Kentech Instruments Ltd.

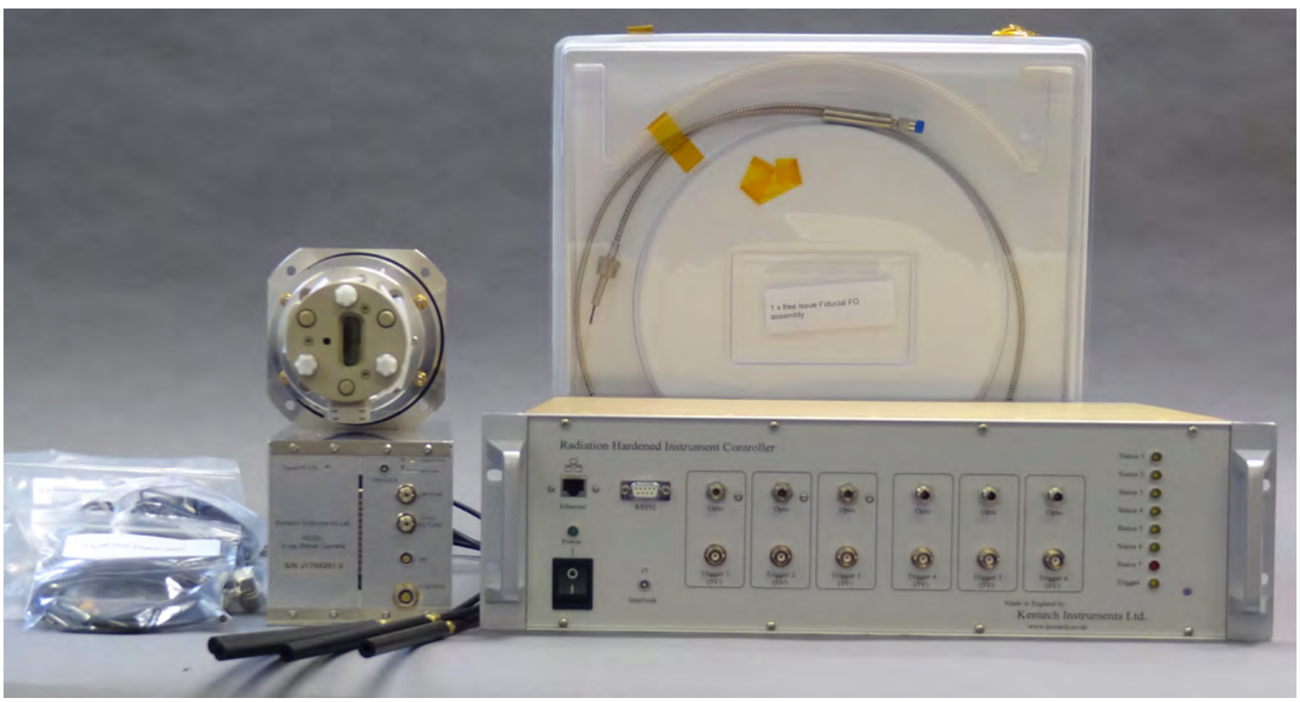
Hardened X-Ray Streak Camera
HDISC

Unit 1 S/N J17xxxxx

Version 1

Last Modified on 2020-02-11 17:13

PLEASE READ THIS MANUAL CAREFULLY BEFORE USING THE CAMERA.



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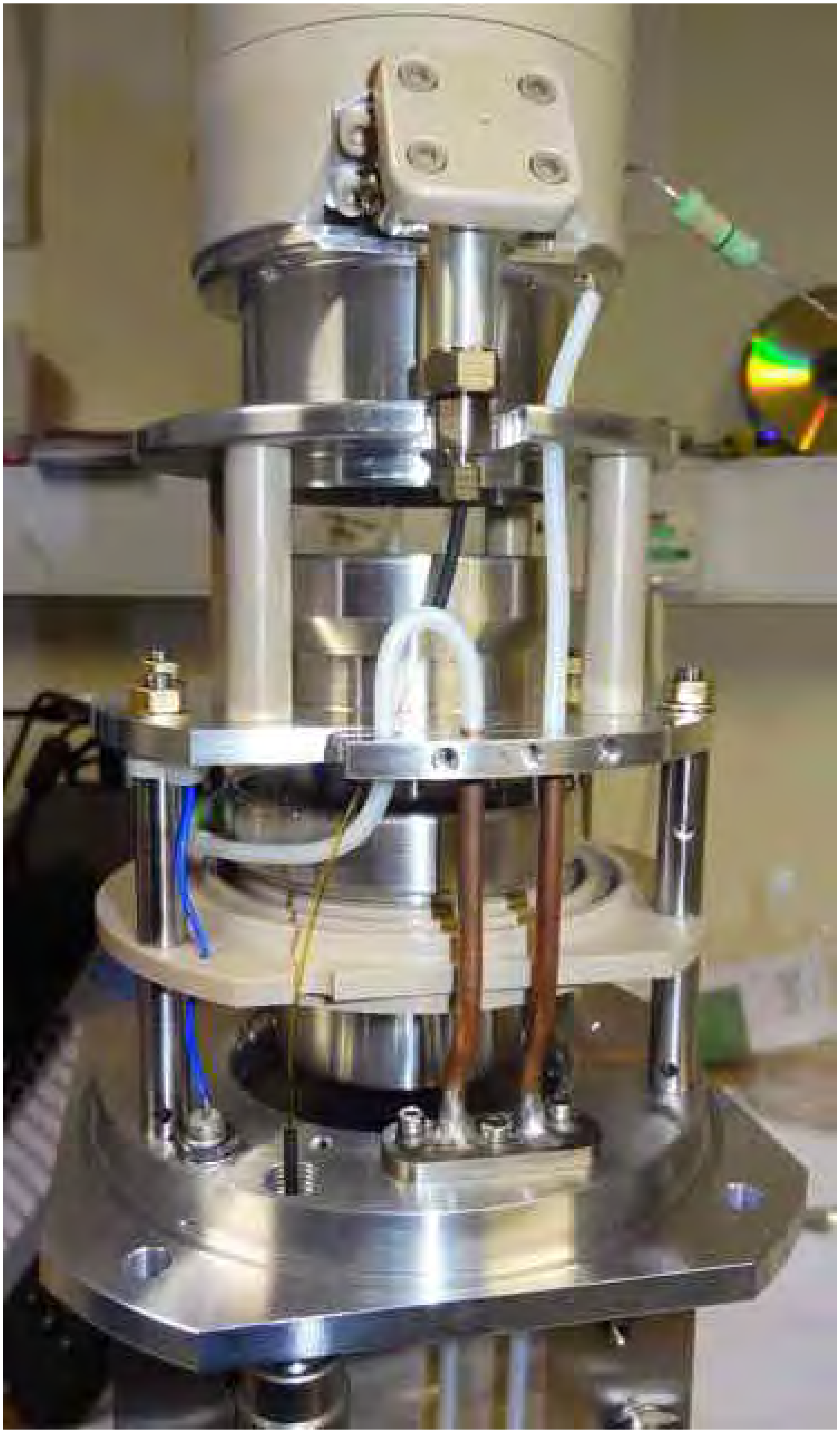

Figure 1 The tube with the FO fiducial fitted.

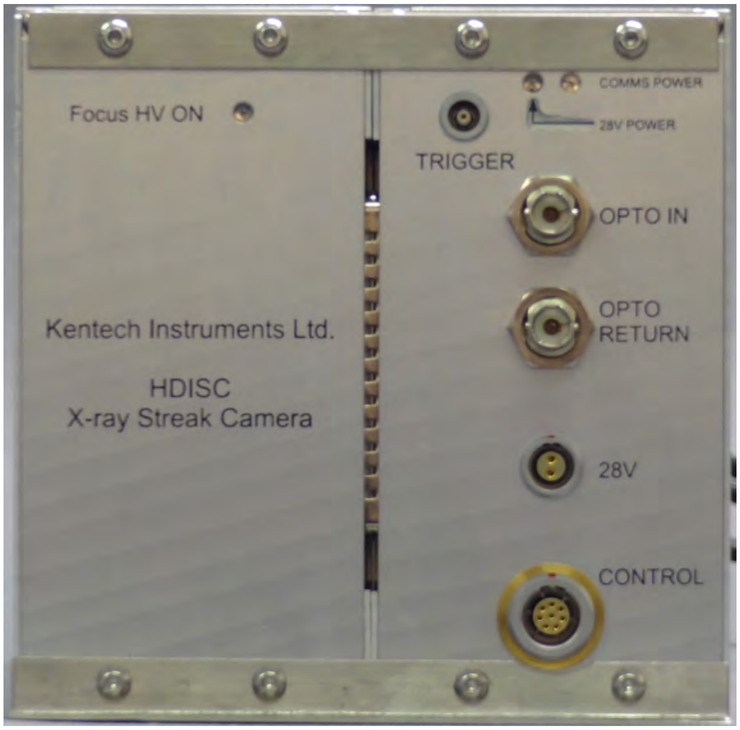

Figure 2 `The rear panel of the head unit.
The focus “ON” led indicates that the high voltages are on. Whilst the 28 volt power is for powering the high voltage supplies.
The comms power indicates that the power for setting relays is on.

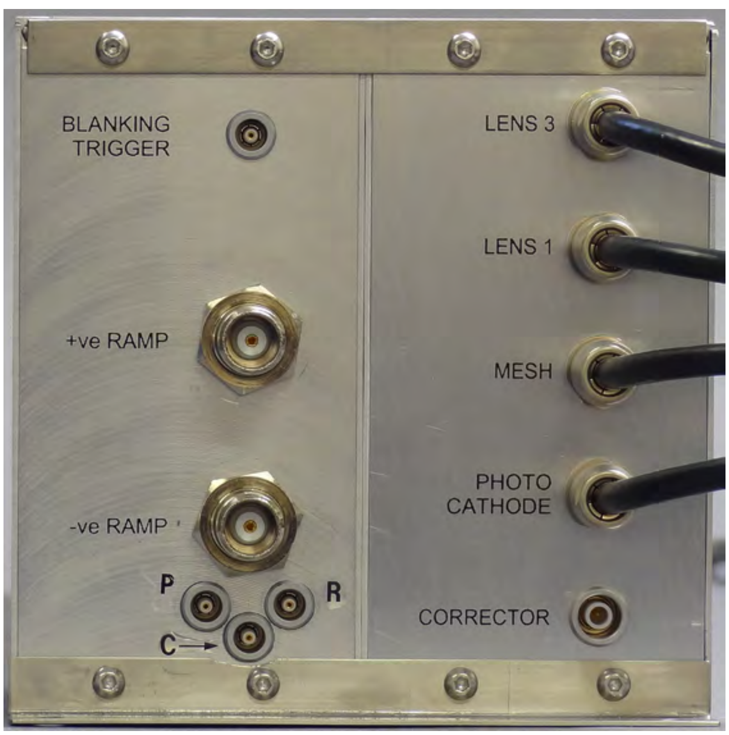

Figure 3 The front panel of the head unit.
Sweep module on the left and Focus module on the right.

1. DISCLAIMER

This equipment contains high voltage power supplies. Although the current supply capacity is small, careless use could result in electric shock. 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 three main components with serial numbers:

Streak Tube	J17xxxxx-1
Head Electronics Pakage	J17xxxxx-2
Radiation Hardened Instrument Controller	J17xxxxx-3

3. ABBREVIATIONS

ADC or adc	Analogue to Digital Convertor
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)
EPLD	Electrically programmable logic device
EPROM	Electrically programmable read only memory, non-volatile
FET	Field Effect Transistor
FN	Foot Note
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
ro	read only
rw	read and write
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.

4.0.1 TOP LEVEL ITEMS

0030-0253 HDISC electronics housing

0030-0252 HDISC Tube

0060-0132 RHIC rack controller

4.0.2 EXTERNAL CABLES

0070-0087 HDISC Sweep Lead x 2

0070-0088 HDISC blanking trigger lead

0070-0089 HDISC corrector supply lead

0070-0090 HDISC HV focus lead x 4 (hard wired to 0060-0140 HDISC focus module)

0070-0124 HDISC interlock lead

4.0.3 EXTERNAL LEADS FOR BENCH TOP TESTING

These are for bench top testing not for installation

0070-0101 HDISC external control lead

0070-0102 HDISC 24 volt power lead

0070-0132 HDISC external FO duplex lead

0070-0143 HDISC trigger lead for testing

4.1 SUB LEVEL ITEMS

Within 0030-0253 HDISC electronics housing

0060-0141 HDISC sweep module

0060-0140 HDISC focus module

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 (Alocrom or Iridite).

5.1 THE TUBE

Aluminium Alloy (the main construction material)
PEEK
Tantalum (the anode)
lead solder
copper, cables
PTFE
Silicone rubber, potting, tubing and two O rings
gold (plating on connectors)
Chromium (plating on connectors)
Brass
Stainless steel
Nickel (meshes) and some plated brass screws
epoxy adhesives
PCB material (FR4)
Electronic components
ink
nitrile rubber (O rings)
nylon
Other materials present in the LLNL photocathode Pack

5.2 THE HEAD ELECTRONICS

Aluminium Alloy (the main housing) with Iridite Chromium free conductive coating
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

5.3 THE RHIC

Aluminium Alloy, some alochomed (Chromate free ROSH compliant), some anodised.
Lead solder
Copper, cables
PTFE
Gold (plating on connectors)
Chromium (plating on connectors)
Brass
Stainless steel
PCB material (FR4)
Electronic components
Glass fibre optic cables
Ink

6. INTRODUCTION

This manual describes the operation and use of the HDISC x-ray streak camera. The camera is based upon a standard Kentech Low magnification tube design with the latest upgrade as the current DISC tubes. The electronics package is split into two units. A head package and a RHIC unit. The head package has been built to withstand neutron radiation by using only electronic components that have been shown to withstand such radiation by testing them on NIF shots. The RHIC sits some 50m away from the head package and is linked by various cables. The RHIC is designed and programmes to be able to control either a HDISC or an HSLOS unit. The software control interface uses similar techniques to the DISC for control of the unit, however, HDISC is a more complex device to use as the level of complexity available in the head package is limited. The system is designed to be used with the customer's own direct electron bombardment sensor. Three triggers are provided to synchronise with this.

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 SPECIFICATIONS OF THE SYSTEM

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[1]
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.
Head power requirements	The head is powered from the RHIC
Dimensions	
Head electronics	340 mm (13.39 inches) plus connectors long by 114 mm (~4.49 inches) square.
RHIC	19 inch rack mount, 3U high x 400 mm deep - plus connectors, front and rear.

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

Vacuum compatibility	The head electronics has **NOT** been designed for operation under vacuum conditions.
Sweep bias voltage on each plate	-800 V to +800 V
Focus Current trip	There is no over current trip on the focus supplies.
Maximum repetition rate	Sweep unit >10 Hz 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	6 triggers (optical or electrical).
Electrical trigger requirements	5 volts into 50Ω rising in < 5ns for all triggers.
Optical triggers (1 through 3)	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 triggers (4 through 6)	Use Broadcom HFBR-1404Z transmitter or similar.

The blanking and crowbar triggers are derived from the main trigger internally at the head electronics. The trigger from the RHIC to the head is a composite one containing the triggers for the HCMOS sensor. For further details see the HSLOS manual see 20 on page 90.

Connectors - Head

Power (28 V)	Lemo EGA.0B.302.CLL
Mating connector	FGA.0B.302.CLAC42.
Control	Lemo EGA.1B.308.CLL
Mating connector	FGA.1B.308.CLAD42
Sweep output	2 x TNC
Trigger Lemo	PSA.00.250.CTL.C33
Mating connector	FFA.00.250.CTAC33
HCMOS output triggers:	
P, C & R	PSA.00.250.CTL.C33
Mating connector	FFA.00.250.CTAC33
Photo-cathode	Custom HV connector on flying lead
Mesh	Custom HV connector on flying lead
Lens 1	Custom HV connector on flying lead
Lens 3	Custom HV connector on flying lead

Corrector	Lemo ERA.0S.403.CTA
Mating connector	FFB.0S.403.CTLC32 - Note reverse pin polarity.
Tube	
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
Sweep monitors	2 x Lemo PSA.00.250.CTL.C33
Mating connector	FLA.00.250.NTA.C31 - note 90°
Blanking drive	Lemo PSA.00.250.CTL.C33
Mating connector	FFA.00.250.CTA.C33

6.2 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

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.

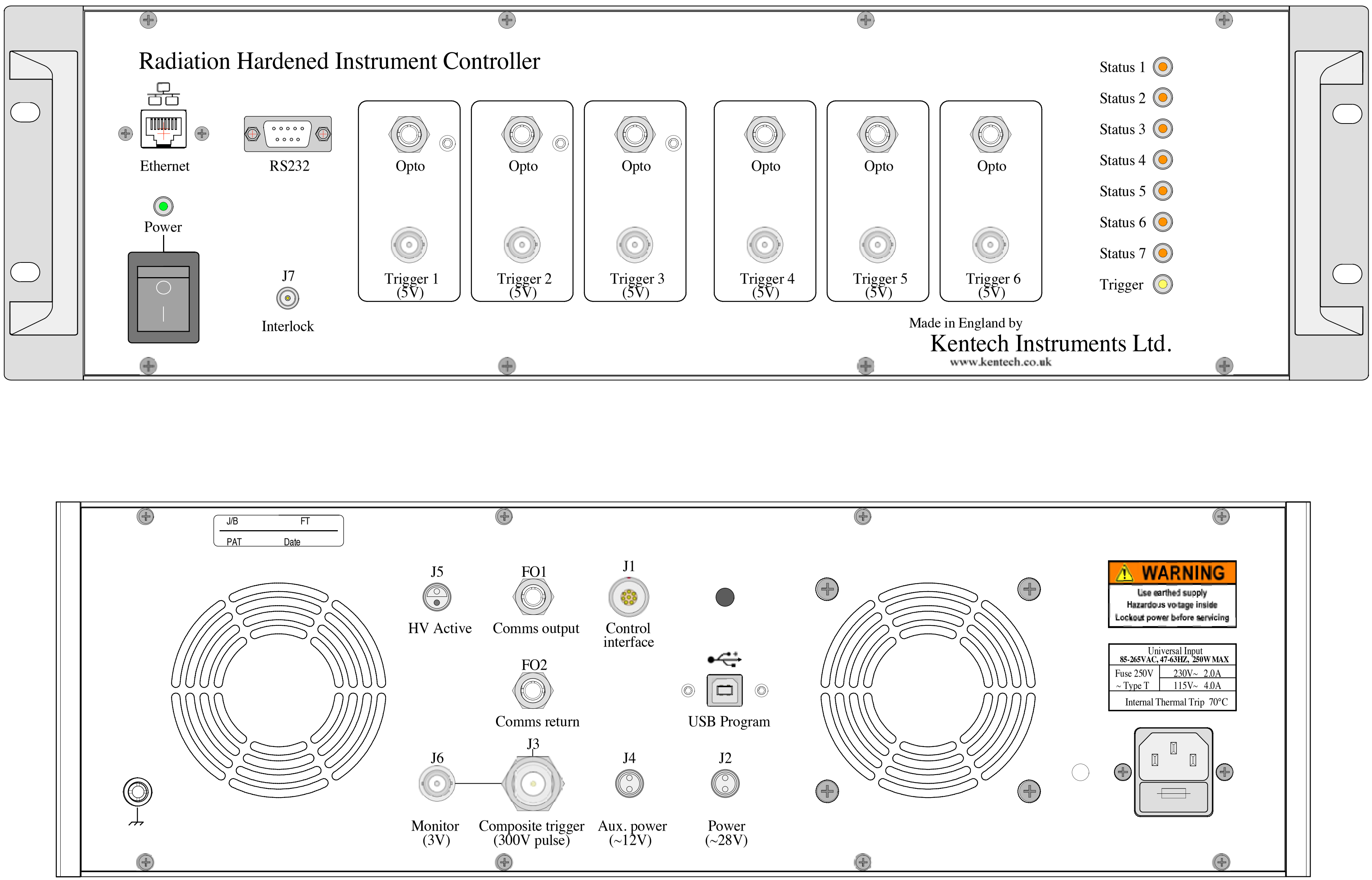

Figure 4 Front and rear panels of te RHIC

Figure 5 Front and rear panels

7. OVERALL DESCRIPTION

7.1 MECHANICS OF THE ELECTRONICS PACKAGE

The head unit electronics package consists of 2 modules strapped together, see Figure 2 on page 6 a control/sweep module and a high voltage (Focus) module. The lower straps having mounting holes.

7.2 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 7.3.3 on page 18

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.

7.3 FITTING THE HCMOS SENSOR AND FIDUCIAL FIBRE OPTIC

Kentech instruments has no experience of these sensors but there are some logistical issues. We understand that the bolts attaching the sensor to the tube have to be screwed through the tube rear flange and into the sensor. In order to access these holes 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 fiducial fibre optic

It may be possible to reverse the order of the last two items. There is a problem with a M3 button head screw under the Swage fitting that holds one of the connector boxes in place. Kentech may adjust this on future units if box compatibility can be retained.

7.3.1 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 washer. Make sure these are in place before refitting the box.

Figure 6 The scrapper ring can be loosened and moved.
If necessary it can be mounted in the reverse direction using the second set of threaded holes.

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

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

The scrapper ring position probably needs 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. A STEP file of the tube will be included with the tube data. The relevant dimension to measure in the model is from the output face of the scrapper 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 scrapper and pulling or pushing the ring in the drift 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. Different aspect ratio scrapper rings are easily accommodated by replacing one aluminium alloy piece. Thisis left to the user, but we are happy to help.

7.3.3 FIT THE SENSOR

7.3.4 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 is held in place by 4 x M3 cap head screws.

