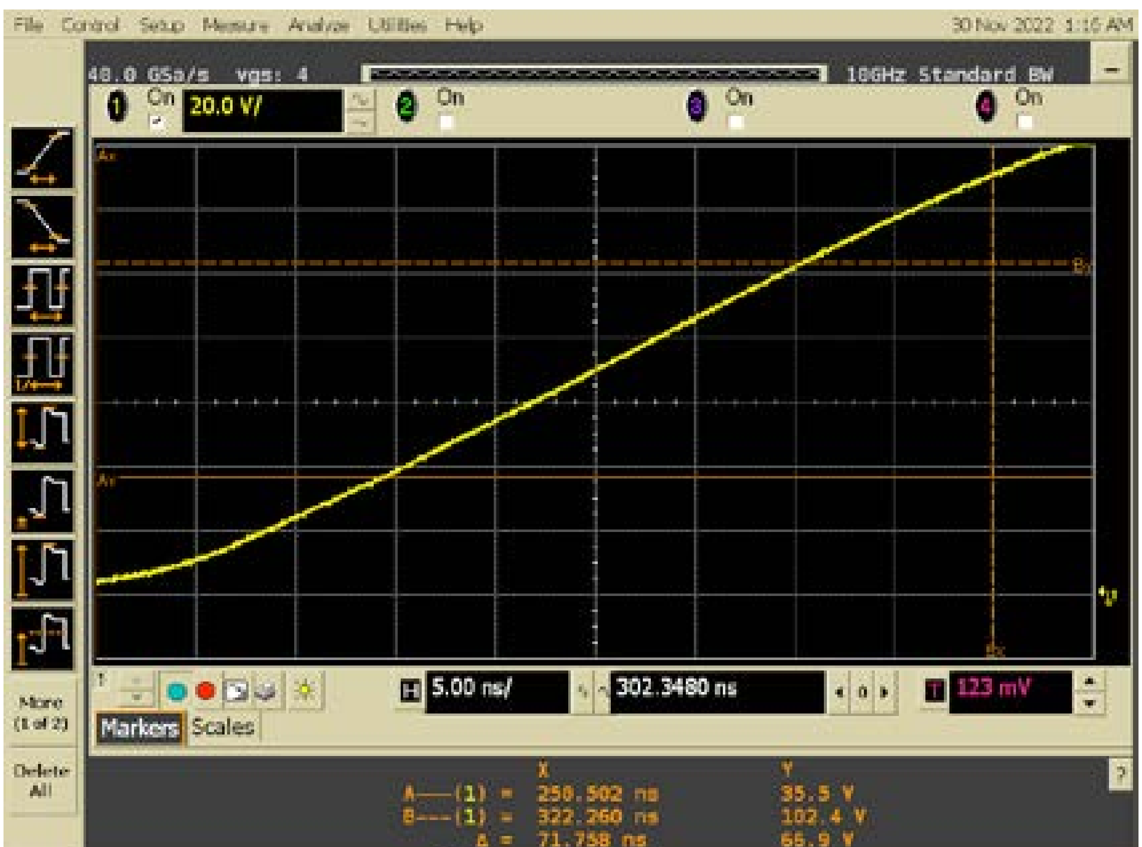


Figure 35 Sweep 3

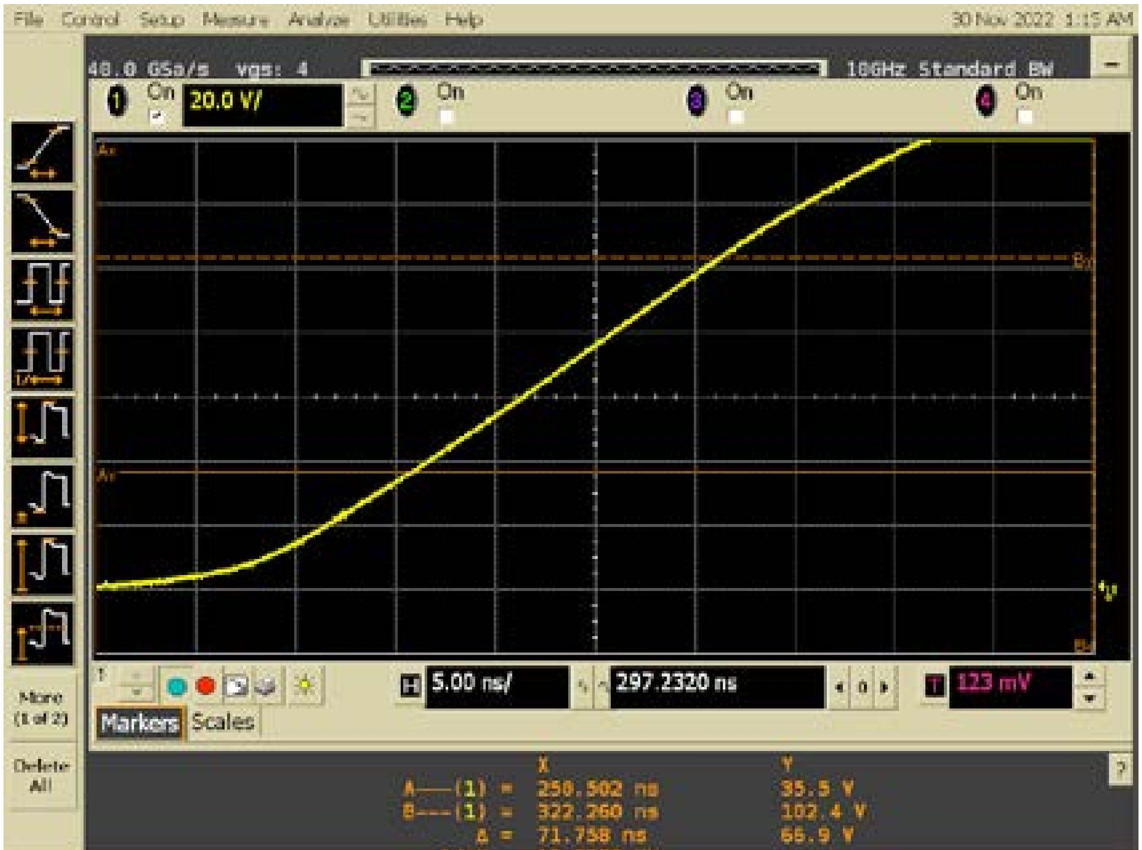


Figure 36 Sweep 4

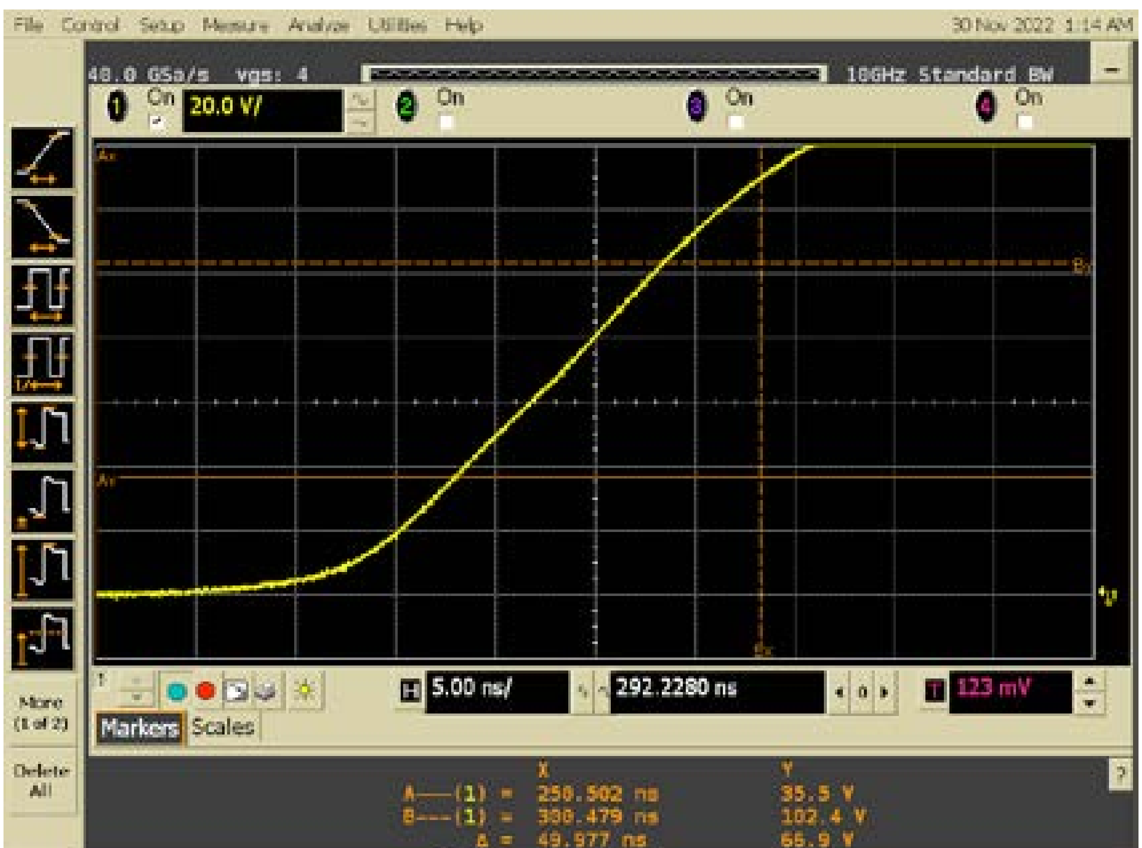


Figure 37 Sweep 5

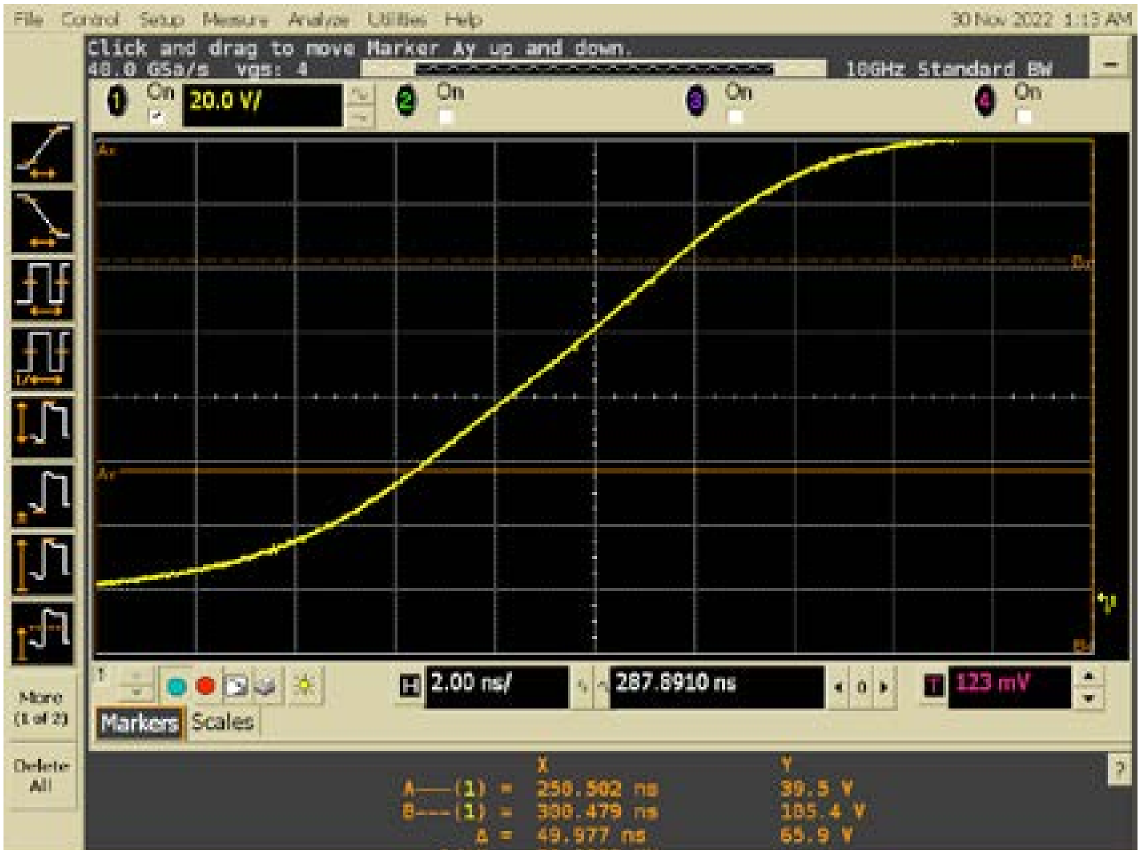


Figure 38 Sweep 6

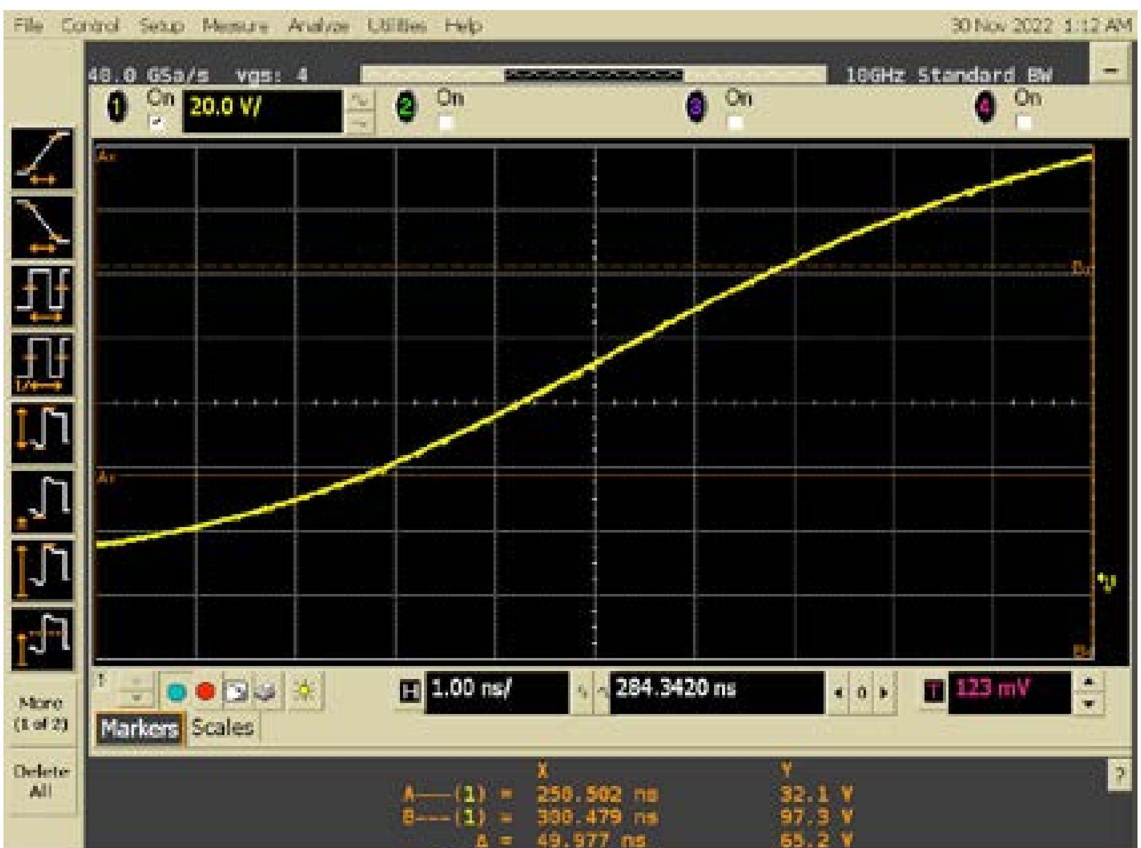


Figure 39 Sweep 7

Figure 40 Sweep 8

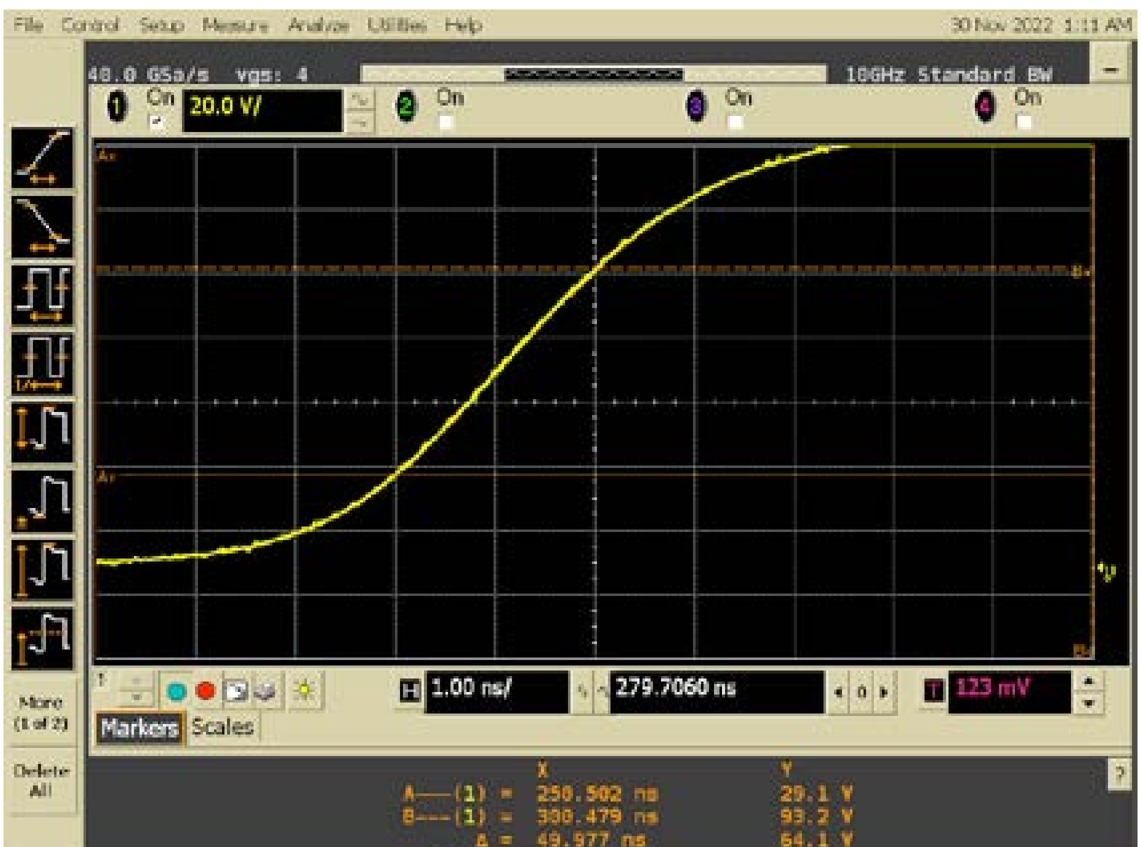


Figure 41 Sweep 9