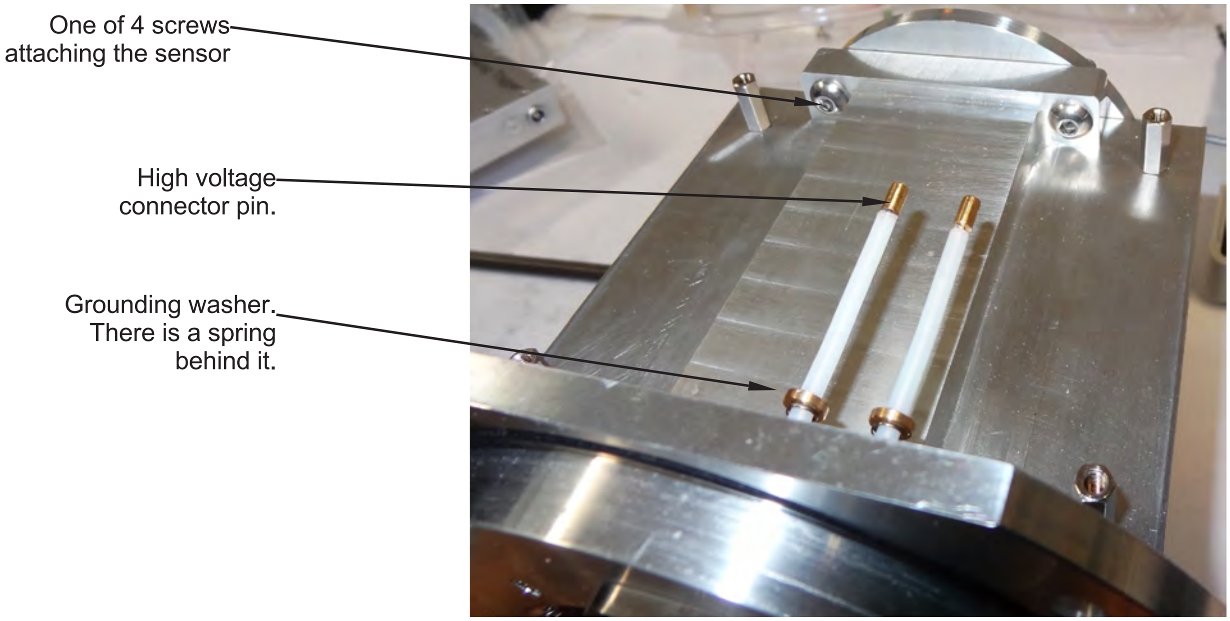

Figure 7 Access to the camera mount holes

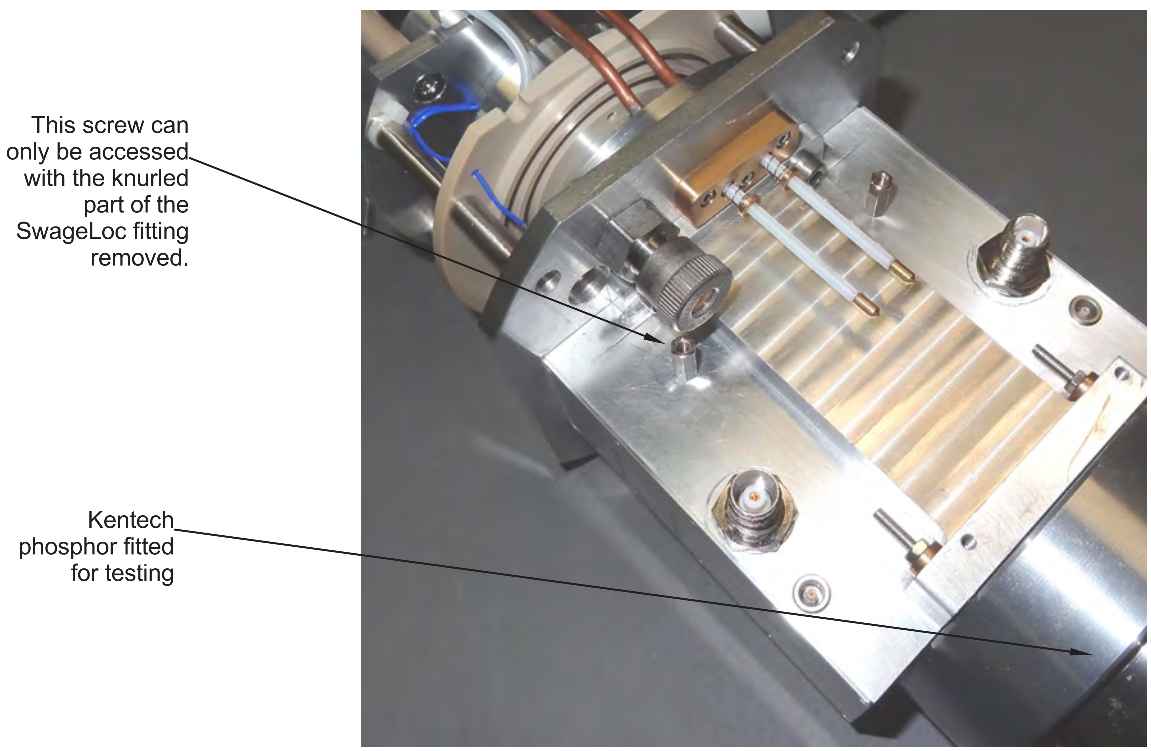

Figure 8 With the connector boxes removed
Take care not to damage the four high voltage
leads or to loose the washers and springs. Check that the brass end connections are in good order and well soldered to the cables. Note that these cables have copper inner conductors and are not as robust as most semirigid cables.
One screw near the FO fiducial input is hard to access unless the knurled nut is moved back.

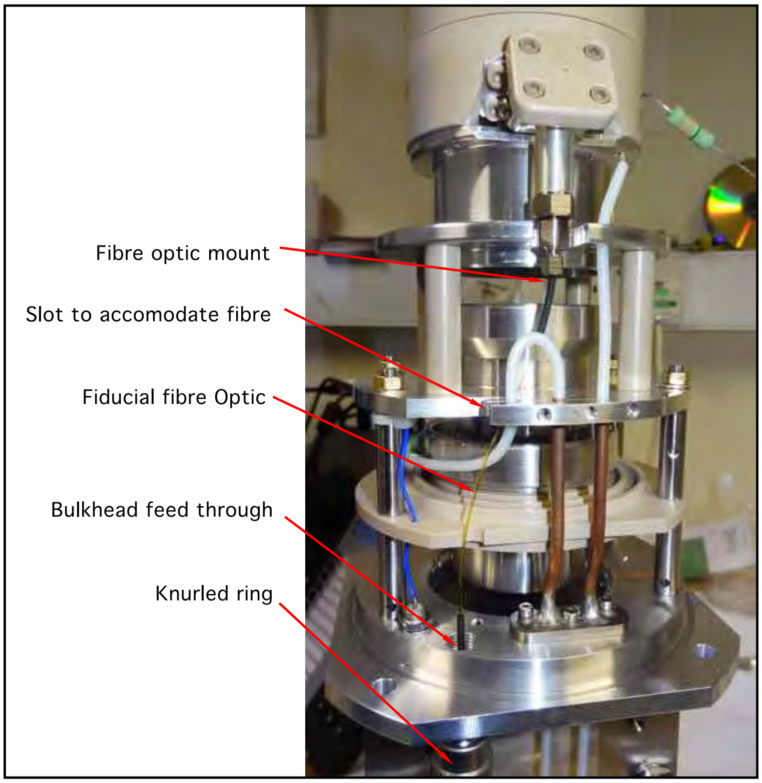

Figure 9 The fiducial fibre optic should be threaded very carefully through the Swage fitting and up to the photocathode pack.
There is a slot in the grounded central lens to retain the fibre. Do not bend the fibre excessively. If you are unhappy about fitting it this way, loosen the photocathode pack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

7.3.5 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 (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.

7.4 CONNECTIONS

7.4.1 CONNECTIONS TO THE MODULES

The head unit is comprised of two units held together with external stainless steel straps. Unlike previous Kentech electronic packages, connections between the modules are via a multi-way connector that is hidden from view when the units are strapped together.

7.4.2 CONNECTING THE STREAK TUBE TO THE HEAD UNIT

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. Blanking drive lead from the head unit to the "Clamp Box"
3. Corrector lead.
4. Focussing high voltage leads.
   These four leads, cathode, mesh, lens1 and lens3 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.

7.4.3 CONNECTIONS BETWEEN THE TUBE AND THE OUTSIDE WORLD

Either or both the sweep plate waveforms may be monitored. Unlike DISC the connections does not go through the head unit.

7.4.4 CONNECTIONS BETWEEN THE RHIC AND THE HEAD UNIT

There are four links between the RHIC and the Head unit:

	RHIC	Head
1.	J2 Power	28V
	Note that power must come from the RHIC as some units are powered down just before the shot to improve their radiation hardening.	
2.	J1 ControlInterface	Control
	This sends several power and analogue signals and reads back analogue signals.	
3.	J3 Composite Trigger	Trigger
	The trigger is a composite one containing edges that drive both the HDISC and the HCMOS triggers.	
4.	FO1 Comms Output	Opto IN
	The Opto in link is for controlling the numerous relays.	
5.	FO2 Comms Input	Opto RETURN
	The Opto out link is for reading back relay states.	

7.4.5 CONNECTIONS FROM THE RHIC TO THE OUTSIDE WORLD

1. Power

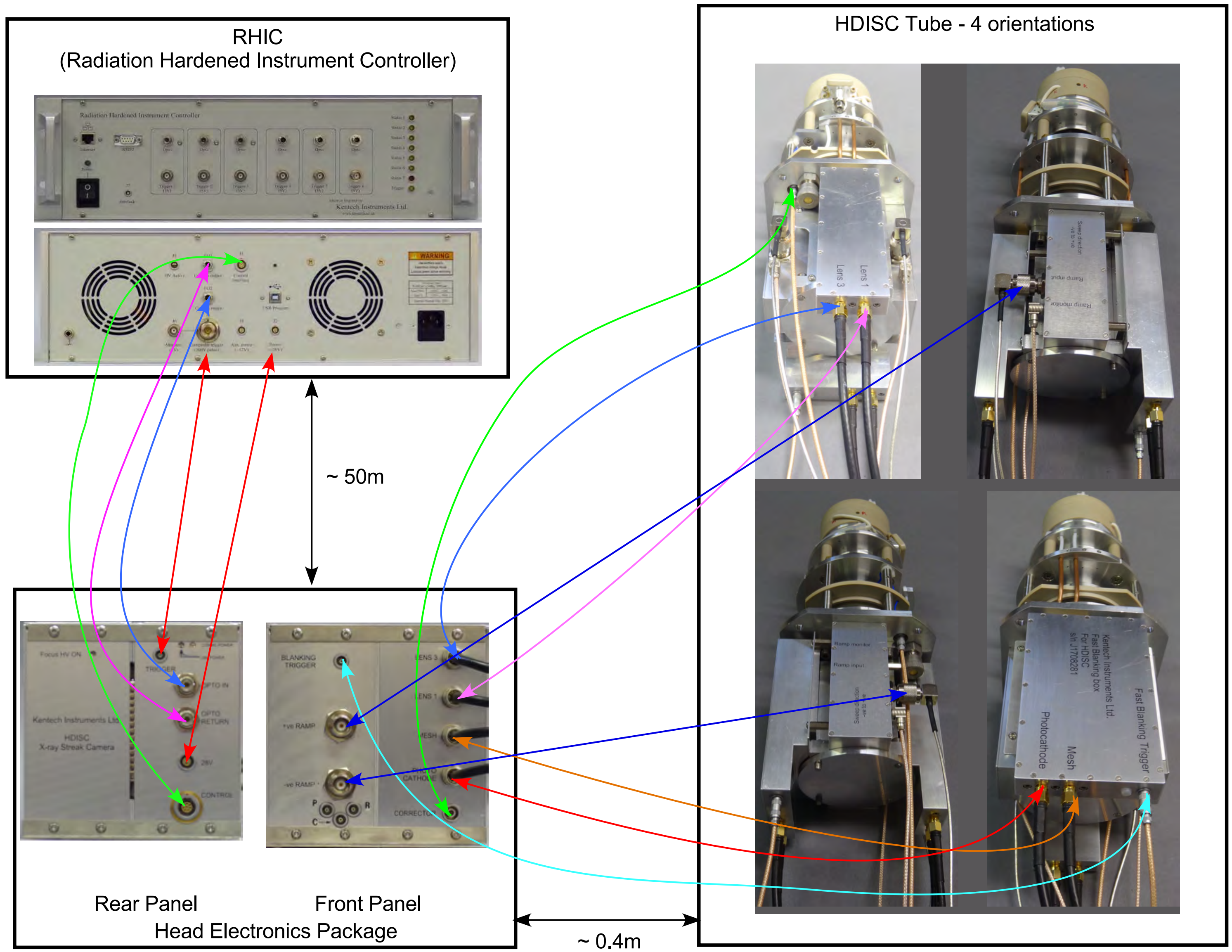

Figure 10 Interconnections between the three main parts of the system

2. Interlock
3. HV active
4. Trigger in x 6
5. Communication RS232 or Ethernet

Details of communicating over ethernet are shown in the HSLOS manual accompanying this manual.

7.5 RUNNING THE ELECTRONICS

The electronics is designed to run in air at atmospheric pressure. However, the unit should be bolted to a heat sink. Without a heat sink the case temperature will rise continuously over a least an hour. There is no built in thermal shutdown. The temperature at a variety of points within the electronics can be monitored and the UCS must be programmed to decide at what temperature to shut down the unit in order to avoid thermal damage.

7.6 DISMANTLING THE MODULES

The electronics unit is simply split into its two modules with the following procedure:-

1 Remove all cables, the focus cables are integrated into the focus unit but may be removed from the streak tube.

2 Remove the four straps, two at either end, one top and one bottom (16 x M3 screws)

3 With a soft bladed tool ease the modules apart. They are connected with a 37 way connector at the rear.

8. RADIATION HARDENED TECHNOLOGY

HDISC 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 neutron damage. However, two groups of components have been found that are useful, one are those that can withstand the neutrons and a secondr group that can survive neutrons if the power is not ON. Both groups are used here. A consequence of using parts that need to powered down for a shot is that during the shot the communications with the head uint is severely restricted.

The head unit uses latching relays to store information. All the delay channels and DAC devices use such relays. Not only are these slow to communicate with, but once the head is armed they cannot be changed unless the unit is disarmed.

The slow speed in communication is still significantly faster than HGXD as HDISC uses many components that were previously thought unsuitable.

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 11 on page 32 The tube fits into a DIM assembly. The vacuum seal is made on the grounded anode of the electron lens. Figure 11 on page 24 shows the internal parts and connections to the camera.

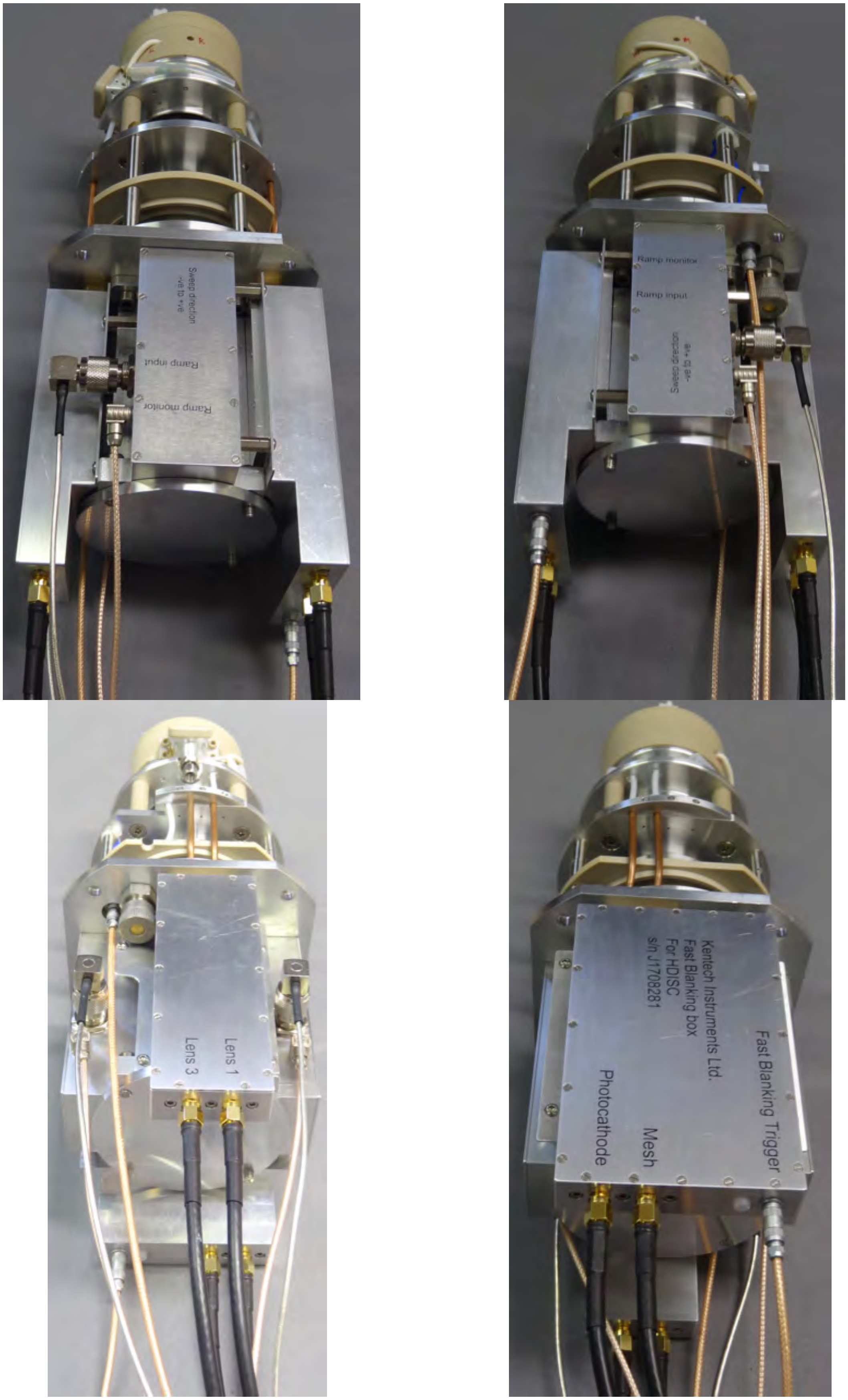

Figure 11   Four views of the tube showing the connections

9.1 VACUUM REQUIREMENTS

The camera 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} mBarr. For thin cathode to grid (mesh) spacers (under 2 mm) pump to under 10^{-5} mBarr.

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 9.10 on page 27. 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} mBarr. 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 cathode 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.

Focussing is achieved most easily with the camera unswept and 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 three focus and mesh potentials adjusted for good focus and desired magnification 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.

9.4 CATHODE BLANKING

The unit is fitted with the option of cathode 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 11 on page 24.

The box contains 6 high voltage FETs that are repeatedly triggered by a signal from the sweep/control unit.

The trigger signal is sent 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 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.

9.6 SWEEP UNIT

The sweep potentials are supplied by a pair of cables from the electronics package to the streak tube.

These are conformable semirigid cables and somewhat fragile although flexible. Replacement of them with identical length semirigid ones once the units have been fixed in the DIM cart would seem a good idea.

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. It also sets the operation point of the ramp. The bias voltages for 5 sweeps have been preset to the optimum values for best sweep linearity. The system is capable of storing up to 16 sweep settings. It is supplied with 5 set up.

The sweep unit has several modes of operation, see 11.7.2 on page 34. These enable the user to do the following:

i nothing

ii normal sweep

iii normal sweep with modified start position for timing

iv flat fielding/focussing, a slow sweep for calibrating the area sensitivity of the sensor or focussing the tube.

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 12 on page 28 . 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.

9.7 SWEEP GENERATION

The sweep circuit works in a similar manner to the DISC system but only uses components that have been tested in high neutron environments. This limitation results in somewhat less fine control over the ramps shapes. However, the basic concept is the same. The ramp is generated by adding the contribution from several high voltage transistors the drives of which can be controlled in level and timing. Both these parameters come from arrays of mechanical relays that either delay the trigger signal to each transistor or adjust the drive current. The level 3 software commands allow one to set up new ramps by adjusting these parameters.

9.8 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.

9.9 CATHODE AND MESH ASSEMBLY

The system has been fitted with a LLNL cathode assembly. It is assumed that the user is familiar with this cathode pack.

9.10 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. At the first application of power there will probably be a slight f lash of light. The focussing supply should be switched on and off a few times, such that no light is visible on the sensor. It may be necessary to wait for the pressure to improve before this test is passed. This test is only required once after venting the vacuum chamber. 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.

9.11 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)

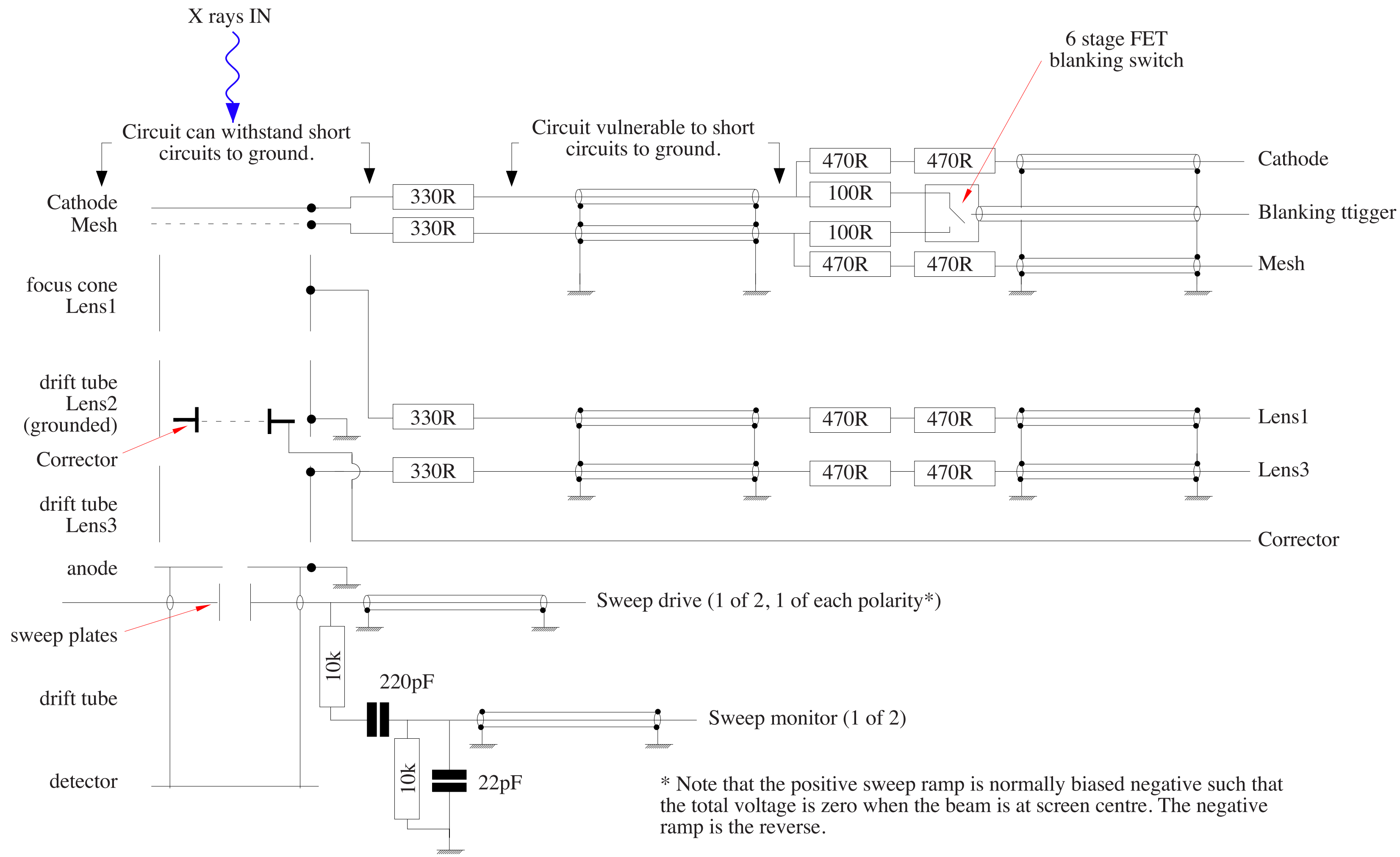

Figure 12 Tube wiring and blanking box

ii the time delay from triggering the sweep unit to the image reaching the middle of the screen. This time depends very much on the sweep speed in use and the distance from the RHIC to the head.

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.

Alternatively timing can be performed in the usual manner, i.e. time up in a “SYNC.” mode and then switch to a “OPERATE” mode. On HDISC there are up to 16 possible sweep rates, although only 5 are preconfigured. For each sweep rate the camera can be in “OPERATE” mode or “SYNC” mode, i.e. with the sweep starting on screen. The mode is controlled by the camera mode command. See 11.7.2 on page 34.

The camera deflection sensitivity is ~18 V/mm when used with a standard Kentech phosphor. For the sweep to start on screen the bias voltage needs to be ~ 300 volts, the exact figure for the edge of the screen will depend upon the size and position of the sensor.

In “SYNC” mode the image starts at on screen at the edge. If the image does not sweep, i.e. it remains in the static untriggered position, then the trigger arrived after the event and the trigger delay must be reduced. Alternatively, if no image is seen on the screen then the trigger arrived too early and the image was swept off screen before the event. In this case the trigger delay should be increased. With this procedure a binary search for the event can be made, but beware of bad shots or other mishaps that can lead one down a false trail in the binary search. Go back and check old positions occasionally as not seeing the image can be caused by a lack of sensor trigger or no focus voltage, also a stationary image can be caused by a loss of sweep signal.

Once a moved image is recorded the timing should be adjusted so that the image is just on the far side of the phosphor (away from the start point) and then the unit can be switched to “OPERATE”. The swept beam spends a significant amount of time off screen before arriving at the screen edge and it may be necessary to trigger a little earlier to see the image on screen in “OPERATE” mode. See the sweep data in section 15 on page 66.

9.12 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. A suitable test resolution cathode should be used. LLNL and Kentech have designed these jointly.

The camera must be operated in a vacuum so the user must provide a suitable pumping system. The vacuum requirement is a pressure of not more than 10^{-4} mBar. A suitable window and cathode must be provided for UV use. (Kentech can advise on the supply of such a cathode, being either 10 nm gold or 100 nm aluminium on a quartz substrate) and a UV mercury vapour lamp, which will operate in the vacuum chamber. Alternatively a more powerful lamp may be imaged through a quartz window onto the cathode.

A typical mercury vapour lamp operating 200 mm from the cathode will give a bright image on an intensifier in contact with a phosphor. With suitable cathodes and reduced lamp to cathode spacing, it is possible to obtain moderately bright images without an intensifier. Remember that the cathode is at -15 kV and that the lamp is probably grounded. It is possible to melt the cathode 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, see 11 on page 32

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.

9.13 POSSIBLE FAULTS

9.13.1 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.

9.13.2 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.

9.13.3 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.

9.13.4 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.

9.13.5 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.

9.13.6 JITTER PRESENT IN IMAGE.

Inadequate or irreproducible trigger signal. The electronics has a jitter of about 20 ps rms. 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.

10. CATHODES

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. It has also been noted that low density cæsium iodide cathodes exhibit a tail in the emission after illumination with a very short pulse. Consequently we recommend solid density cathodes for high time resolution. As these have a very limited lifetime the user will have to be able to recoat the cathodes supplied regularly or be extremely careful about their exposure to anything but a clean vacuum.

TRANSFER THE CATHODES, IF SUPPLIED, TO AN EVACUATED DESICCATOR OR EVACUATED CONTAINER AS SOON AS POSSIBLE AFTER RECEIPT OF THE CAMERA

11. HDISC SOFTWARE INTERFACE

11.1 VERSIONS AND REVISIONS

Revisions

0.0 26 March 2019 PK

0.1 04 April 2019 PK

11.2 CAUTIONS

1. No internal thermal shutdown, temperature sensors should be regularly monitored. Temperatures over ~50°C should raise concern.
2. No current trip for the high voltage connections to the streak tube.

11.3 COMMAND LEVELS

11.4 INTRODUCTION

The software used in HDISC is intended to be also used on HSLOS.

It provides two comprehensive sets of commands to control either type of instrument using a robust protocol similar to hGXD. This manual is concerned only with HDISC.

The HDISC uses a Forth operating system running on an M3 Cortex microprocessor in the rack controller unit. The program is stored in EEPROM and can be upgraded by a simple drag and drop process if the "Program USB" port on the rear panel is plugged into a PC.

Calibration data is stored in an EEPROM. The calibration data is write protected by a momentary action push button on the rear panel. The calibration data is read into RAM at power up. It is intended that the calibration data for all HDISC (and HSLOS) units will ultimately reside in the EEPROM. So any rack controller (RHIC) can be used with any head.

Commands are supplied that allow the IBC to overwrite this calibration with the unit in situ on NIF if necessary. The modified data will be lost if the power is cycled or the unit is reset.

Other operational settings such as camera mode and sweep number are stored in volatile memory. These settings are lost after power is cycled and must be downloaded and checked for each shot using Level 1 operational commands.

11.5 ARCHITECTURE

The HDISC hardware consists of a rack controller and a remote head. The remote head consists of a sweep module and a focus module. There is no intelligence in the head which is intended to be neutron resistant. No intensifier is provided, this unit is intended to be used with the users CMOS camera and three trigger signals are provided from the sweep module to control this. The remote head is based largely on relay circuitry and is therefore slow to operate. To minimise latency for the IBC the HDISC processor has a fully multitasking operating system. There is a "Remote Task" which is responsible for supervising and sequencing the operation of the head.

The IBC uses the protocol commands to issue requests to the remote task which will configure the head as necessary, a process that might take some seconds. The IBC can use protocol commands to monitor the status of the remote task and the head.

11.6 OPERATING STATES OF THE REMOTE HEAD

The HDISC software is similar to the HSLOS software and rather different from DISC. For the HDISC head there are five defined operating states. These are:-

i. UNINITIALISED
28 V power is OFF
Comms power is OFF
The relays in the head are in an undefined state
Triggering is disabled

ii. SAFE
28 V power is OFF
Comms power is OFF
The relays in the head are set to a defined safe state
The sweep pulser and sweep bias are off.
The focus module HV dads are set to zero and focus HV is inhibited.
Triggering is disabled

iii. STANDBY
28 V power is ON
Comms power is ON
The sweep pulser and sweep bias are ON.
The focus module HV supplies are OFF
Triggering is disabled or enabled depending on the trigger mode

iv. ENERGISE
28 V power is ON
Comms power is ON
The sweep pulser and sweep bias are ON
The focus module HV supplies are ON
Triggering is disabled

v. ARMED
28 V power is ON
Comms power is OFF
The sweep pulser and sweep bias are ON
The focus module HV supplies are ON
Triggering is enabled

11.6.1 THE HEAD OPERATING STATE

The state of the head can be verified with the HDISC status read command **hd@stat**. Amongst other parameters this command returns:

sv_remstate	- this is the currently set value of the head operating state
dv_remstate	- the head operating state last requested

11.6.2 SET VALUES OF THE OPERATING STATE

sv_remstate	Description
-1	uninitialised
0	safe
1	standby
2	energise
3	not used in HDISC
4	armed

11.7 CAMERA OPERATIONAL VARIABLES

The operation of the HDISC system in the above operating states is also influence and controlled by the operational variables. These are:-

i. Sweep# A number selecting a set of sweep data

ii. Camera Mode A number defining the operating mode

iii. Trigger Mode A number defining the trigger behaviour

iv. Trigger Source A number defining the trigger source

11.7.1 SWEEP NUMBER

The sweep data is stored in write protected calibration eeprom in an area known as the sweep table. The sweep table has the capacity for 16 different data sets, each set defining one sweep speed. The sweep# can have values of 0 through 15 to select the data set to be used.

As shipped sweeps 0 through 5 have been pre-configured

See section 15 on page 66

11.7.2 CAMERA MODES

The camera mode defines the mode of operation of the HDISC. There are three basic modes and two synchronisation modes:

i. 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.

ii. Repetitive (OPERATE) mode in which the camera may be repetitively triggered when armed, with crowbar and blanking inhibited.

iii. Sinlge shot (OPERATE) mode in which the camera may be triggered once after arming and the blanking and crowbar are enabled.

iv. Repetitive SYNC mode in which the sweep starts on screen and in the camera may be repetitively triggered when armed, with crowbar and blanking inhibited.

v. Single shot SYNC mode in which the sweep starts on screen and in the camera may be triggered once when armed, with crowbar and blanking enabled.

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

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

11.7.3 TRIGGER MODE

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

This allows the operation of the fast sweep pulser 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

11.7.4 TRIGGER SOURCE

The trigger source flag selects either electrical or optical triggering.

Trigger Source	Behaviour
0	All inputs electrical
1	All inputs optical

11.7.5 TRIGGER LATCHES

The trigger latches can only be set by a trigger received when the unit is in the ARMED state. The ARMED state can only be reached from the ENERGISE state. Consequently the trigger latches are not useful for testing in the STANDBY state, i.e. Trigger mode =1. The triggers will work in the STANDBY state if the trigger mode = 1.

The trigger latches are re-set with the 0triggers command. Setting the unit state to ARMED does no re-set the trigger latches. The latches are stored in the RHIC and so are available for interrogation at any time.

11.7.6 TRIGGER STATUS

Explanation of bits in trigger status latches (1= set, 0 = NOT set) as returned by **hd@status**

	HSLOS	HDISC
bit0 = T6	hcmos_reset trigger latch	hcmos_reset trigger latch
bit1 = T5	pc_prebias trigger latch	hcmos_pretrig trigger latch
bit2 = T4	solenoid trigger latch	pretrig trigger latch
bit3 = T3	hcmos2 l trigger atch	not used
bit4 = T2	hcmos1 trigger latch	hcmos trigger latch
bit5 = T1	ramp trigger latch	sweep trigger latch

These are decoded into separate flags in the command **hd@trigger**s

11.8 THE HEAD STATUS

The head status command returns the status of several flags. In particular r3 the remote task activity has the following meanings:

00 = OFFing = stopped
05 = INIing = changing hardware to SAFE
06 = STBing = changing hardware to STANDBY
07 = ENEing = changing hardware to ENERGISE
09 = ARMing = changing hardware to ARM
10 = UPDing = writing updated values to relays
12 = IDLing = idle

Generally these are intended for factory diagnostics and the user can ignore them. The head status also includes the current trigger state see 11.7.6 on page 35.

11.9 POWER UP SEQUENCE

After cycling the power or a reset the rack controller applies only 12 V comms power to the head and attempts to communicate with it and determine the head type (HDISC or HSLOS) and serial number. Then it waits for instructions from the IBC.

The results of this process should be read using the rack controller hardware status read command **rc@ hrdw** .This will return the Kentech job number, the rack controller serial number (1 through 20), the head type (see below), the head serial number (1 through 10) and the rack controller software version.

Head type	Description
0	No head found
1	HSLOS
2	HDISC

If the head type is returned as zero, this indicates no optical communications was received from the head. This should be investigated before proceeding.

After receiving the head type the head is in the UNINITIALISED operating state.

If the head type is HDISC and the serial number is correct, the HDISC driver can be started with the

hd_strt command. This takes a single parameter (1 through 10) which is confirmation of the serial number of the HDISC head. This number is used to locate and load the correct calibration information for the head.

Starting the HDISC software in this way will startup the HDISC remote task and request it to change the head operating state to SAFE.

A change of state can be requested by the IBC. If the change is allowed, the desired state will appear immediately in dv_remstate, then after a delay of some seconds as the head responds it will appear in sv_remstate.

After the power up sequence the HDISC head operating state should eventually be SAFE.

At this point there is no power to the head and the trigger is disabled.

The IBC should now set the operational variables

Sweep#, Trigger Mode, Camera Mode and Trigger Source

This is done with hd!cmmd and can be verified with hd@cmmd

11.10 NORMAL OPERATION IN REPETITIVE MODE

Now the state can be changed to STANDBY using the request standby command hd_rqsb The IBC should verify the state change using hd@stat. At this point there is 28 V and comms power to the head. The sweep pulser and sweep bias are enabled. The focus HV is OFF. In normal operation trigger mode will be zero, so the trigger will be inhibited.

11.10.1 ENERGISE

Now the state can be changed to ENERGISE using the request ENERGISE command hd_rqen The IBC should verify the state change using hd@stat.

Note that this state change is particularly slow due to the slow start routine for the focus HV,

At this point there is:

28 V and comms power to the head.
The sweep pulser and sweep bias are enabled.
The trigger is inhibited.
The focus HV is ON.

11.10.2 ARMED

Finally the state can be changed to ARMED state using the request command hd_rqar. The IBC should verify the state change using hd@stat.

At this point there is:

28 V power but no comms power to the head.
The sweep pulser and sweep bias are enabled.
The trigger is enabled
The focus HV is ON.

The system can now be triggered. The trigger latches can be read with @_trig and reset with 0_trig. From ARMED, ENERGISE or STANDBY states operation can be terminated at any point by requesting a change to SAFE using hd_rqsf.

11.11 OPERATION IN ONE SHOT MODE

In one shot mode, from the ARMED state, if the system is triggered, the cathode blanking pulser and the crowbar circuit will be active and the system will return to SAFE. It is then necessary to cycle the system to STANDBY, ENERGISE and ARMED before the next shot.

11.12 SCANNING THE ANALOGUE SIGNALS

Due to the slow response of the head circuitry, the various analogue monitor signals in the remote head are not continuously monitored.

They can be scanned at any point in STANDBY or ENERGISE states using the scan request command hd_rqsc.

On start up both flags are set low. Immediately after sending a scan command the request scan flag will be high and the scan completed flag low. The status should be checked with hd@stat until scan completed flag goes high. Then the analogue signals can be read.

11.13 OPERATION OF THE INTERLOCK

An interruption of the interlock contact on the front panel of the RHIC or on the control connector to the HDISC head will cause the interlock latch to be set and the system will change state to UNINITIALISED.

The interlock latch and the current state of the contacts can be read using hd@intk. If the latch is set it must be cleared with hd0intk before the HDISC software can be restarted with hd_strt. It cannot be cleared unless the interlock connection is remade.

11.14 THE PROTOCOL

This is the protocol used for in-situ control using the level 1 operation and level 2 engineering commands below. Level 3 expert commands require the use of a terminal emulator program on a PC and are not fully covered in this manual (some commands are included to help with focussing and sweep ramp set up). The protocol is very similar to that used on the GXD and LFC.

HDISC will generate responses to valid commands and will not generate any unsolicited output. Invalid commands will be ignored. All commands and response will be in ASCII characters. Commands are case sensitive.

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

HDISC will not echo command characters as they are received, no output will be generated until a valid command is recognised. When a valid command is recognised, HDISC will output a response.

Responses are preceded with a cr and lf, then an ascii { character and end with an ascii }. The response will be delimited into fields by an ascii ; character. The first field in the response will be a repeat of the command. If the command cannot be completed HDISC will return an error code in the second field. The possible error codes are:

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

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

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

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

Examples:

1) To set up camera in a condition with:

Trigger source 0 (default electrical trigger)

Trigger mode 0 (only triggerable in armed mode)

Sweep# 5

Mode 1 (repetitive mode)

the command would be

0 0 5 1 hd!cmmd

and the response would be

{0 0 5 1 hd!cmmd; 0}

2) as above but with a missing parameter

0 0 5 hd!cmmd

and the response would be:-

{-1 -1 -1 -1 hd!cmmd;?stack}

The command interpreter detects the wrong stack depth, corrects this by clearing the stack and adding some dummy parameters then flags the error. No execution will result.

3) as above with invalid parameter

0 0 20 1 hd!cmmd

and the response would be:-

{0 0 20 1 hd!cmmd ;?param}

Again no execution will result.

Error 2 will take precedence over error 3.

11.15 THE LED DISPLAYS

The RHIC has 9 LEDs, the sweep unit 2 and the focus unit 1, see Figure 14 on page 46.

The left hand LED on the RHIC just indicates that the unit is powered up.

The array of 8 LEDs on the right hand side indicate the following when lit:

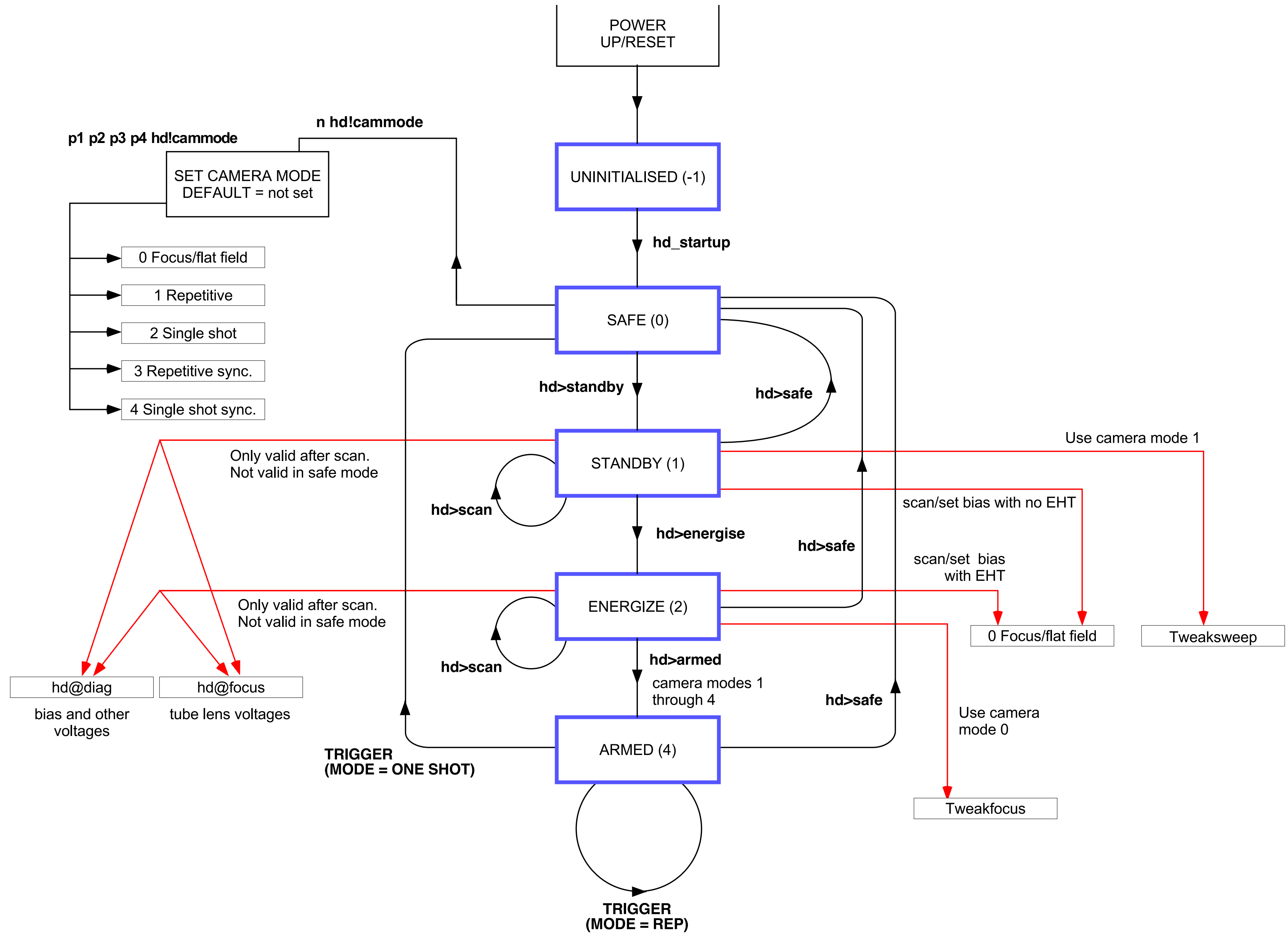

Figure 13 Flow diagram for set up and operation in single shot and repetitive modes.

11.16 COMMANDS

It is intended that level 1 commands should be sufficient for routine use of HDISC, these are non expert commands.

Level 2 commands are intended to provide the facility to focus and set up HDISC in-situ using the standard protocol.

Level 3 commands provide for detailed engineering work in the laboratory.

For example focussing the streak tube or adjusting sweep waveforms.

Level 3 commands do not use the standard protocol and are for manual use only using a terminal emulation program, e.g. Hyperterminal.

Explanatory notes:

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

2) For returned parameters, true = -1, false = 0.

11.16.1 LEVEL 1 OPERATIONAL COMMANDS

Name	**hd_startup**
Explanation	Start up HDISC software (as opposed to HSLOS software)
Format	**p1 hd_strt**
parameter 1	p1 head serial number 1 through 10
returned value 1	r1 0 => command completed, -1 => unable
Notes	will execute only if the system is in UNINITIALISED state with interlock latch zero p1 will determine the calibration data set loaded to operate the head

Name	**hd>safe**
Explanation	Request system change to SAFE state
Format	**hd_rqsf**
returned value 1	r1 0 => command completed, -1 => unable
Notes	will execute in STANDBY, ENERGISE, ARMED states

Name	**hd>standby**
Explanation	Request system change to STANDBY state
Format	**hd_rqsb**
returned value 1	r1 0 => command completed, -1 => unable
Notes	will execute in SAFE state

Name	**hd>energise**
Explanation	Request system change to ENERGISE state
Format	**hd_rqen**
returned value 1	r 0 => command completed, -1 => unable
Notes	will execute in STANDBY state

Name	**hd>armed**
Explanation	Request system change to ARMED state
Format	**hd_rqar**
returned value 1	r1 0 => command completed, -1 => unable
Notes	will execute in ENERGISE state will not re-set the trigger latches, use command 0triggers

Name	**hd>scan**
Explanation	Request scan of analogue signals in the head
Format	**hd_rqsc**
returned value 1	r1 0 => command completed, -1 => unable
Notes	will execute in STANDBY and ENERGISE states will not execute in ARMED state as the comms power will be off.

Name	**hd!cammode**
Explanation	store write mode settings
Format	**p1 p2 p3 p4 hd!cmmd**
parameter 1	p1 = Trigger source, range 0 through 1
parameter 2	p2 = Trigger mode, range 0 through 1
parameter 3	p3 = Sweep#, range 0 through 15
parameter 4	p4 = Camera mode, range 0 through 4
returned value 1	r1 0 => command completed, -1 => unable
Notes	will execute in SAFE state

Name	**hd@cammode**
Explanation	read mode settings
Format	**hd@cmmd**
returned value 1	r1 = Trigger source, range 0 through 1
returned value 2	r2 = Trigger mode, range 0 through 1
returned value 3	r3 = Sweep#, range 0 through 15
returned value 4	p4 = Camera mode, range 0 through 4
Notes	readback of values set with hd!cammode

Name	**hd!auxpsuen**
Explanation	Enable aux psu on rear panel of rack controller
Format	**p1 hd!auxp**
parameter 1	p1 = enable psu?, true or false
returned value 1	r1 0 => command completed, -1 => unable
Notes	will execute in any state

Name	**hd@auxpsuen**
Explanation	Read aux psu enable flag
Format	**hd@auxp**
returned value 1	r1 = ax psu enabled? -1 = enabled.

Notes	read back of value set with hd!uaxpsuen

Name	**@>i_hcmos**
Explanation	Read measured output current of hcmos supply
Format	**hd@>ihc**
returned value 1	r1 = supply current in mA
Notes	read the output of current ADC in HCMOS supply in rack controller

Name	**@>i_28V**
Explanation	Read measured output current of 28 V supply
Format	**hd@>i28**
returned value 1	r1 = supply current in mA
Notes	read the output of current ADC in 28 V supply from rack controller

Name	**@interlock**
Explanation	Read interlock status
Format	**hd@intk**
returned value 1	r1 = interlock input, true = open circuit, false = short circuit = ok
	r2 = head interlock, true = open circuit, false = short circuit = ok
	r3 = interlock latch, true = tripped, false = ok

Name	**0interlock**
Explanation	Reset interlock latches
Format	**hd0intk**
returned value 1	r1 0 => command completed, -1 => unable

Name	**hd@triggers**
Explanation	Read trigger latches
Format	**hd@trig**
returned value 1	r1 = hcmos reset (R)
	r2 = hcmos pre trigger (P)
	r3 = shot pretrig (HSLOS solenoid)
	r4 = hcmos fast 2 (not used on HDISC)
	r5 = hcmos fast 1 (C)
	r6 = sweep (HSLOS ramp)
Notes	1 = set
	latches will SET after an ARM and a trigger.
	ARM (hd_rqar) can only be executed in Energise State.

Name	**0triggers**
Explanation	Reset trigger latch
Format	**hd0trig**
returned value 1	r1 0 => command completed, -1 => unable
Note	ARM does not re-set the trigger latches.

Name	**hd@status**
Explanation	Read status
Format	**hd@stat**
returned value 1	r1 = machine state
	r2 = requested state
	r3 = remote task activity
	r4 = req scan flag
	r5 = scan complete flag
	r6 = interlock latch
	r7 = current trigger state

Name	**rc@hardware**
Explanation	Read hardware status
Format	**rc@hrdw**
returned value 1	r1 = Kentech job number from rack controller
	r2 = rack controller serial number (1 through 20)
	r3 = id type of head (0 through 2)
	r4 = HSLOS/HDISC head serial number (1 through 10)
	r5 = software version

Name	**hd@>temps**
Explanation	Read measured remote temperatures
Format	**hd@>tmp**
returned value 1	r1 = Focus module T1 (degrees C)
	r2 = Focus module T2 (degrees C)
	r3 = Sweep module T1 (degrees C) - currently not fitted
	r4 = Sweep module T2 (degrees C) - currently not fitted
	r5 = not used
	r6 = not used
	r7 = not used
	r8 = not used
Notes	Only valid after an analogue scan has been completed

Name	**hd@>Vtube**
Explanation	Read measured sweep tube voltages
Format	**hd@>vtb**
returned value 1	r1 = Photocathode (V)
	r2 = Mesh (V)
	r3 = Lens 3 (V)
	r4 = Lens 1 (V)
	r5 = Corrector (V)
	r6 through r8 = not used
Notes	Only valid after an analogue scan has been completed. Not valid in Safe state.

Name	**hd@>Itube**
Explanation	Read measured sweep tube currents
Format	**hd@>itb**
returned value 1	r1 = Photocathode (nA)
	r2 = Mesh (nA)
	r3 = Lens 3 (nA)
	r4 = Lens 1 (nA)
	r5 = not used
	r6 = not used
	r7 = not used
	r8 = not used
Notes	Only valid after an analogue scan has been completed. Not valid in Safe state. Measures load current plus current into 1G sense resistor plus crowbar bias current on the photocathode

Name	**hd@>diag**
Explanation	Read measured diagnostic voltages
Format	**hd@>dia**
returned value 1	r1 = 20 V referenced (mV)
	r2 = 22 V unregulated (mV)
	r3 = Blanking pulser supply (V)
	r4 = Bias supply 1 monitor (mV)
	r5 = Bias supply 2 monitor (mV)
	r6 = Bias output (V)
	r7 = 1.4 kV supply (V)
	r8 = not used
Notes	Only valid after an analogue scan has been completed

Status 1	STANDBY state active
Status 2	ENERGISE - focus voltages are on. This will illuminate once the focus voltages have reached their preset values.
Status 3	Charge - not used in HDISC
Status 4	ARMED state active - focus voltages are on, sweep and bias voltages enabled.
Status 5	HCMOS PSU enabled[1]
Status 6	OPTO trig, set by Camera mode in SAFE state but only indicates after requesting a standby.
Status 7	DC on. Power for focus, Sweep and bias supplies
Trigger	Flashes if triggered in an armed state[2]. Any trigger will cause it to flash except HCMOS Pretrigger (trigger 5).