Figure 42 Sweep 10

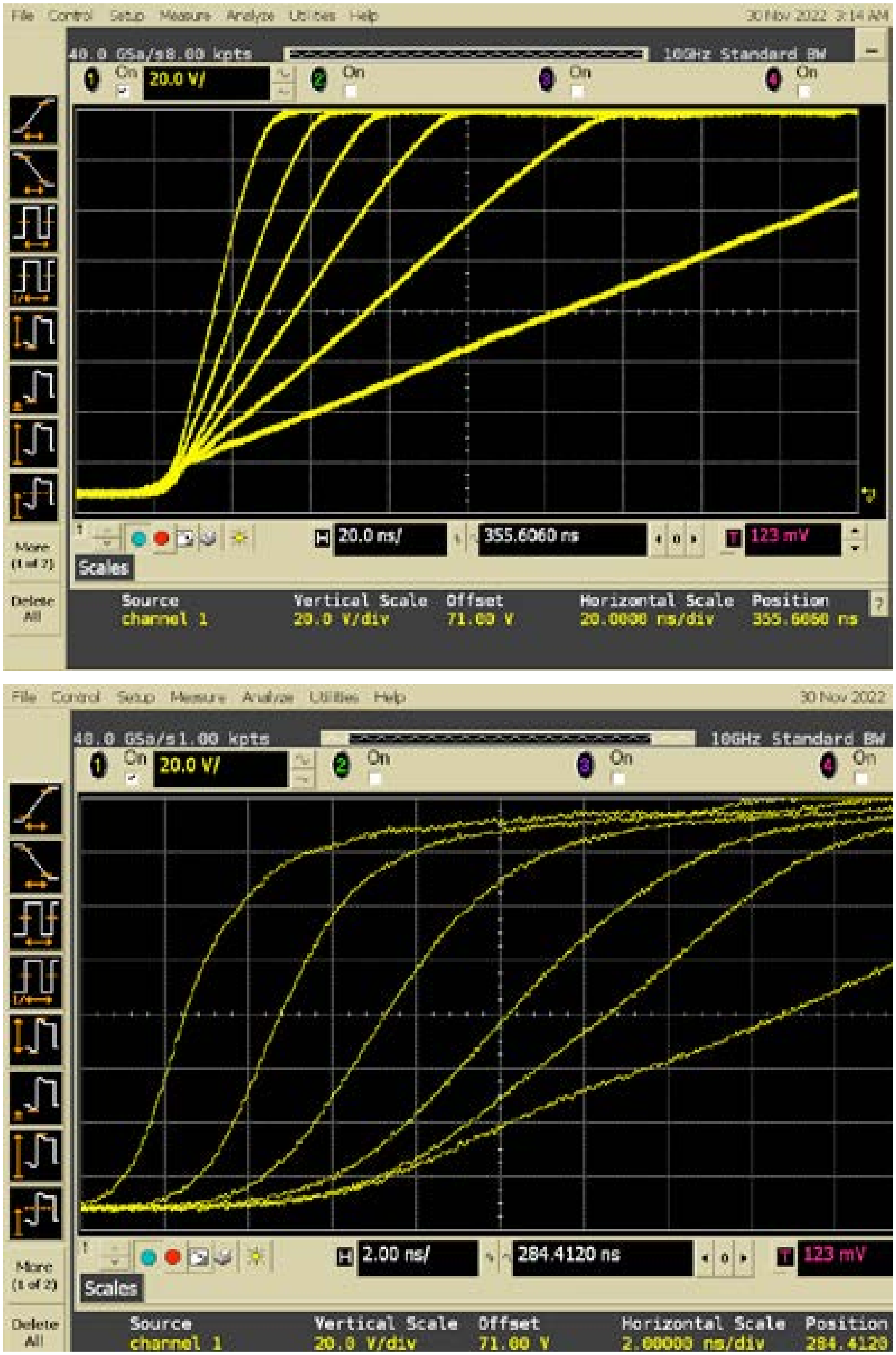


Figure 43 Top is sweeps 0 through 5, lower is sweeps 5 through 10

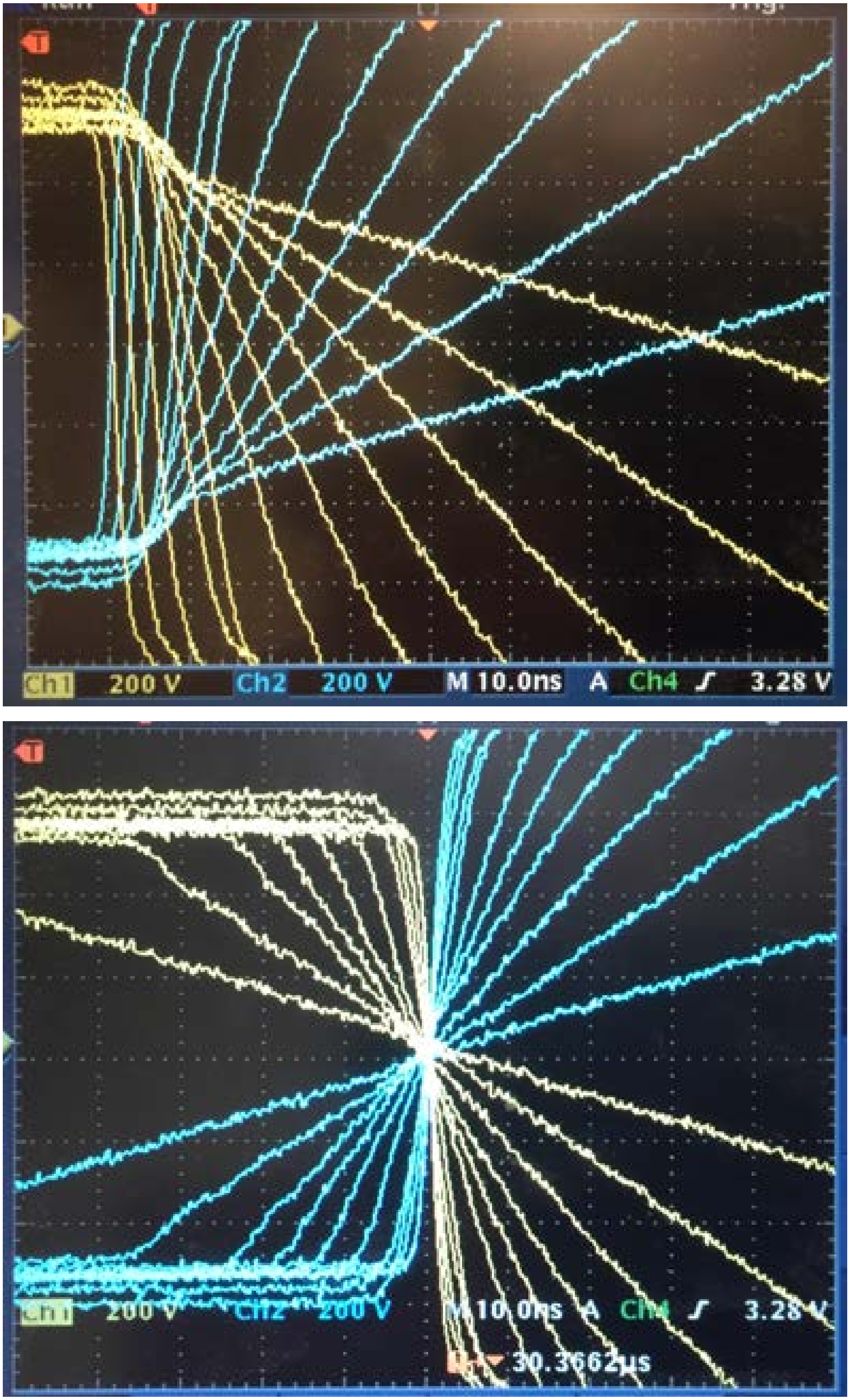


Figure 44 All sweeps. The lower figure is with delay about centre active

18. PACKING LIST

The numbers refer to Kentech part numbers.

1 off 0010-0159 Scorpion-Z Streak camera for the Z machine comprising of the following:

Electronics package

1 off 0060-0154 Scorpion-Z rack unit (serial No. J2104091-1) fitted with:
0060-0169 Control module for Scorpion Rack controller
0060-0170 Sweep module for Scorpion Rack controller
0060-0171 Max module for Scorpion Rack controller
0060-0172 HV module for Scorpion Rack controller

Interface boxes

2 off 0060-0155 Scorpion-Z interface box (serial No. J2104091-3 & J2104091-4)

Cables

4 off 0070-0161-002 Scorpion-Z HV leads interface box to tube
4 off 0070-0161-004 Scorpion-Z HV leads rack to interface box

1 off 0070-0162-002 Scorpion-Z corrector leads rack to interface box
1 off 0070-0162-004 Scorpion-Z corrector leads interface box to tube

1 off 0070-0163-002 Scorpion-Z blanking trigger lead rack to interface box
1 off 0070-0163-004 Scorpion-Z blanking trigger lead interface box to tube

1 off 0070-0164-005 Scorpion-Z sweep leads interface box to tube positive
1 off 0070-0164-006 Scorpion-Z sweep leads interface box to tube negative

1 off 0070-0165-005 Scorpion-Z sweep monitor leads tube to interface box positive
1 off 0070-0165-006 Scorpion-Z sweep monitor leads tube to interface box negative

1 off 0070-0166-002 Scorpion-Z phosphor leads rack to interface box
1 off 0070-0166-004 Scorpion-Z phosphor leads interface box to tube (max module)

1 off 0070-0166-007 Scorpion-Z phosphor return leads interface box to rack
1 off 0070-0166-009 Scorpion-Z phosphor return leads tube (max module) to interface box

4 off 0070-0167-002 Scorpion-Z MCP leads rack to interface box
4 off 0070-0167-005 Scorpion-Z MCP leads interface box to tube (max module)

1 off 0070-0168 Scorpion-Z HV enabled lead
1 off 0070-0169 Scorpion-Z interlock lead

1 off US style power lead - IEC

Streak Tube

1 off 0030-0252 HDISC Tube later than J2012101,

special options:
SMA sweep monitor variant (serial No. J2104091--2)
fitted with free issued LLNL photocathode pack

Miscellaneous

1 off CD with manual and test data