[1] If enabled in an UNINITIALISED state this LED will not illuminate until the head is initialised.

[2] In repetitive mode arming the camera causes the armed flag to be set. The triggered light will flash every time the unit is triggered if it is armed. Triggering in standby mode will not cause the triggered light to flash as the unit is not armed.

Figure 14 The RHIC status LEDs and their behaviour

11.16.2 LEVEL 2 ENGINEERING COMMANDS TO ADJUST THE FOCUS

Name	**hd_focus**
Explanation	setup camera focus condition
Format	**p1 hd_fcus**
parameter 1	p1 = bias voltage for focus (voltage on one plate).
returned value 1	r1 0 => command completed, -1 => unable
Notes	will execute only in focus/flat field mode

Name	**hd_flatarm**
Explanation	Arm the camera system in flat field mode
Format	**p1 hd_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/flat field mode restores sweep bas to flat field start condition

Name	**hd_flattrig**
Explanation	Trigger the camera system in flat field mode
Format	**hd_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	**hd_incvcathode**
Explanation	add an increment to the cathode voltage
Format	**p1 hd_+vpc**
parameter 1	p1 = voltage increment, range +/-1000 V
returned value 1	r1 = revised cathode 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. Will execute in STANDBY or ENERGISE

Name	**hd_incvmesh**
Explanation	add an increment to the mesh voltage
Format	**p1 hd_+vme**
parameter 1	p1 = voltage increment, range +/-1000 V
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. Will execute in STANDBY or ENERGISE

Name	**hd_incvlens3**
Explanation	add an increment to the lens 3 voltage
Format	**p1 hd_+vl3**
parameter 1	p1 = voltage increment, range +/-1000 V
returned value 1	r1 = revised lens 3 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. Will execute in STANDBY or ENERGISE

Name	**hd_incvlens1**
Explanation	add an increment to the lens 1 voltage
Format	**p1 hd_+vl1**
parameter 1	p1 = voltage increment, range +/-1000 V
returned value 1	r1 = revised lens 1 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. Will execute in STANDBY or ENERGISE

Name	**hd_incvcor**
Explanation	add an increment to the corrector voltage
Format	**p1 hd_+vco**
parameter 1	p1 = voltage increment, range +/-1000 V
returned value 1	r1 = revised corrector 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. Will execute in STANDBY or ENERGISE

11.16.3 COMMANDS TO UPLOAD/DOWNLOAD CALIBRATION DATA

The following commands have been included to allow a scheme whereby the control computer downloads all the calibration data to the HDISC at power up. It is probably not necessary to implement all these commands unless this scheme is to be used.

Name	**hd@focus**
Explanation	Read back of the focus voltages
Format	**hd@focs**
returned value 1	r1 = Photocathode r2 = Mesh r3 = Lens 1 r4 = Lens 3 r5 = Corrector r6 - r16 not used

Name	**hd!focus**
Explanation	store focus voltages
Format	**p1 p2 … p16 hd!focs**
parameter 1	p1 = Photocathode (V)
parameter 2	p2 = Mesh (V)
parameter 3	p3 = Lens 1 (V)
parameter 4	p4 = Lens 3 (V)
parameter 5	p5 = Corrector (V)
	r6 - r16 not used
returned value 1	r1 0 => command completed, -1 => unable
Notes	will execute in SAFE state

Name	**hd@fdacal**
Explanation	Read back of the focus module dac calibration
Format	**hd@focs**
returned value 1	r1 = cathdac@15kv
	r2 = cathdac@10kv
	r3 = meshdac@14kv
	r4 = meshdac@7kv
	r5 = L1dac@14kv
	r6 = L1dac@7kv
	r7 = L3dac@14kv
	r8 = L3dac@7kv
	r9 = COdac@1kv
	r10 = COdac@100v
	r11 - r16 not used

Name	**hd!fdacal**
Explanation	Write the focus module dac calibration
Format	**p1 p2 … p16 hd!fdcl**
Parameter 1	p1 = cathdac@15kv
	p2 = cathdac@10kv
	p3 = meshdac@14kv
	p4 = meshdac@7kv
	p5 = L1dac@14kv
	p6 = L1dac@7kv
	p7 = L3dac@14kv
	p8 = L3dac@7kv
	p9 = COdac@1kv
	p10 = COdac@100v
	p11 - p16 not used
returned value 1	r1 0 => command completed, -1 => unable
Notes	Will execute in SAFE state

Name	**hd@fmoncal**
Explanation	Read back of the focus module monitor calibration
Format	**hd@fmcl**
returned value 1	r1 = cathmon@15kv
	r2 = cathmon@10kv
	r3 = meshmon@14kv
	r4 = meshmon@7kv
	r5 = L1mon@14kv
	r6 = L1mon@7kv
	r7 = L3mon@14kv
	r8 = L3mon@7kv
	r9 = COmon@1kv
	r10 = COmon@100v
	r11 = imon@14kv
	r12 - r16 not used

Name	**hd!fmoncal**
Explanation	Write the focus module dac calibration
Format	**p1 p2 … p16 hd!fmcl**
Parameter 1	p1 = cathmon@15kv
	p2 = cathmon@10kv
	p3 = meshmon@14kv
	p4 = meshmon@7kv
	p5 = L1mon@14kv
	p6 = L1mon@7kv
	p7 = L3mon@14kv
	p8 = L3mon@7kv
	p9 = COmon@1kv
	p10 = COmon@100v
	p11 = imon@14kv
	p12 - p16 not used
returned value 1	r1 0 => command completed, -1 => unable
Notes	will execute in SAFE state

Name	**hd@misccal**
Explanation	Read back misc. calibration block
Format	**hd@micl**
returned value 1	r1 = syncbias
	r2 = mVbiasreq@+700V
	r3 = mVbiasreq@-700V
	r4 = ffendbias
	r5 = ffstartbias
	r6 = vm14@ref
	r7 = Vm14ref
	r8 = vm22@ref
	r9 = vm22ref

r10 = vm20@ref
r11 = vm20ref
r12 = vmBL@ref
r13 = vmBLref
r14 - r16 not used

Name	**hd!misccal**
Explanation	Write the misc calibration block
Format	**p1 p2 … p16 hd!micl**
Parameter 1	p1 = syncbias p2 = mVbiasreq@+700V p3 = mVbiasreq@-700V p4 = ffendbias p5 = ffstartbias p6 = vm14@ref p7 = Vm14ref p8 = vm22@ref p9 = vm22ref p10 = vm20@ref p11 = vm20ref p12 = vmBL@ref p13 = vmBLref p14 - p16 not used
returned value 1	r1 0 => command completed, -1 => unable

Name	**hd@swpcal**
Explanation	Read back sweep calibration block
Format	p1 hd@swcl
Parameter 1	p1 = sweep# (0 through 15)
returned value 1	r1 = swp_time r2 = swp_hold r3 = swp_diode r4 = swp_T1dac r5 = swp_T2dac r6 = swp_T3dac r7 = swp_T4dac r8 = swp_T5dac r9 = swp_bidac r10 = swp_T2del r11 = swp_T3del r12 = swp_T4del r13 = swp_T5del r14 - r16 not used
Notes	There are 16 blocks of sweep data, one for each value of sweep# 0 through 15.

Name	**hd!swpcal**
Explanation	Write sweep calibration block
Format	**p1 p2 … p17 hd!swcl**
Parameter 1	p1 = sweep# (0 through 15)
	p2 = swp_time
	p3 = swp_hold
	p4 = swp_diode
	p5 = swp_T1dac
	p6 = swp_T2dac
	p7 = swp_T3dac
	p8 = swp_T4dac
	p9 = swp_T5dac
	p10 = swp_bidac
	p11 = swp_T2del
	p12 = swp_T3del
	p13 = swp_T4del
	p14 = swp_T5del
	p15 - p17 not used
returned value 1	r1 0 => command completed, -1 => unable
Notes	There are 16 blocks of sweep data, one for each value of sweep# 0 through 15.

11.17 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 accessible in DEBUG mode only. The mode can be changed using:-

+debug - change into debug mode

-debug - change into normal mode

In debug mode, the standard short form protocol commands can be used as in normal mode, but in debug mode the rack controller will also recognise the long form name of the function. This allows them to be combined into macros. Macros can only be executed in debug mode.

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 destructive 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 sequence is reversed. The top of the stack contains the last parameter to be returned from a command.

The following commands are defined to print out status and data in a plain English format:

hD.CAMmode- a decoded version of hD@CAMmode
hD.status - equivalent to hD@status
RC.hardware- equivalent to rc@hardware
HD.triggers - etc
HD.>temps
HD.>Vtube
HD.>Itube
HD.>diag

11.18 TWEAKERS

There are two level 3 commands provided to simplify the tasks of focussing the streak tube and adjusting the sweep waveforms.

11.18.1 FOCUSSING

Tweakfocus

If the system is in ENERGISE state with the camera mode set to Focus/Flat field, this command runs a routine to simplify the adjustment of the voltage outputs from the focus supply.

In this routine, pressing:-

W or Q changes the selected supply to be adjusted
1 or 2 decrements/increments the set value by 1 V
3 or 4 decrements/increments the set value by 10 V
5 or 6 decrements/increments the set value by 100 V
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 unless it is explicitly saved in the calibration eeprom. The data can be read with hd@focus. Note that when the HDISC system is in SAFE state the default calibration focus data can be overwritten using hd!focus. This allows the facility to keep the focus calibration data for each HDISC head in the remote computer rather than in the calibration eprom.

The complete DAC and HV system is contained in the HDISC head, so the focus data is the property of the HDISC head serial number rather than of the rack controller serial number. On exit from tweakfocus a parameter is returned on the stack. This is 0 for success and -1 for fail.

If tweakfocus returns non zero this means the system is not in ENERGISE, or the mode is not FOCUS.

Note the Tweakfocus leaves a character on the stack. This will prevent the short format level 1 and 2 commands from operating the first time. After one has failed the stack will be cleared and it will work the second time. Generally conclude a tweak focus session with a “drop” command to clear the stack. The number of items left on the stack is indicated by the number following the response ok. e.g. ok-3 means there are three items on the stack and three drops are required. Failing to execute a legal command also clears the stack.

11.18.2 ADJUSTING THE RAMP SPEEDS

The ramp generator is very similar to that used on DISC except that the components are neutron resistant. The circuit adds together the outputs from 6 negative going pulse generators. Each generator can have a preset slope to the leading edge and have a preset delay w.r.t. the previous pulser (except for the first pulser). Consequently there are 5 parameters defining the slopes and 4 parameters defining the delays. There are four more parameters that define a sweep table:

1. Wether to use an array of “speed-up” diodes which speed up the fastest ramp slightly.
2. The state of a switch in the hold off delay for a separate circuit that props up the ramp at late times (holds the electron beam off the sensor). This is only likely to be needed for slow ramps.
3. The optimum bias voltage for a given sweep rate that allows the most linear part of the ramp to be used.
4. An unused number that represents the swpp duration.

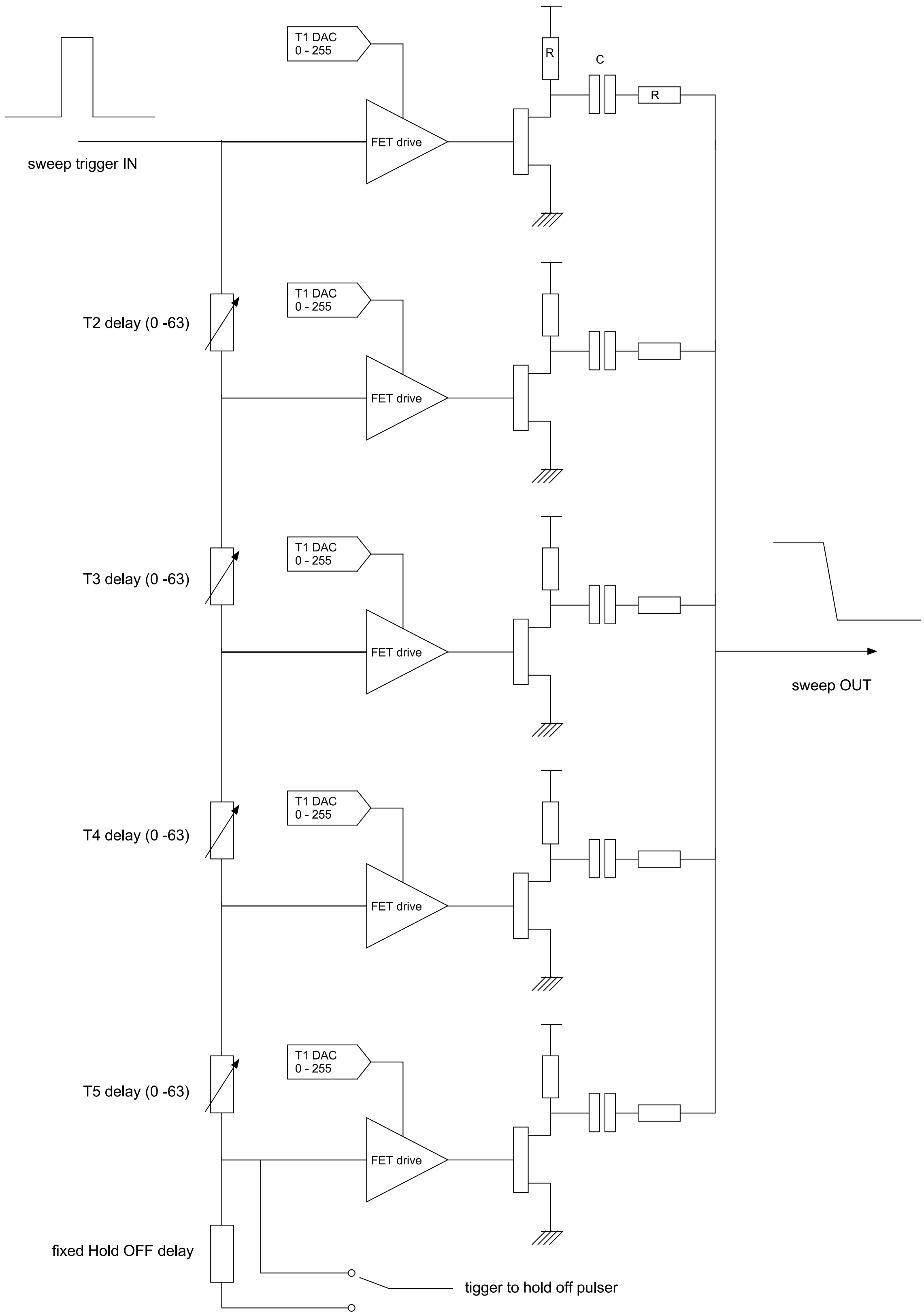

Figure 15 The ramp generator has 5 stages added together.
This gives 4 delays and 5 voltages that need setting. The DACs are relay based for neutron resistance. The delay circuits are also relay based, switching in various lengths of delay line.

Tweaksweep

This command is similar in character to tweakfocus. If the system is in STANDBY and the mode is REPETITIVE this command runs a routine to simplify the adjustment of the sweep waveform arbitrary waveform generator. Note that to observe the waveforms on a scope it is also necessary to have trigger mode set to 1 to allow sweep triggering in STANDBY.

In this routine pressing:-

W or Q changes the selected parameter to be adjusted
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
ESC will exit the routine

Tweaksweep uses abbreviations of the 14 parameters to be adjusted (14 = the 13 of the table entries + the sweep number that sets which table is being modified).

Sweep #	Swp#
swp_T1dac	1dac
swp_T2del	2del
swp_T2dac	2dac
swp_T3del	3del
swp_T3dac	3dac
swp_T4del	4del
swp_T4dac	4dac
swp_T5del	5del
swp_T5dac	5dac
swp_bidac	Bdac
swp_diode	Dbia
swp_hold	hdel
swp_time	psec

On exit the parameters will remain as they have been adjusted, but note that this data is volatile. It will be lost if the system power is cycled unless it is explicitly save in the calibration eeprom. The data can be read with hd@sweepcal.

Note that when the HDISC system is in SAFE state the default calibration sweep data can be overwritten using hd!sweepcal. This allows the facility to keep the sweep calibration data for each HDISC head in the remote computer rather than in the calibration eprom.

The complete sweep AWG system is contained in the HDISC head, so the sweep data is the property of the HDISC head serial number rather than of the rack controller serial number.

On exit from tweaksweep a parameter is returned on the stack. This is 0 for success and -1 for fail. If tweaksweep returns non zero this means the system is not in STANDBY, and/or the mode is not REPETITIVE.

The number that Tweaksweep leaves on the stack will prevent the short format level 1 and 2 commands from operating the first time. After one has failed, the stack will be cleared and it will work the second time. Generally conclude a tweak focus session with a “drop” command to clear the stack. The number of items left on the stack is indicated by the number following the response ok. e.g. ok-3 means there are three items on the stack and three drops are required. Failing to execute a legal command also clears the stack.

```
********************************
MPE ROM PowerForth for Cortex-M3
v7.06 [build 0716] 3 Apr 2019, 11:44:42
********************************
19488 bytes free

 ok

1 hd_strt {1 hd_strt;0 }
 ok

hd_rqsb {hd_rqsb;0 }
 ok

tweaksweep

use q and w choose param then decrement/increment with 1 2 3 4 5 6
Swp# 1dac 2del 2dac 3del 3dac 4del 4dac 5del 5dac Bdac Dbia hdel psec
  0  255    0  255    0  255    0  255    0  255   42    1    0 1000
^^^^^
Swp# 1dac 2del 2dac 3del 3dac 4del 4dac 5del 5dac Bdac Dbia hdel psec
  0  255    0  255    0  255    0  255    0  255   42    1    0 1000
^^^^^
Swp# 1dac 2del 2dac 3del 3dac 4del 4dac 5del 5dac Bdac Dbia hdel psec
  0  255    0  255    0  255    0  255    0  255   42    1    0 1000
    ^^^^^
Swp# 1dac 2del 2dac 3del 3dac 4del 4dac 5del 5dac Bdac Dbia hdel psec
  0  255    0  255    0  255    0  255    0  255   42    1    0 1000
         ^^^^^
 ok-1
hd_rqsb {hd_rqsb;?stack}
 ok
hd_rqen {hd_rqen;0 }
 ok

hd_rqsf {hd_rqsf;0 }
 ok
```

```
0 0 0 0 hd!cmmd {0 0 0 0 hd!cmmd;0 }
 ok
hd_rqsb {hd_rqsb;0 }
 ok
  ok
hd_rqen {hd_rqen;0 }
  ok      Wait for the unit to energise ~ 10 seconds.
tweakfocus

use q and w choose param then decrement/increment with 1 2 3 4 5 6

VPC   VME   VL1   VL3    VCO
15000 10616 10254 10286   900
^^^^^

VPC   VME   VL1   VL3    VCO
15000 10616 10254 10286   900
      ^^^^^

VPC   VME   VL1   VL3    VCO
15000 10616 10254 10286   900
            ^^^^^

VPC   VME   VL1   VL3    VCO
15000 10616 10154 10286   900
            ^^^^^

VPC   VME   VL1   VL3    VCO
15000 10616 10054 10286   900
            ^^^^^

VPC   VME   VL1   VL3    VCO
15000 10616 10054 10286   900
      ^^^^^

VPC   VME   VL1   VL3    VCO
15000 10516 10054 10286   900
      ^^^^^ ok-1
```

Figure 16 Example of how to use the two tweakers **tweaksweep** and **tweakfocus**.

11.18.3 STORING NEW DATA INTO THE CALIBRATION FILE

Any new set up can be stored into non-volatile EEPROM. Note however, that this will store the data for a particular head into a particular RHIC. If the head is connected to a different RHIC the data which that unit has stored will be loaded up. There is no way to store the data in the head. The two options are either to add the new data to all RHICs, or not to use the facility and always download data at boot time from the user's computer system.

To store into the RHIC eprom execute the following command (The small black write enable button on the rear of the RHIC should be held down as the carriage return is hit. This button is not labelled.):

ee!cal cr

We recommend that the storage of the data be checked after this operation. Cycle the power, restore the device to the previous state and read the current data values that should have changed to the new default specified by the new data in the EEPROM.

Users who wish to switch between several sets of data may find it easier to download this data each time the unit is powered up. In this way all the RHICs will retain the same data and the user will always download the required set up data. The **hd!focus** and **hd!swpcal** commands will enable this see 11.16.3 on page 48.

11.18.4 READING AND WRITING THE SWEEP TABLES

The sweep table is part of the calibration data, this is read from the calibration EEPROM at power up or reset. Any changes will be lost unless it is explicitly saved to EEPROM.

ee!cal saves the current calibration data, including the sweep table, to EEPROM

Note that the calibration EEPROM is write protected and the write enable button on the rear panel of the rack controller must be operated.

A good procedure is:- 1) type ee!cal 2) press and hold write enable button

3) press return 4) wait for "ok" prompt 5) release write enable button

The sweep table can hold data for 16 different sweeps, numbered 0 thru 15. Currently defined sweeps are:-

0 1ns 1 2ns 2 5ns 3 10ns 4 20ns

Each sweep entry consists of 13 fields.

swp_time

swp_hold

swp_diode

swp_T1dac

swp_T2dac

swp_T3dac

swp_T4dac

swp_T5dac

swp_bidac

swp_T2del

swp_T3del

swp_T4del

swp_T5del

The first field “swp_time” is intended to hold the physical sweep speed in picoseconds but is not used at present. The ramp circuit works by adding five stages together. The timing of four of the stages w.r.t. the previous stage, and the bias conditions of all five stages can be adjusted independently. This gives a degree of arbitrary waveform generation ability. See Figure 15 on page 55

There is a hold off circuit that clamps the deflection to stop retrace.

In addition there is a signal to trigger the cathode -mesh blanking circuit at the end of the ramp but the timing of this is not adjustable in hDISC.

There are 13 fields to control the sweep module hardware. The fields do the following things:

swp_time		for reference, not used
swp_bidac	(0 thru 255)	the setting of the relay bias dac for optimum bias voltage for this sweep speed
swp_hold	(-1, 0,1)	delay for hold off circuit (0 = none, -1 or 1 = delayed ~10ns cable delay)
swp_diode	(0 thru 2)	setting of diode bias current dac. Used to increase the speed slightly Only used on the fastest sweep.
swp_T1dac	(0 thru 255)	the setting of the relay dac bias for stage T1
swp_T2dac	(0 thru 255)	the setting of the relay dac bias for stage T2
swp_T3dac	(0 thru 255)	the setting of the relay dac bias for stage T3
swp_T4dac	(0 thru 255)	the setting of the relay dac bias for stage T4
swp_T5dac	(0 thru 255)	the setting of the relay dac bias for stage T5
swp_T2del	(0 thru 63)	the setting of the relay delay cct for stage T2
swp_T3del	(0 thru 63)	the setting of the relay delay cct for stage T3
swp_T4del	(0 thru 63)	the setting of the relay delay cct for stage T4
swp_T5del	(0 thru 63)	the setting of the relay delay cct for stage T5

The fields can be individually read with the following words:-

Word	Stack effect
@swp_time	(swp# -- n)
@swp_hold	(swp# -- n)
@swp_diode	(swp# -- n)
@swp_T1dac	(swp# -- n)
@swp_T2dac	(swp# -- n)
@swp_T3dac	(swp# -- n)
@swp_T4dac	(swp# -- n)
@swp_T5dac	(swp# -- n)
@swp_bidac	(swp# -- n)
@swp_T2del	(swp# -- n)
@swp_T3del	(swp# -- n)
@swp_T4del	(swp# -- n)
@swp_T5del	(swp# -- n)

e.g. 3 @swp_bidac .

will print the bias dac setting for sweep 3

The fields can be individually written to RAM with the following words:-

Word	Stack effect
!swp_time	(n swp# --)
!swp_hold	(n swp# --)
!swp_diode	(n swp# --)
!swp_T1dac	(n swp# --)
!swp_T2dac	(n swp# --)
!swp_T3dac	(n swp# --)
!swp_T4dac	(n swp# --)
!swp_T5dac	(n swp# --)
!swp_bidac	(n swp# --)
!swp_T2del	(n swp# --)
!swp_T3del	(n swp# --)
!swp_T4del	(n swp# --)
!swp_T5del	(n swp# --)

e.g. 27 5 !swp_T2del will set the relay trigger delay of T2 in sweep five to twenty seven.

Existing sweeps can be edited by changing individual fields as above, though it is recommended that new sweeps are defined rather than changing existing ones.

To set up a new sweep one needs to define all twelve fields (sweep time is unused). To simplify this process we have provided the command tweaksweep, see "Tweaksweep" on page 56. This can be used in connection with a terminal emulator program e.g. Hyperterminal to edit all the parameters in the sweep table while the ramp waveforms are monitored on a scope. This can be most conveniently done in STANDBY with trigger mode set to 1 and camera mode set to repetitive, this allows editing of the ramps without applying high voltages to the tube.

Don't forget to save the calibration to EEPROM with ee!cal and button as stated above.

12. CATHODE PACK

The unit is delivered with a user supplied 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.

13. TUBE DATA

13.1 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. HDISC has more adjustable electrodes than our standard camera tube and more than the upgraded DISC tubes. There will be many focus conditions. This has been done to accommodate a smaller sensor placed closer to the sweep plates than our standard set up has.

The following voltages produced a good focus on our detector.

VPC	VME	VL1	VL3	VCO
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.

13.2 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.

14. 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 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.

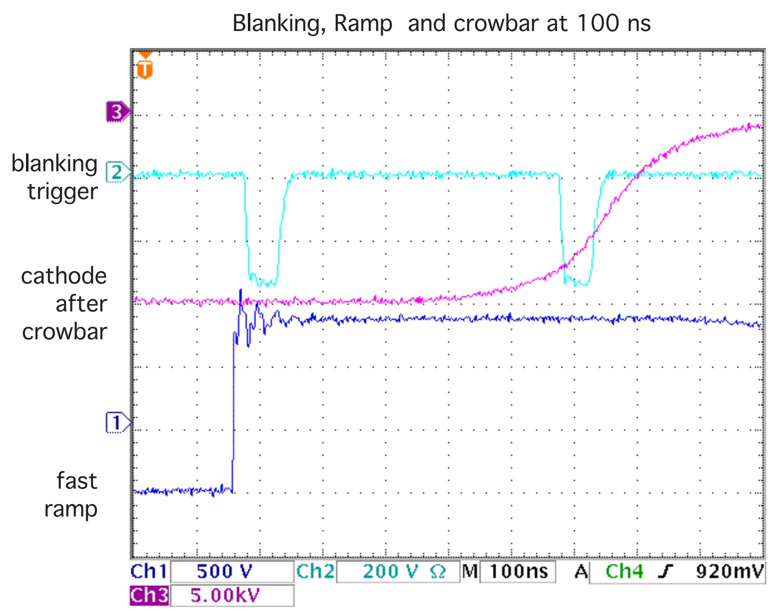

Figure 17 The relative timing of the blanking trigger and cathode voltage w.r.t. the fastest sweep. The cathode voltage goes to zero due to the crowbar switch.

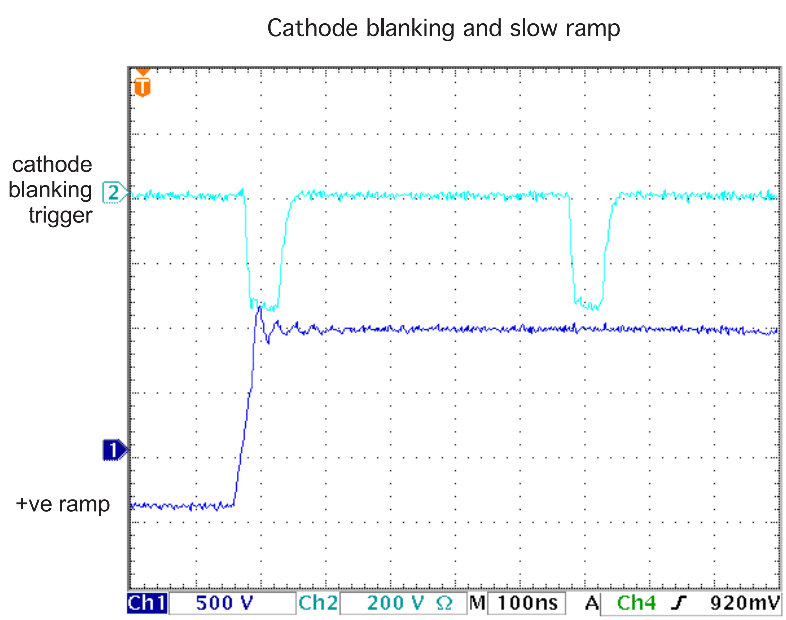

Figure 18 The relative timing of the blanking trigger and cathode voltage w.r.t. the slowest sweep.

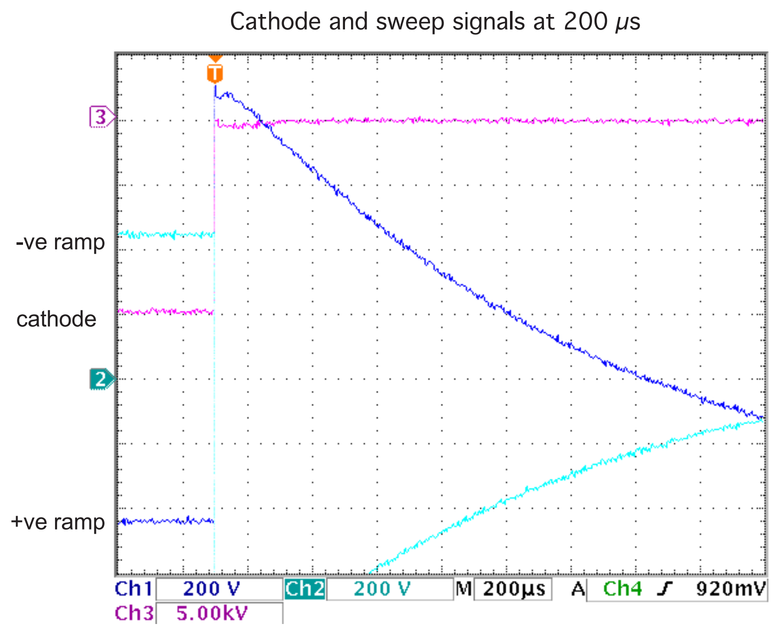

Figure 19 The cathode voltage and sweep output ramps on a 1 ms time scale.

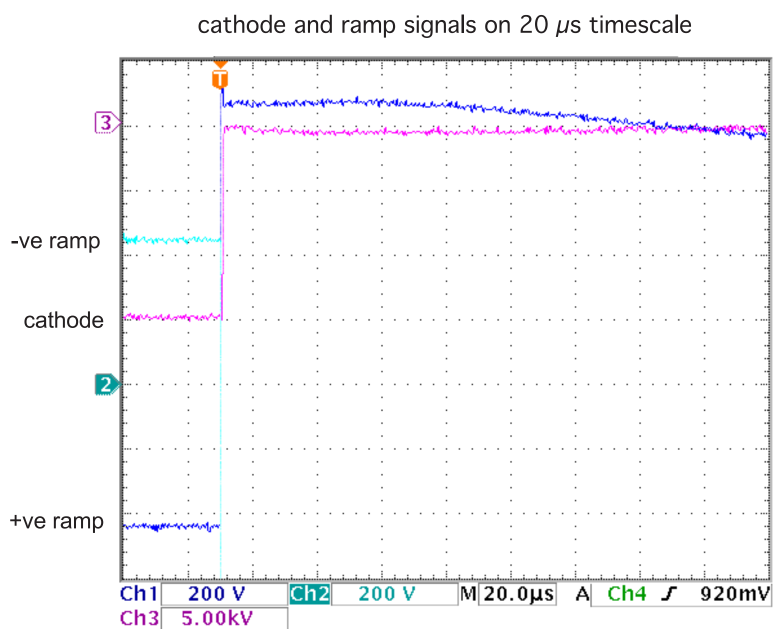

Figure 20 The cathode voltage and sweep output ramps on a 100 µs time scale.

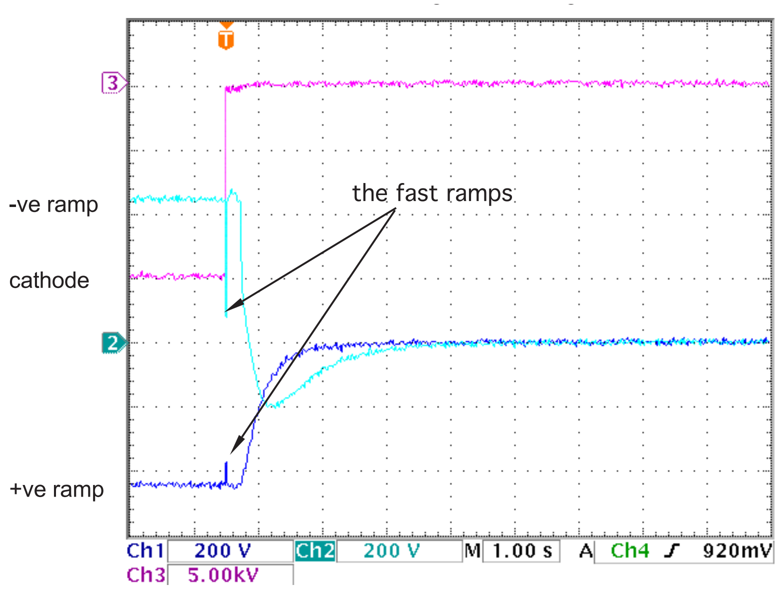

Figure 21 The cathode voltage and sweep output ramps on a 100 ms time scale in single shot mode. The ground for the ramp signal is at the “2” label. The ramps sweep and then after ~10 ms they return to zero. I.e. the beam will end up in the centre of the output sensor.

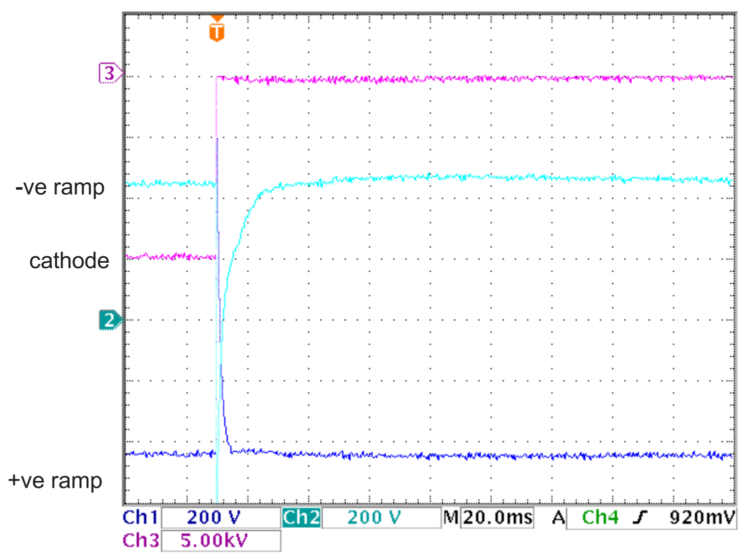

Figure 22 The cathode voltage and sweep output ramps on a 100 ms time scale in repetitive mode. The ground for the ramp signal is at the “2” label. The ramps sweep and then after ~10 ms they return to the pre sweep setting. I.e. the beam will re-cross the output sensor.

Long time history of bias voltages in single shot mode with crowbarring and blanking

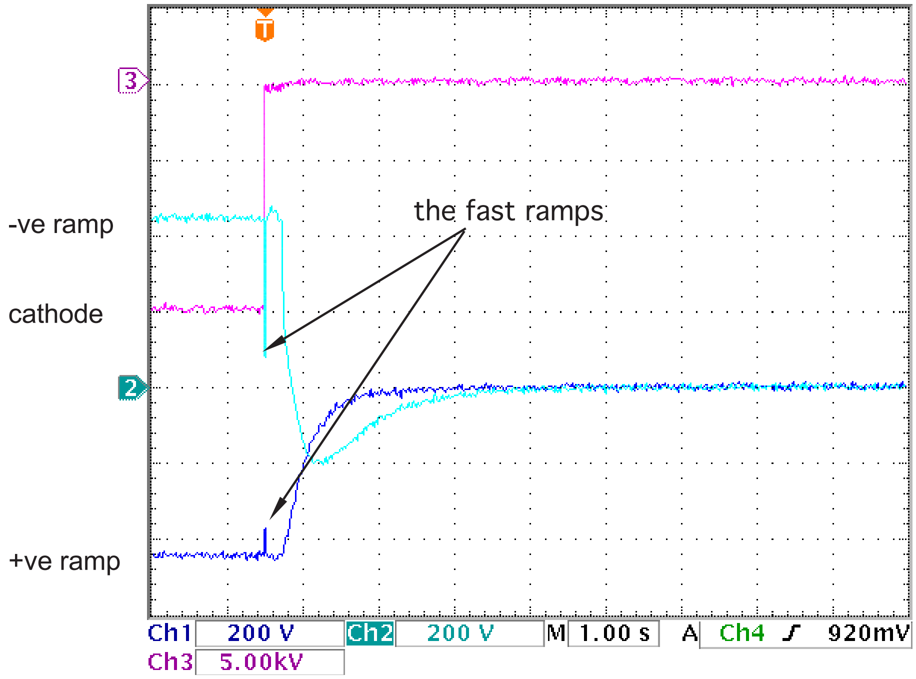

Figure 23 Note: in single shot mode the bias is turned off so the end state is with the beam in the sensor centre. In repetitive mode the beam returns to the start position.

15. SWEEP DATA

With a Kentech phosphor fitted and the cathode set at 14 kV (the voltage DISC currently operates at), the deflection sensitivity is ~17 V/mm.[FN2] The phosphor is 39 mm diameter giving a voltage requirement of 633 volts to go across the screen. It is anticipated that the user will fit their own directly bombarded CMOS or HCMOS sensor. This will be rectangular but although it will be closer to the sweep plates it is likely to use a similar angular deflection as our standard configuration. Consequently the deflection voltage to cross the sensor will be similar to that required to cross the projection of the sensor onto the phosphor. i.e. <633 volts. In the sweep data presented here the sweep wave from is superimposed on a pair of lines that represent a range of 640 volts. The ramp drives the plates in an unterminated configuration so for waveforms shown driving 50Ω the two lines represent the halved voltage of 320 V. It is necessary to drive the ramp into 50Ω to see the fast characteristics. These lines represent the linear range required over the sensor. A bias voltage is added to the ramps. This sets the start position off screen and also selects the most linear part of the particular ramp by biasing the waveform to put the middle of the linear part at sensor centre. The different ramp speeds require a different bias voltages to make the best use of the linear part of the ramp. The bias voltages are stored in the calibration data along with the parameters required to set up a ramp speed. Note that the time the swept beam takes to arrive at screen centre after a trigger depends upon the ramp speed and also the starting point. So if the beam starts further off centre an earlier trigger is required. As the users system trigger drives the RHIC which is located up to 50m from the head making absolute measurements of the trigger delay is not useful. However, the relative timing between different ramps will be useful at least for initial estimates of the trigger timing.

15.1 EXAMPLE OF SWEEP DATA

In Figure 24 on page 67 the output of the ramps into a 50 Ω load is shown. The horizontal cursors are set at -156 V and -476.6 V. These are with respect to the negative going (yellow) ramp. The difference between the figures is the voltage needed to cover the sensor (plus a margin) = 320.6 V The offset to the average of the two cursors is the bias voltage that must be added to the ramp to move the operating point to sensor centre. However, as these measurements are into 50 Ω, all the voltages need to be doubled to give the figure for driving the sweep plate at the end of a cable. So the bias added to the negative ramp is +632.6 V. Similarly the bias added to the positive ramp will be -632.6 V. At sensor centre the sum of the two biases and the two ramps = 0.

The 50Ω load is useful for looking at the transition of the ramp waveforms i.e. the actual ramp. It is not useful for looking at the long time history of the waveform as it loads the driver and pulls down the voltage. To see the long time history the ramp is driven into a high impedance monitor. This does not have the bandwidth to see the ramps in detail. On a long timescale it is important that the difference between the ramp voltages does not collapse early or the beam will be brought back onto the sensor. Note that it is the ramp difference that is important for this, not the absolute value of each ramp. The two ramps are generated from a single pulser but one needs inverting. The inverted ramp will collapse to ground faster than the uninverted one but the difference between the ramps will be maintained during this collapse. The uninverted one will rise as the inverted on collapses.

For the 20 ns ramp, driving 50 Ω is too low an impedance and the data is shown with this driving 1 kΩ. There is therefore a correction factor of 0.9524 due to the transmission coefficient form 50 Ω into 1 kΩ compared to an open circuit termination.

FN2 For both the bias and the ramp, these voltages are the single plate voltages. The other plate is driven by the same amplitude but with opposite polarity. The bias voltage has the opposite polarity to the ramp.

15.2 SWEEP (0) 1ns DURATION

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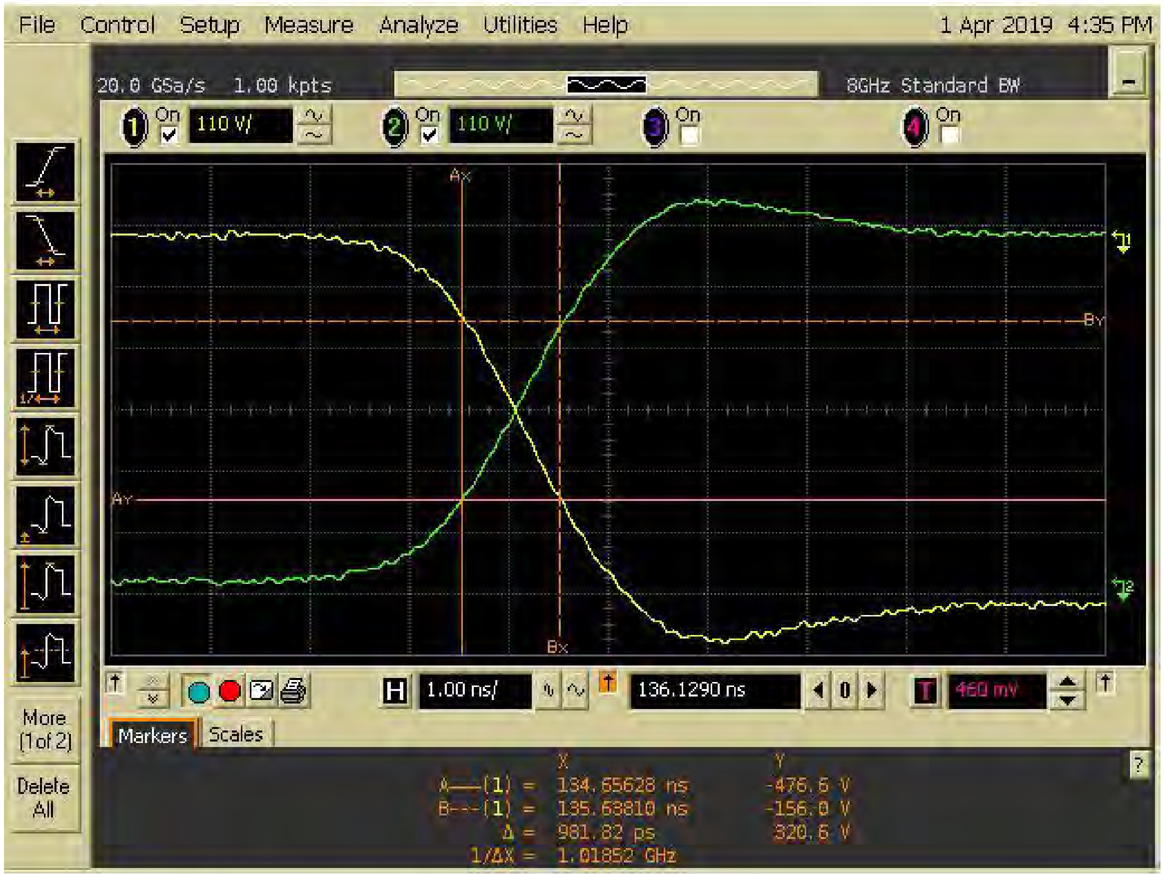
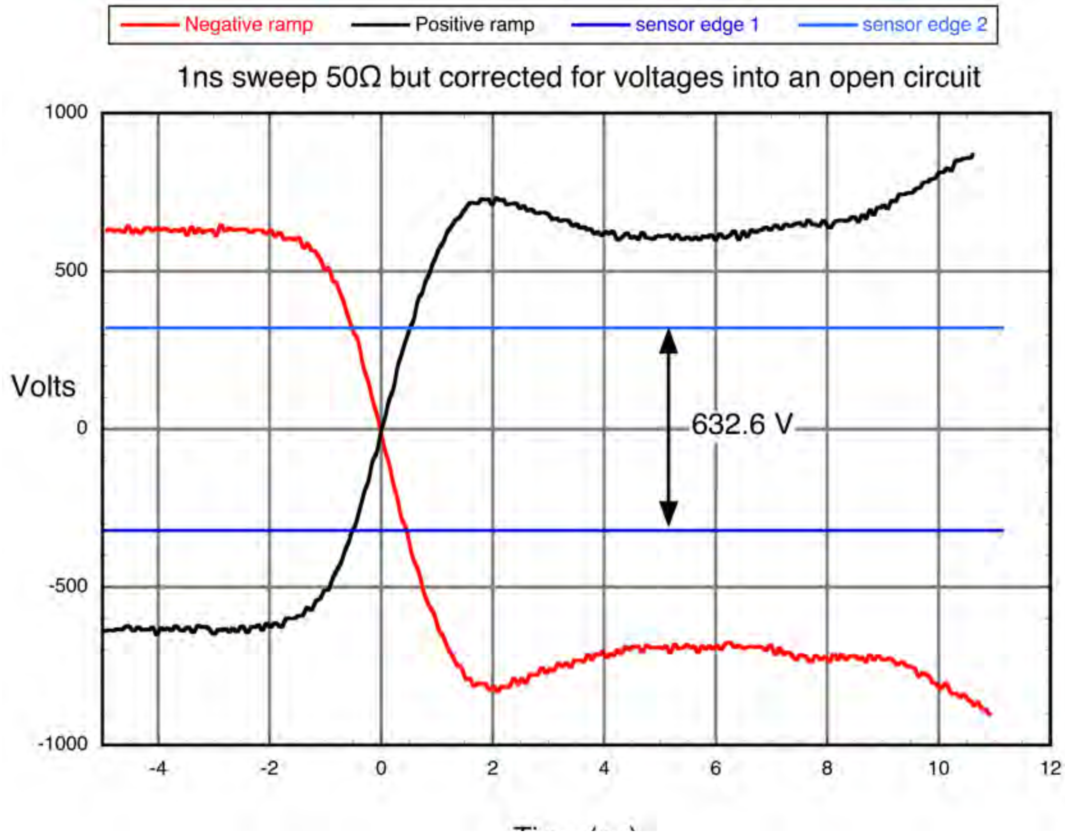


Acquisition	Sampling mode real time Normal Memory depth automatic 1000 pts Sampling rate automatic Sampling rate 20.0 GSa/s Averaging off Interpolation on
Channel 1	Scale 110 V/ Offset -314.0 V Coupling DC Impedance 50 Ohms
Channel 2	Scale 110 V/ Offset 306.0 V Coupling DC Impedance 50 Ohms
Channel 4	Scale 100 mV/ Offset 60.0 mV Coupling DC Impedance 50 Ohms
Time base	Scale 1.00 ns/ Position 136.1290 ns Reference center
Trigger	Mode edge Sweep triggered Sensitivity low Holdoff time 100 ns Source channel 4 Trigger level 460 mV Slope rising

Marker

	X	Y
A——(1) =	134.65628 ns	-476.6 V
B---(1) =	135.63810 ns	-156.0 V
Δ =	981.82 ps	320.6 V
1/ΔX =	1.01852 GHz	

Figure 24 The 1 ns duration sweep output into 50 Ω.
All voltages are half the actual one.



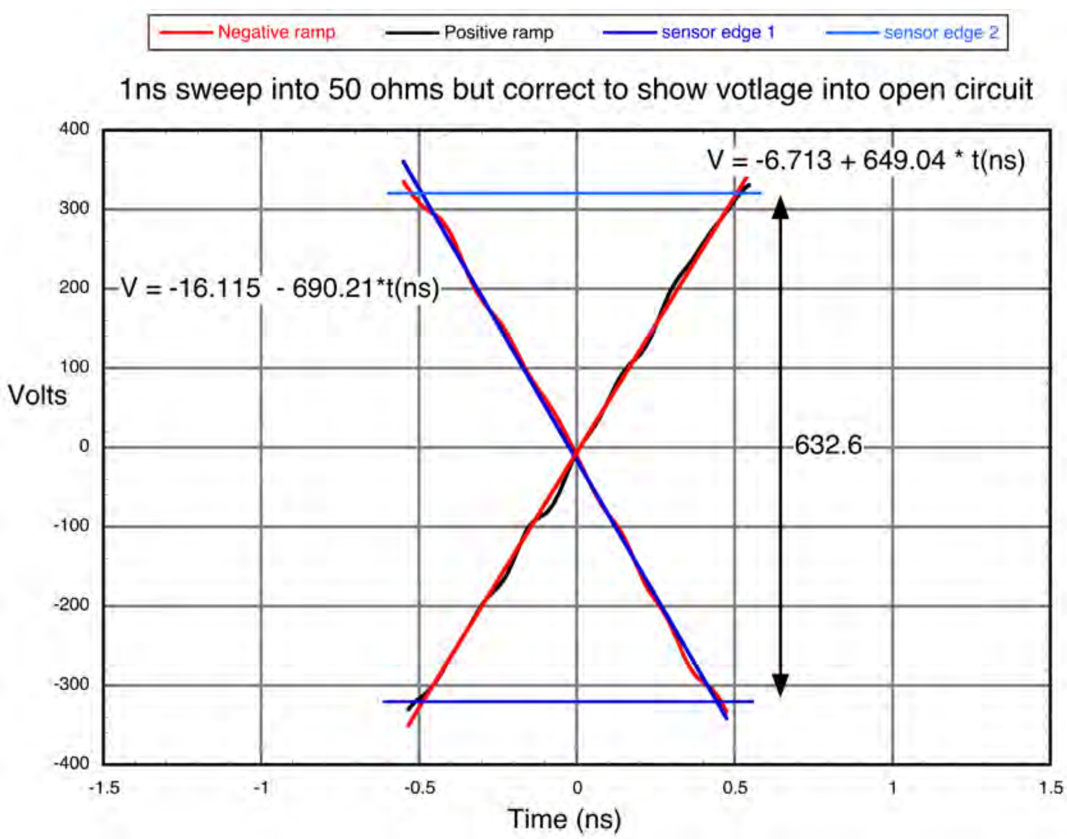


Figure 25 1ns sweep details

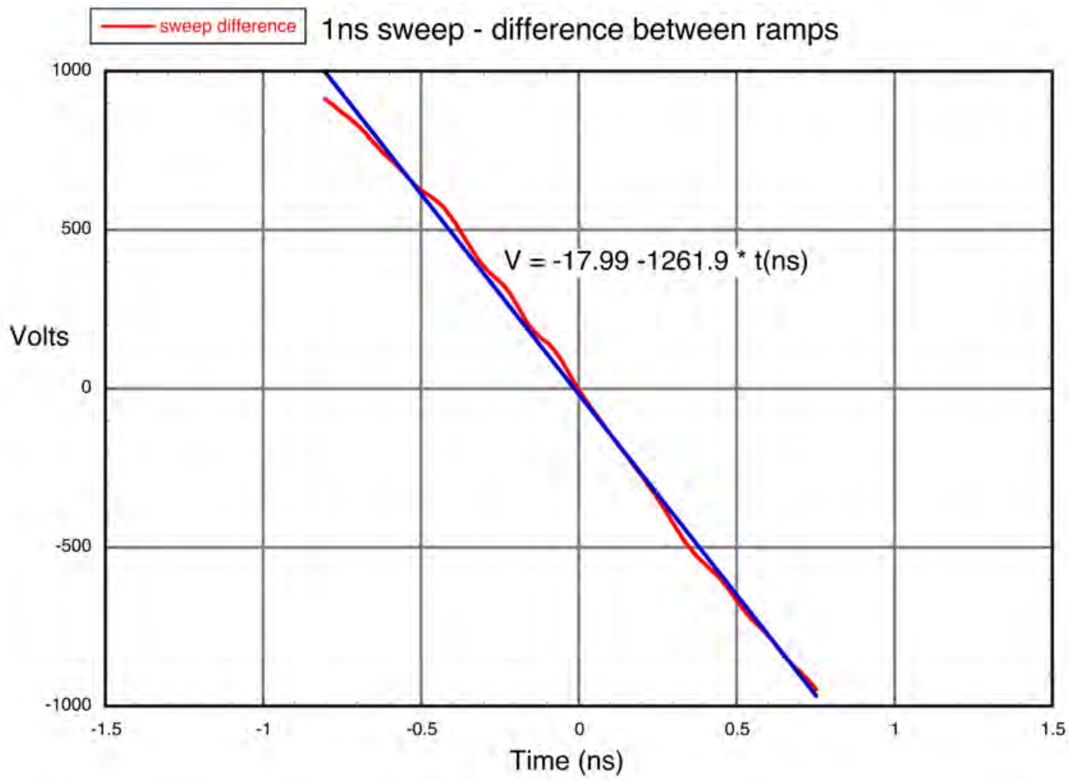


Figure 26 1 ns sweep ramp difference
showing that most wrinkles cancel but leaving some low
frequency movement that can be calibrated out.

15.3 SWEEP (1) 2 ns DURATION

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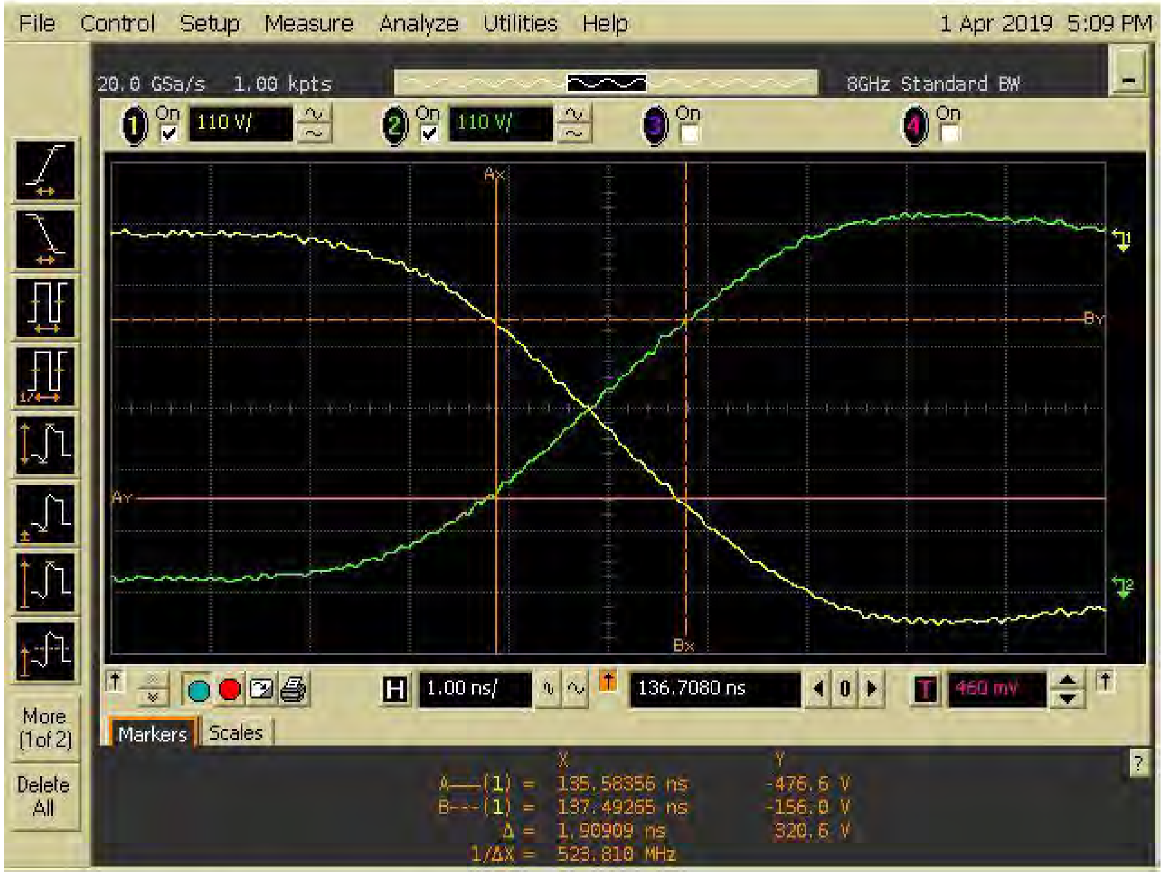


Acquisition	Sampling mode real time Normal Memory depth automatic 1000 pts Sampling rate automatic Sampling rate 20.0 GSa/s Averaging off Interpolation on
Channel 1	Scale 110 V/ Offset -314.0 V Coupling DC Impedance 50 Ohms
Channel 2	Scale 110 V/ Offset 306.0 V Coupling DC Impedance 50 Ohms
Channel 4	Scale 100 mV/ Offset 60.0 mV Coupling DC Impedance 50 Ohms
Time base	Scale 1.00 ns/ Position 136.7080 ns Reference center
Trigger	Mode edge Sweep triggered Sensitivity low Holdoff time 100 ns Source channel 4 Trigger level 460 mV Slope rising

Marker

	X	Y
A——(1) =	135.58356 ns	-476.6 V
B---(1) =	137.49265 ns	-156.0 V
Δ =	1.90909 ns	320.6 V
1/ΔX =	523.810 MHz	

Figure 27 The 2 ns duration sweep output into 50 Ω.
All voltages are half the actual one.

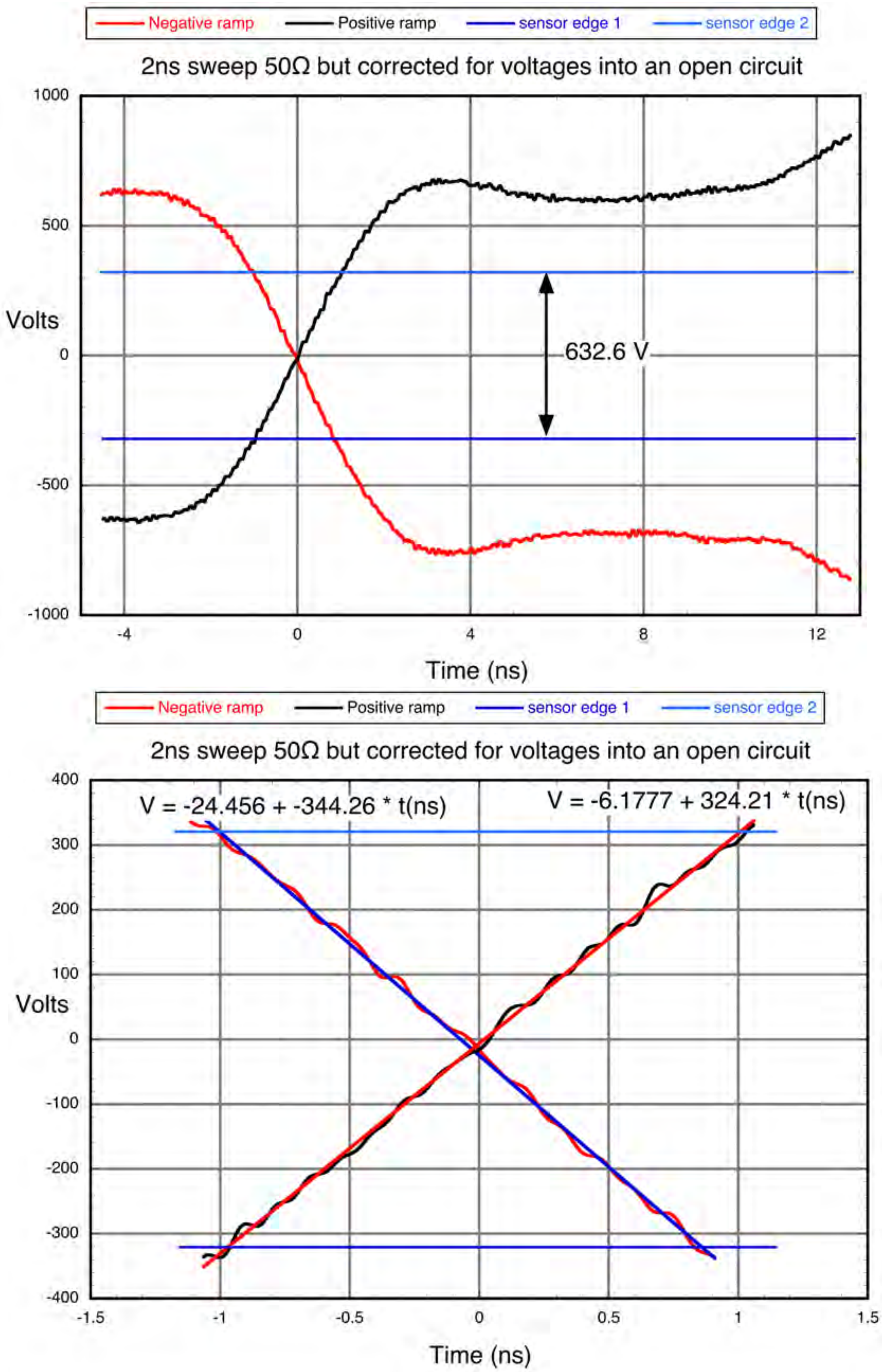


Figure 28 2 ns sweep details

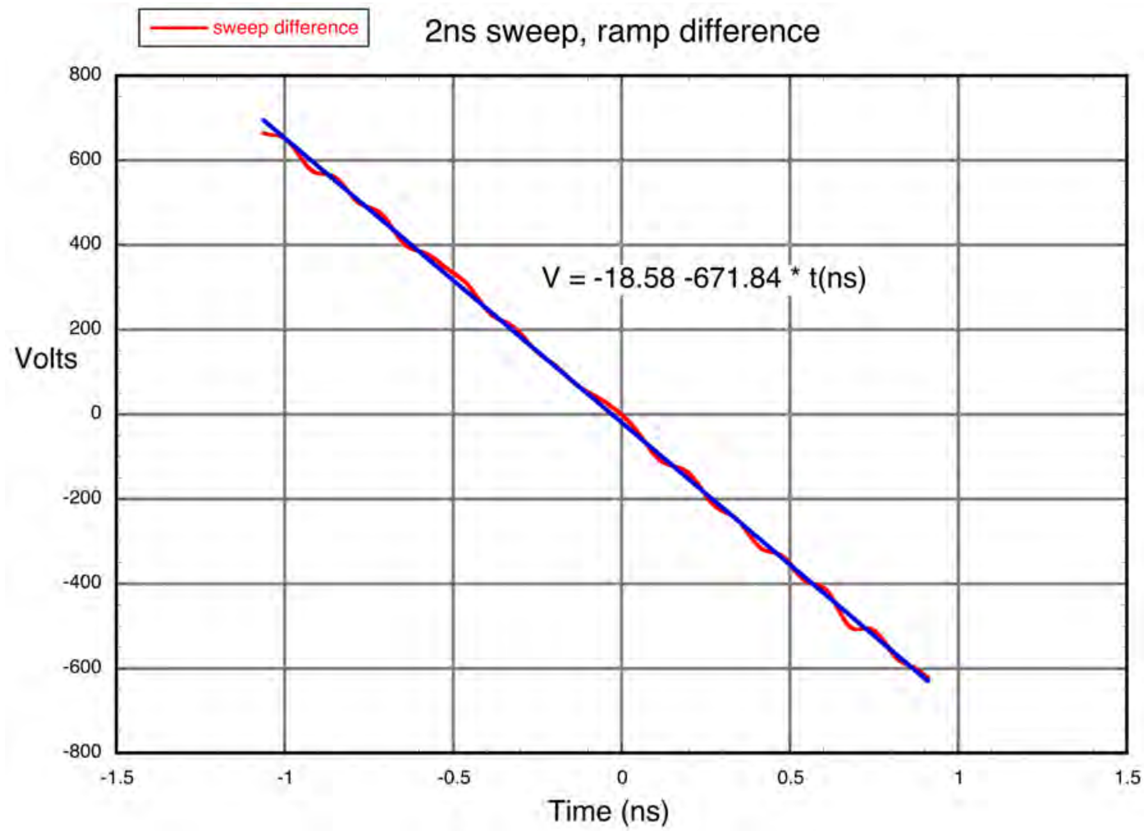
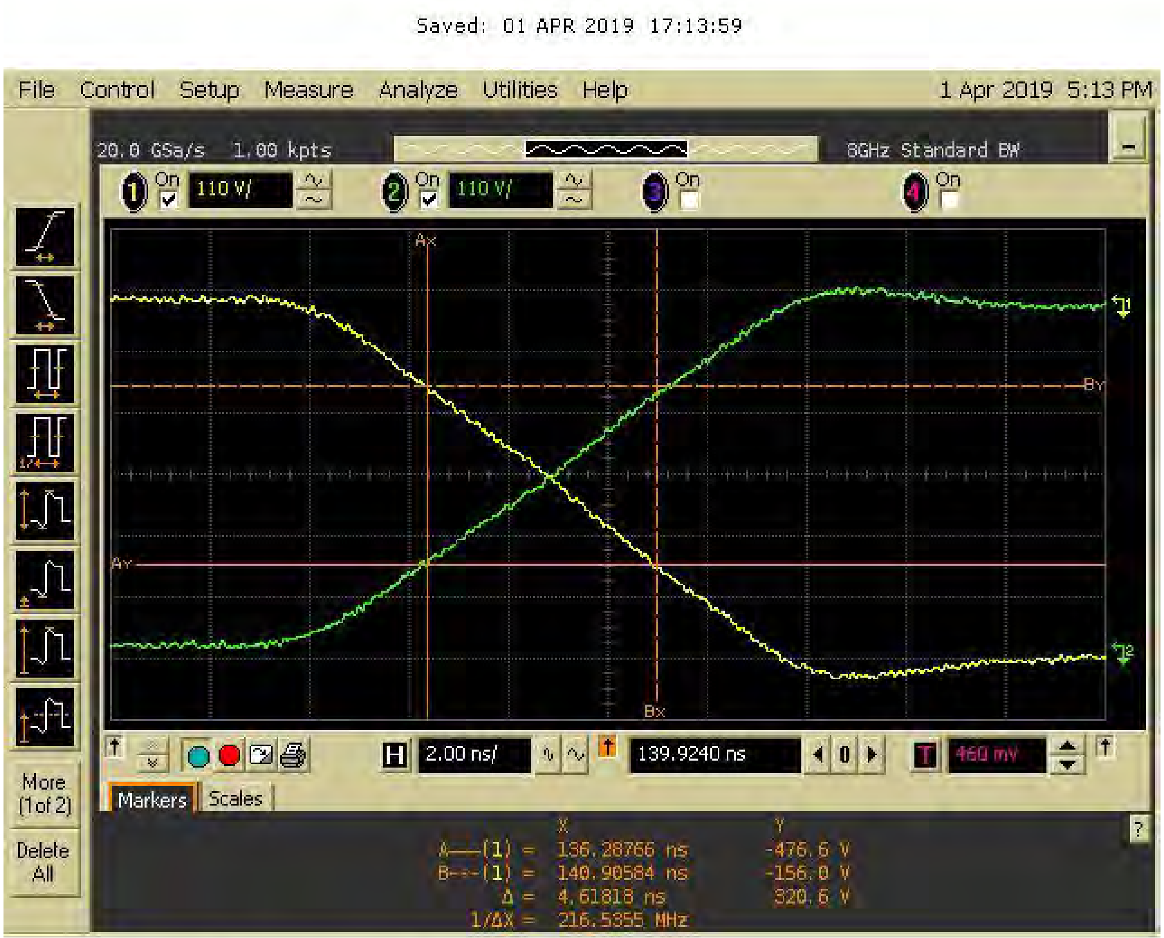


Figure 29 2 ns sweep ramp difference
showing that most wrinkles cancel but leaving some low frequency movement that can be calibrated out.

15.4 SWEEP (2) 5 ns DURATION

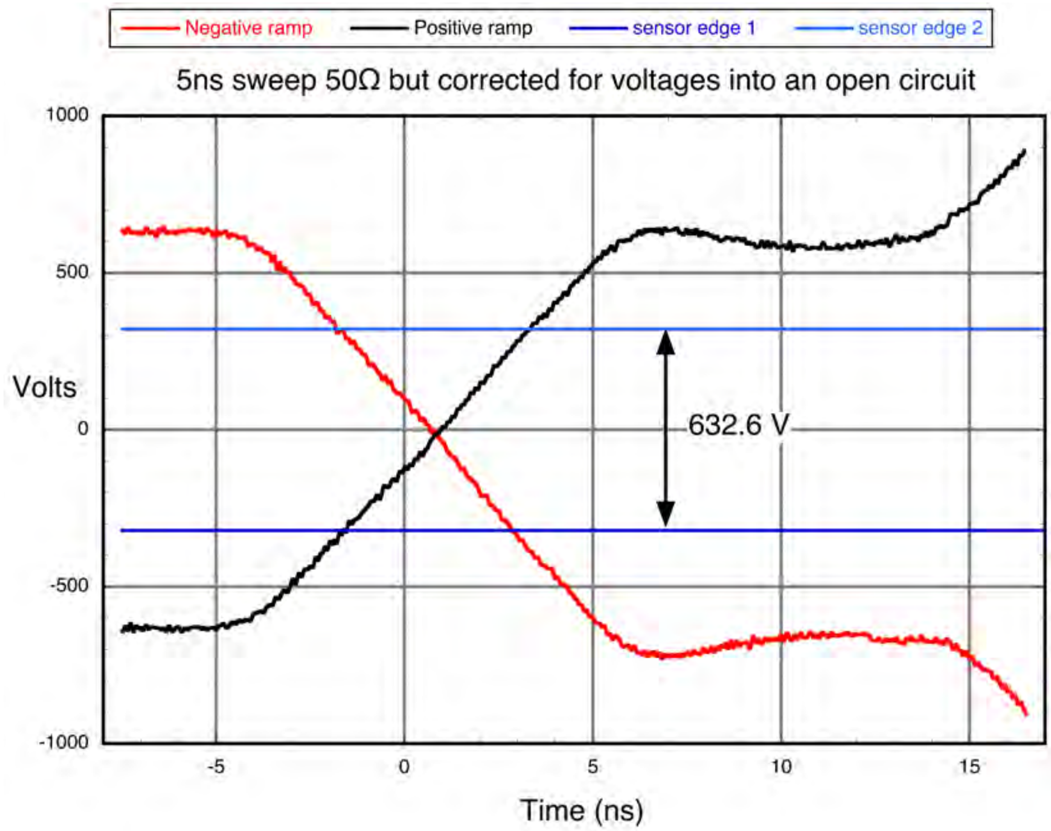


Acquisition	Sampling mode real time Normal Memory depth automatic 1000 pts Sampling rate automatic Sampling rate 20.0 GSa/s Averaging off Interpolation on
Channel 1	Scale 110 V/ Offset -314.0 V Coupling DC Impedance 50 Ohms
Channel 2	Scale 110 V/ Offset 306.0 V Coupling DC Impedance 50 Ohms
Channel 4	Scale 100 mV/ Offset 60.0 mV Coupling DC Impedance 50 Ohms
Time base	Scale 2.00 ns/ Position 139.9240 ns Reference center
Trigger	Mode edge Sweep triggered Sensitivity low Holdoff time 100 ns Source channel 4 Trigger level 460 mV Slope rising

Marker

	X	Y
A—(1) =	136.28766 ns	-476.6 V
B---(1) =	140.90584 ns	-156.0 V
Δ =	4.61818 ns	320.6 V
1/ΔX =	216.5355 MHz	

Figure 30 The 5 ns duration sweep output into 50 Ω.
All voltages are half the actual one.



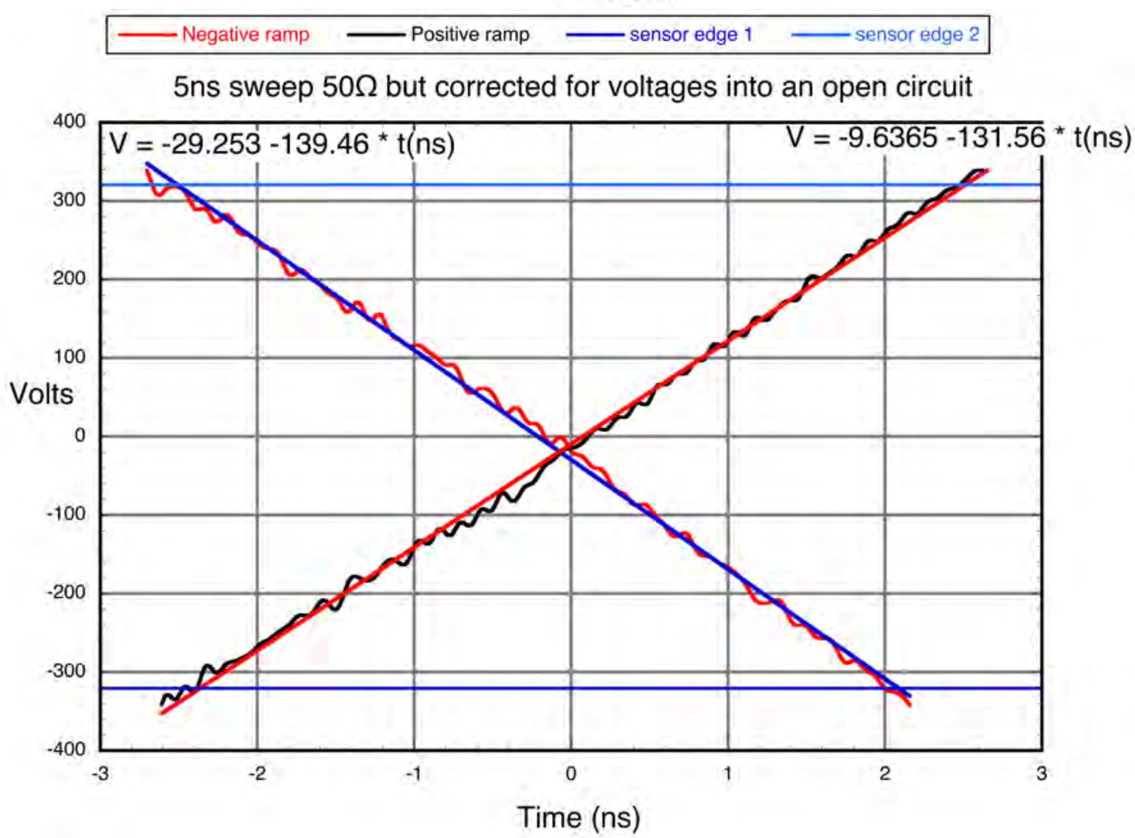


Figure 31 5 ns sweep details

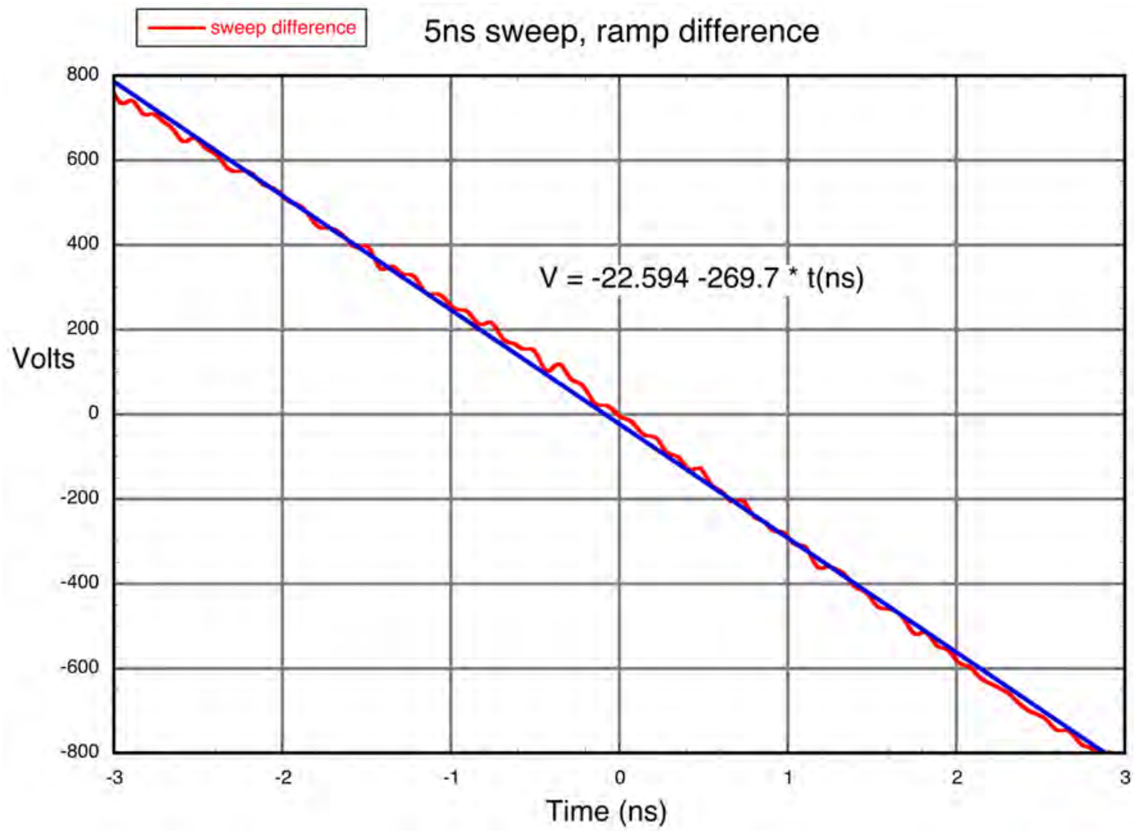


Figure 32 5 ns sweep ramp difference
showing that most wrinkles cancel but leaving some low frequency movement that can be calibrated out.

15.5 SWEEP (3) 10 ns DURATION

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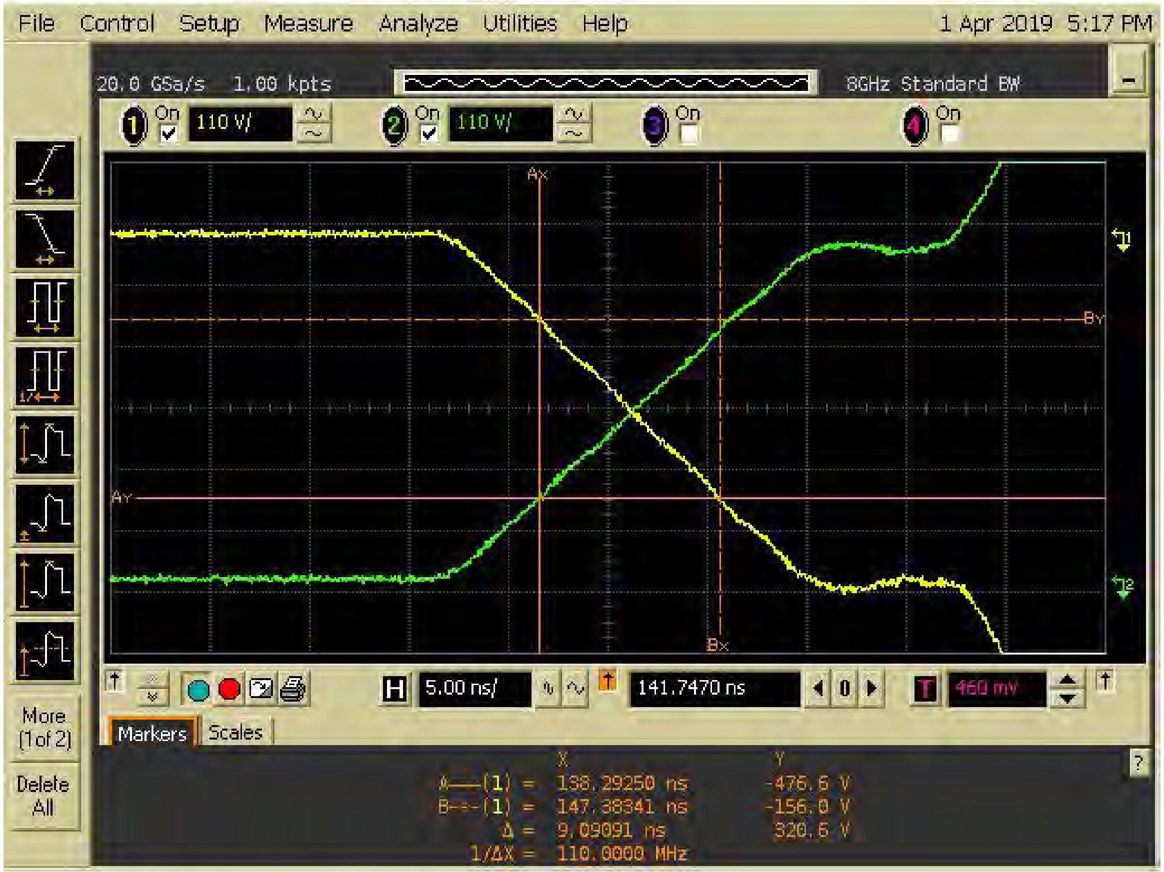
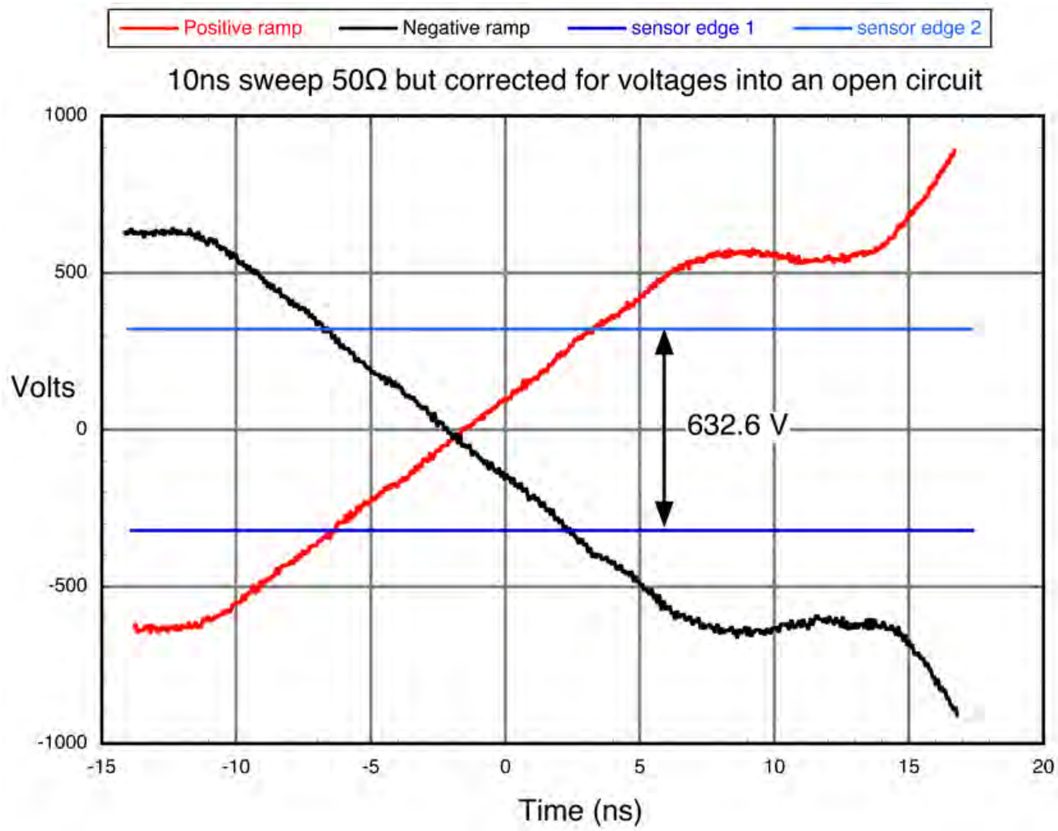


Acquisition	Sampling mode real time Normal Memory depth automatic 1002 pts Sampling rate automatic Sampling rate 20.0 GSa/s Averaging off Interpolation on
Channel 1	Scale 110 V/ Offset -314.0 V Coupling DC Impedance 50 Ohms
Channel 2	Scale 110 V/ Offset 306.0 V Coupling DC Impedance 50 Ohms
Channel 4	Scale 100 mV/ Offset 60.0 mV Coupling DC Impedance 50 Ohms
Time base	Scale 5.00 ns/ Position 141.7470 ns Reference center
Trigger	Mode edge Sweep triggered Sensitivity low Holdoff time 100 ns Source channel 4 Trigger level 460 mV Slope rising

Marker

	X	Y
A—(1) =	138.29250 ns	-476.6 V
B---(1) =	147.38341 ns	-156.0 V
Δ =	9.09091 ns	320.6 V
1/ΔX =	110.0000 MHz	

Figure 33 The 10 ns duration sweep output into 50 Ω.
All voltages are half the actual one.



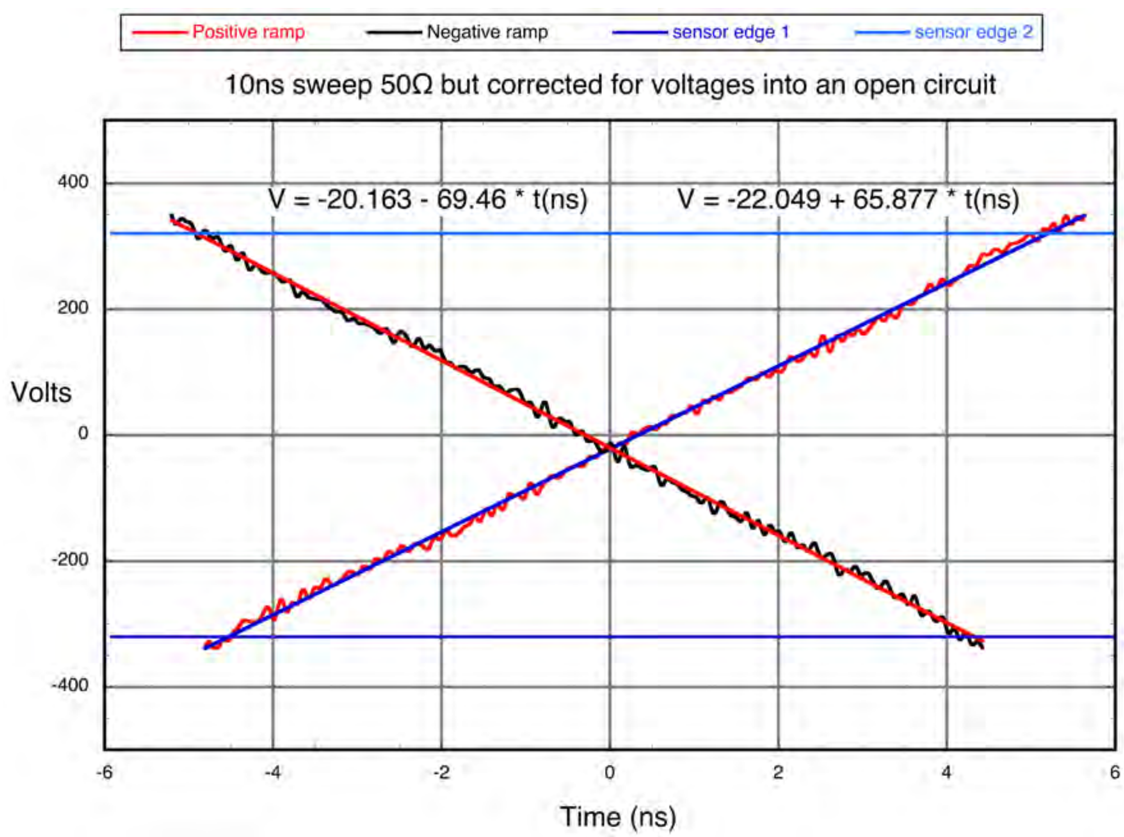


Figure 34 10 ns sweep details

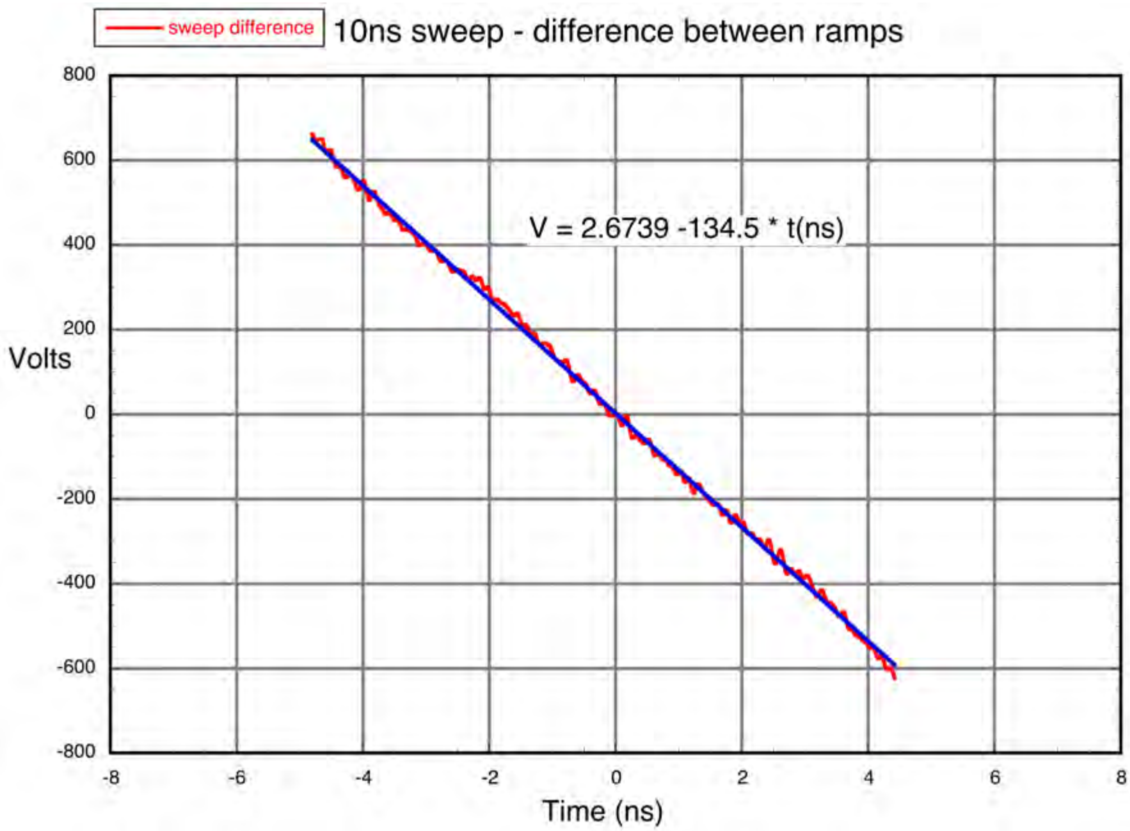
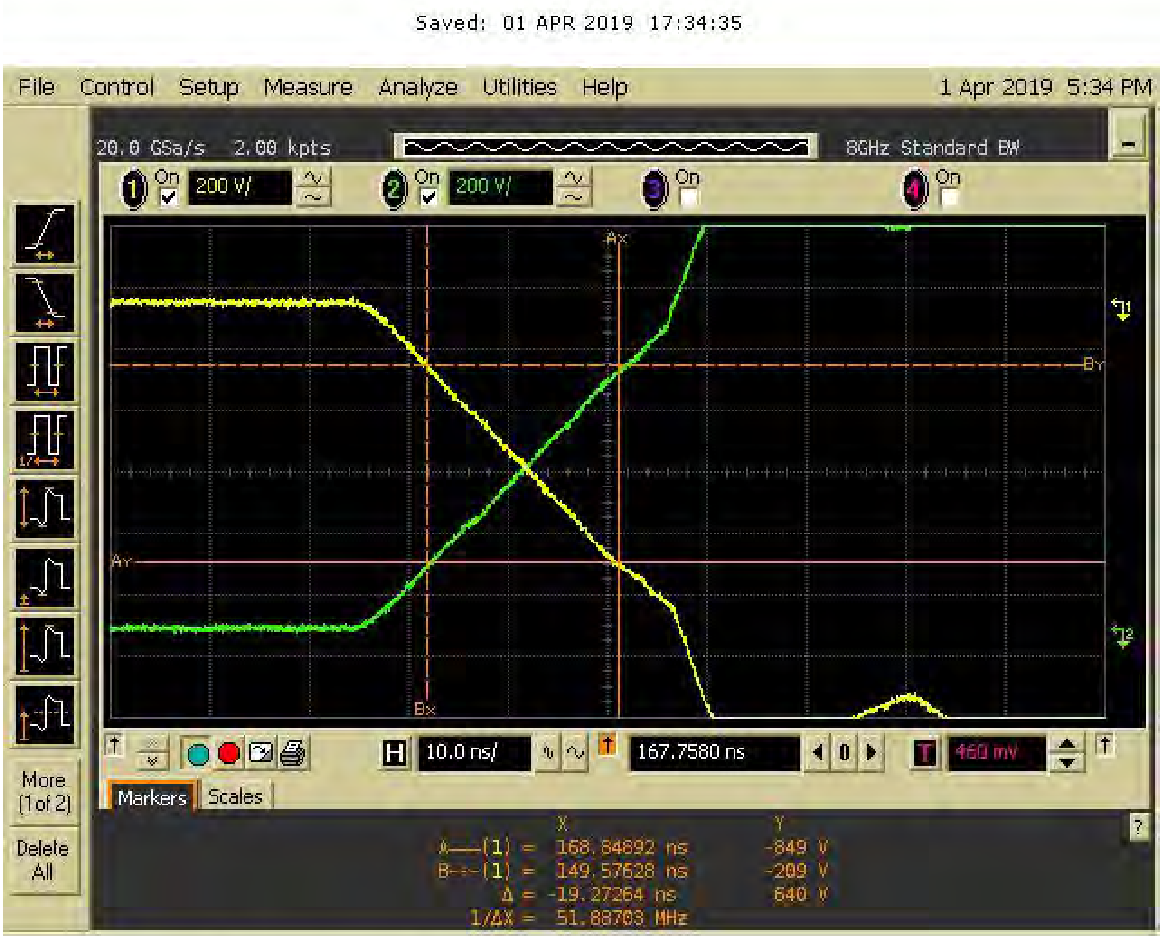


Figure 35   10 ns sweep ramp difference

15.6 SWEEP (4) 20 ns DURATION



Acquisition	Sampling mode real time Normal Memory depth automatic 2002 pts Sampling rate automatic Sampling rate 20.0 GSa/s Averaging off Interpolation on
Channel 1	Scale 200 V/ Offset -554.0 V Coupling DC Impedance 50 Ohms
Channel 2	Scale 200 V/ Offset 509.5 V Coupling DC Impedance 50 Ohms
Channel 4	Scale 100 mV/ Offset 60.0 mV Coupling DC Impedance 50 Ohms
Time base	Scale 10.0 ns/ Position 167.7580 ns Reference center
Trigger	Mode edge Sweep triggered Sensitivity low Holdoff time 100 ns Source channel 4 Trigger level 460 mV Slope rising

Marker

	X	Y
A—(1) =	168.84892 ns	-849 V
B---(1) =	149.57628 ns	-209 V
Δ =	-19.27264 ns	640 V
1/ΔX =	51.88703 MHz	

Figure 36 The 20 ns duration sweep output into 1 kΩ.
The ramp voltages are ~0.92524 of actual ones.

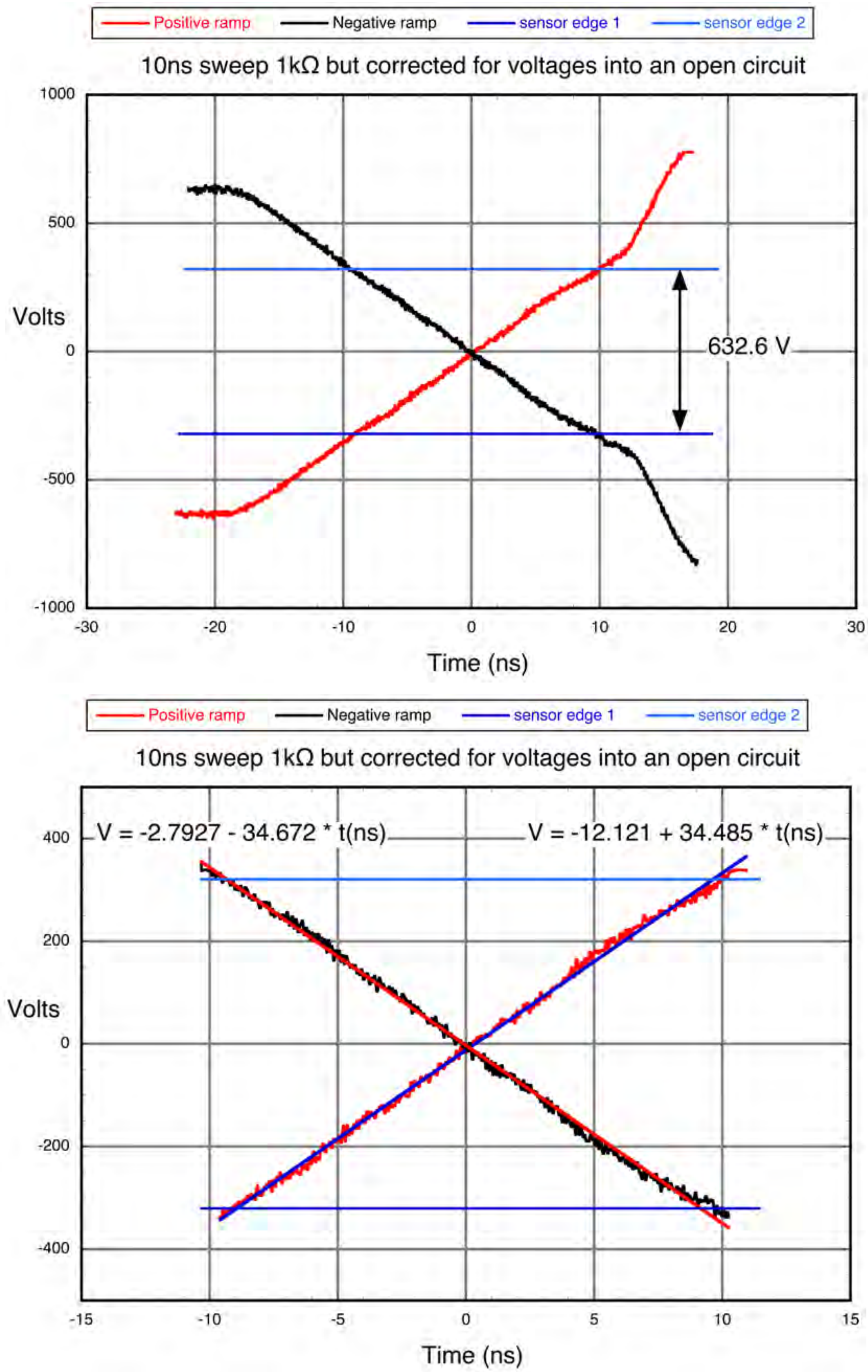


Figure 37   20 ns sweep details

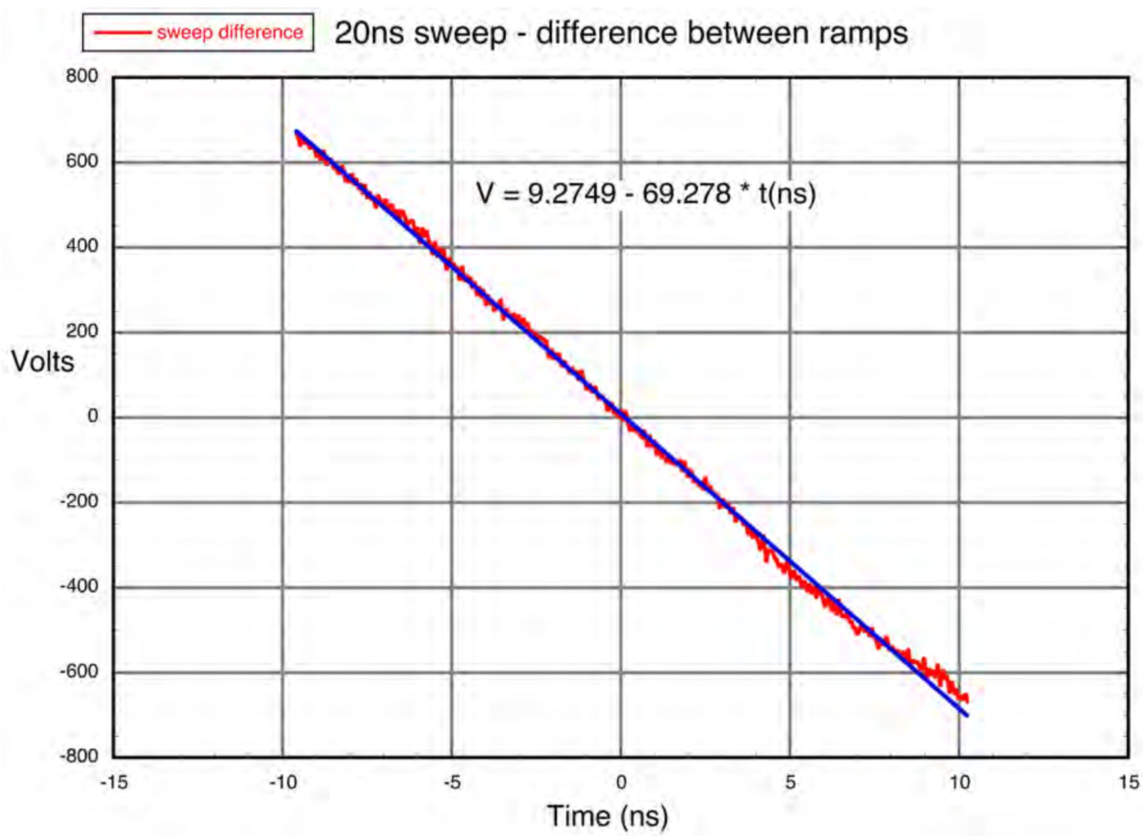
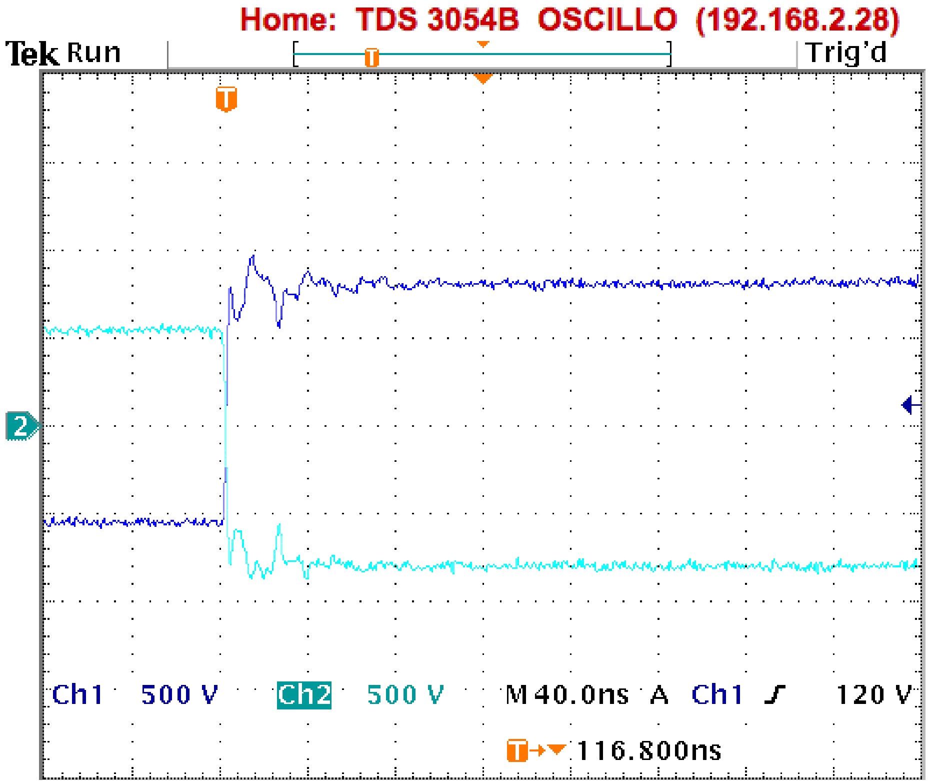


Figure 38 20 ns sweep ramp difference

15.7 SWEEP LONG TIME HISTORY



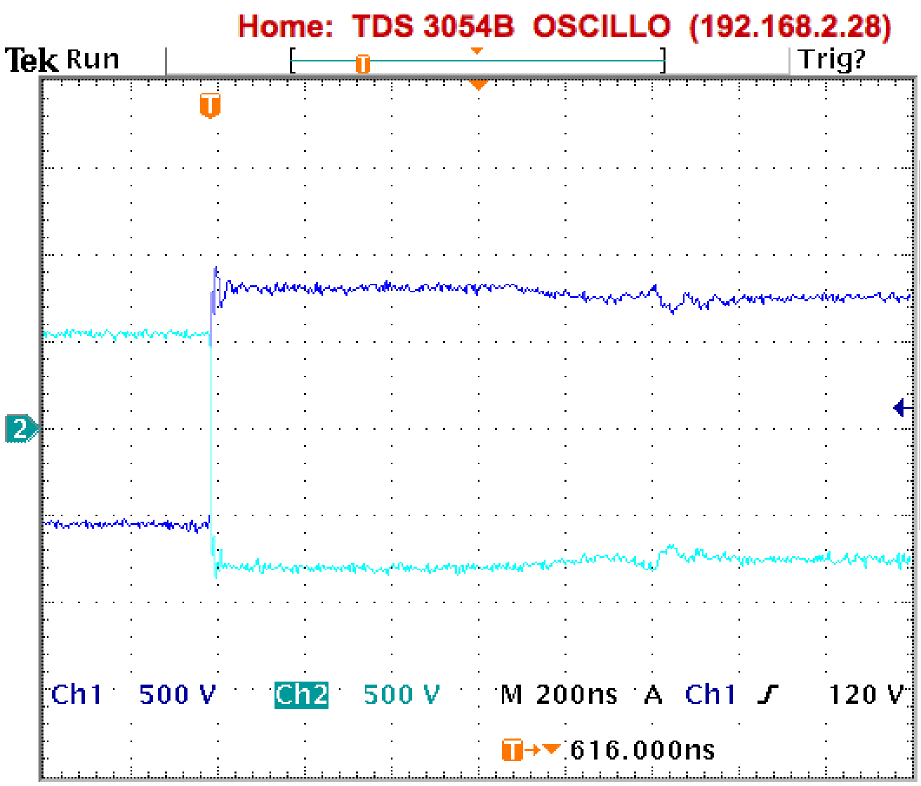


Figure 39 Long time history at 40 ns/div and 200 ns/div

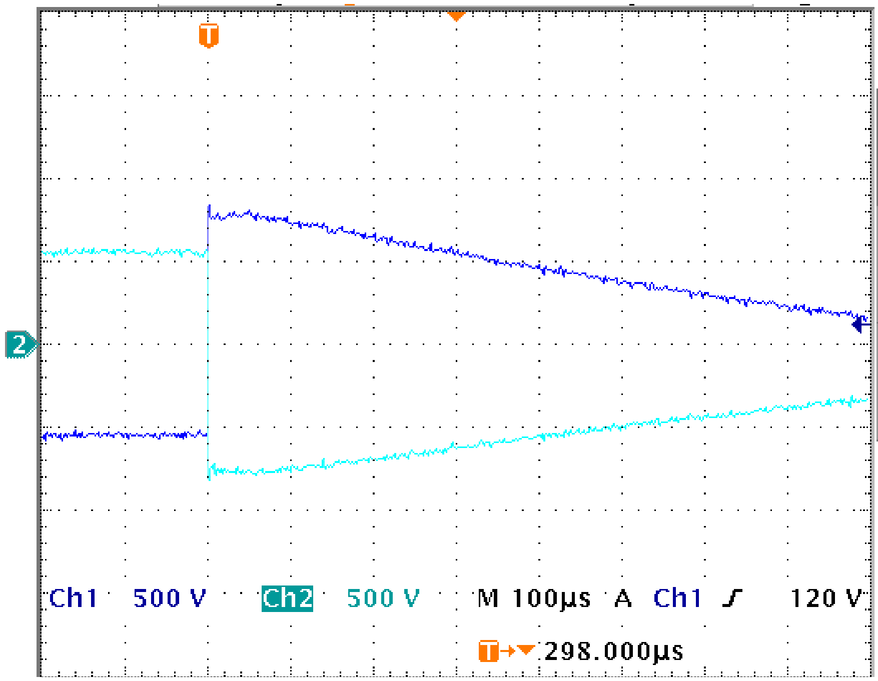


Figure 40 Long time history at 100 µs/div

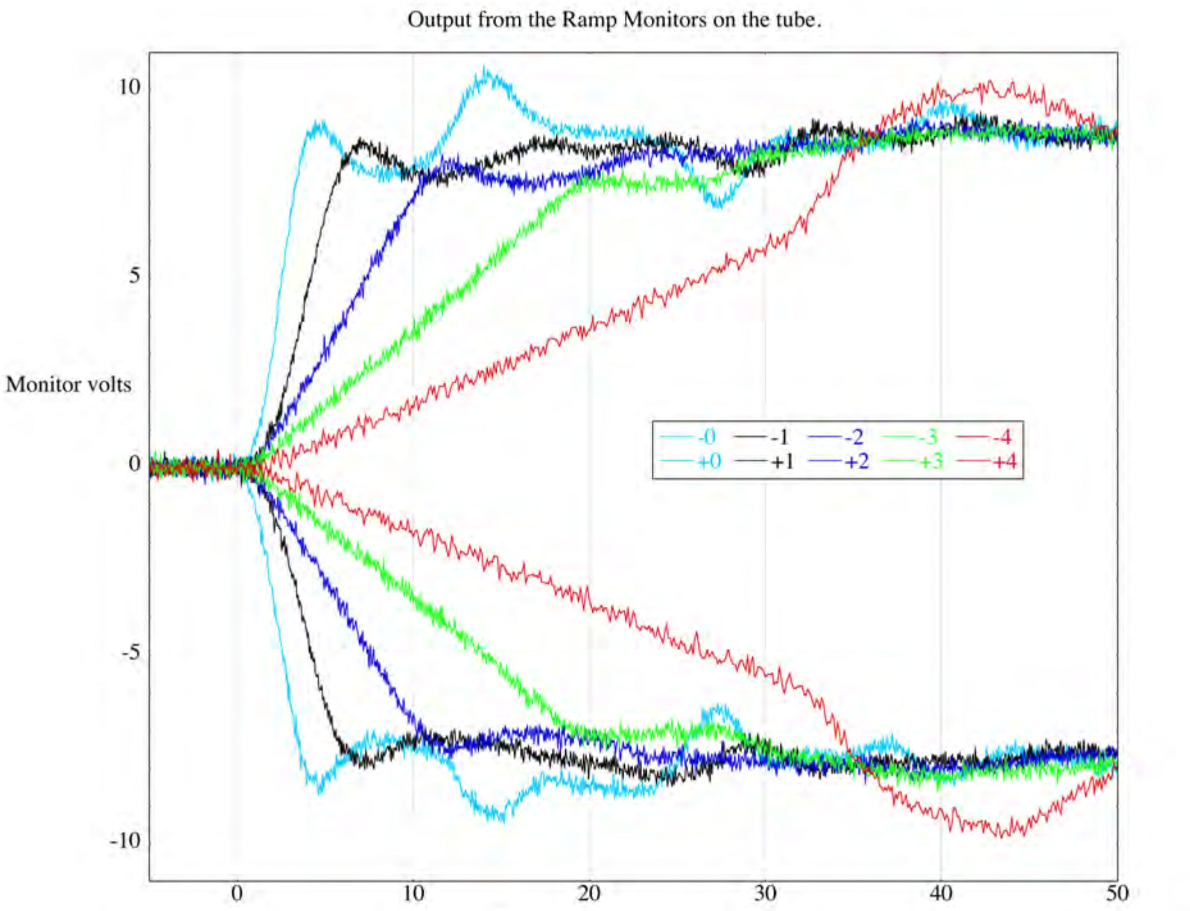


Figure 41 Ramp monitor outputs into 50 Ω. 5 superimposed

16. SLOW SCAN FOR FLAT FIELDING

In order to do a flat field calibration of the sensor HDISC has a slow scan mode, see “Name hd_flatarm” on page 47.

The electronics in the head is not capable of adjusting the bias voltages on the sweep plates smoothy as is required for a flat fielding slow scan. Consequently a smooth drive signal is delivered from RHIC.

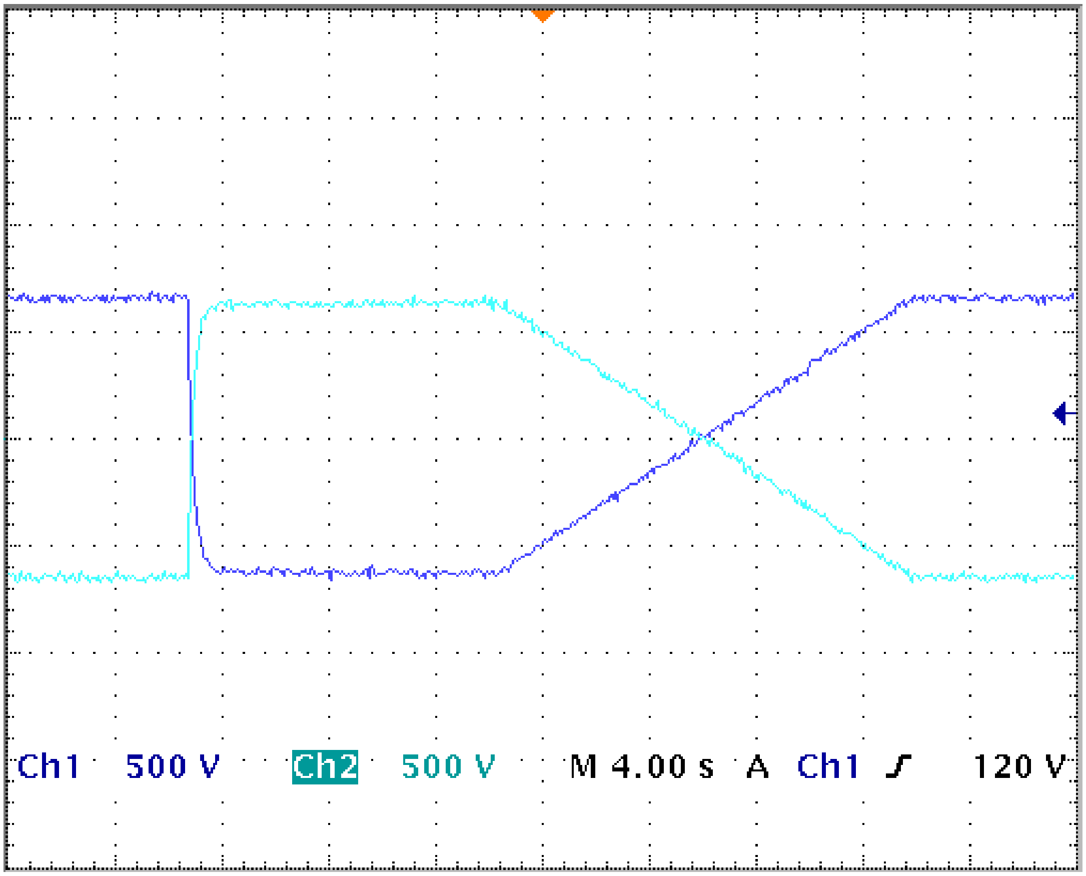


Figure 42 Slow scan for flat fielding.
In this case the scan takes ~16 seconds.

The waveform that is delivered to the sweep plates is shown in Figure 42 on page 84

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):

1 hd_strt;	{1 hd_strt;0 }	initialise unit
0 0 0 0 hd!cmmd	{0 0 0 **0** hd!cmmd;0 }	set camera mode to zero = flat field/slow scan
;0 }	request standby mode	
5 hd_farm	{5 hd_farm;0 }	arm slow scan - beam moves off screen to start position
hd_ftrg;700	{hd_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).

The same can be done with the tube focus potential on:

1 hd_strt	{1 hd_strt;0 }	initialise unit
0 0 0 0 hd!cmmd	{{0 0 0 **0** hd!cmmd;0 }	set camera mode to zero = flat field/slow scan
hd_rqsb	{hd_rqsb;0 }	request standby mode
hd_rqen	{hd_rqen;0 }	request energise - turns on focus voltages
hd@stat	{hd@stat;**1** ;2 ;7 ;0 ;0 ;0 ;0 }	check machine state is energised, it takes around 10 seconds for the voltages to come up.
hd@stat	{hd@stat;**1** ;2 ;7 ;0 ;0 ;0 ;0 }	
hd@stat	{hd@stat;**2** ;2 ;12 ;0 ;0 ;0 ;0 }	energised.
5 hd_farm	{5 hd_farm;0 }	
hd_ftrg	{hd_ftrg;700 ;0 }	

17. HCMOS TRIGGERS

Three HCMOS trigger pulses are provided at the output of the sweep unit in the head package. They are labelled P, R & C. These correspond to the Pre, R & C1 on HSLOS. There is no C2 trigger.

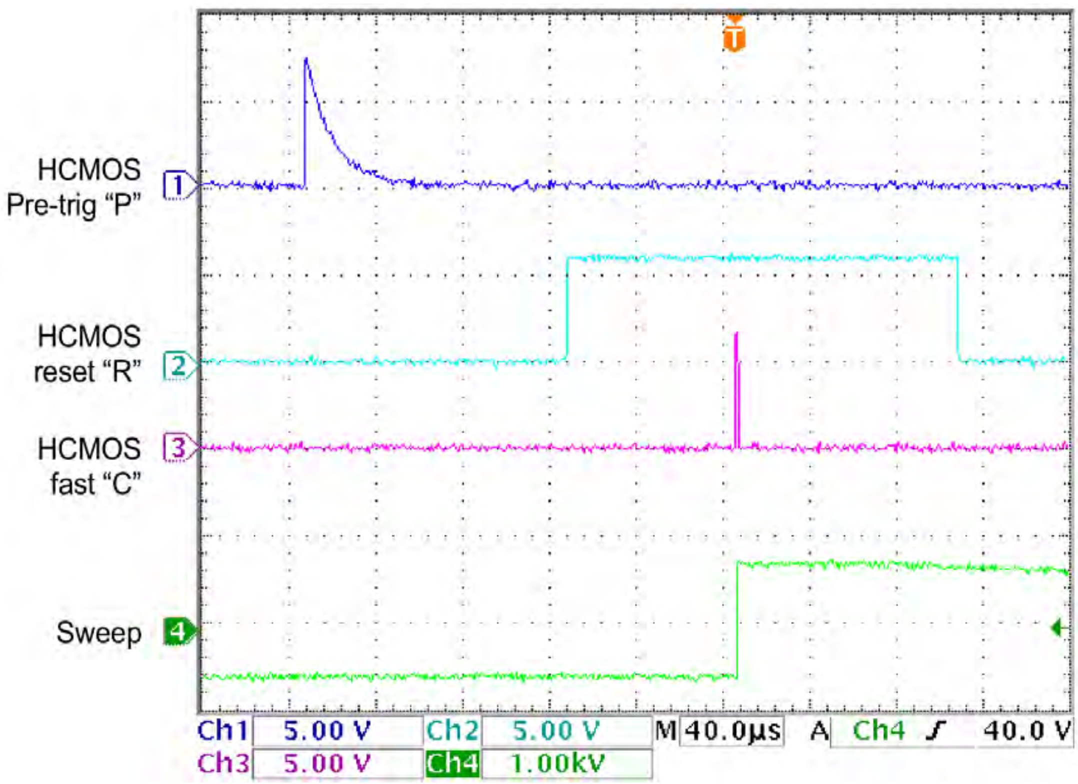


Figure 43 These are the signals coming out of the sweep head unit.
The signals going into the RHIC are similar but there is also a pulse needed at the beginning called “solenoid trigger’ HDISC does not have a solenoid and does not need a solenoid trigger but to use the HCMOS triggers the solenoid trigger pulse is required to put the trigger multiplexer into the correct state.

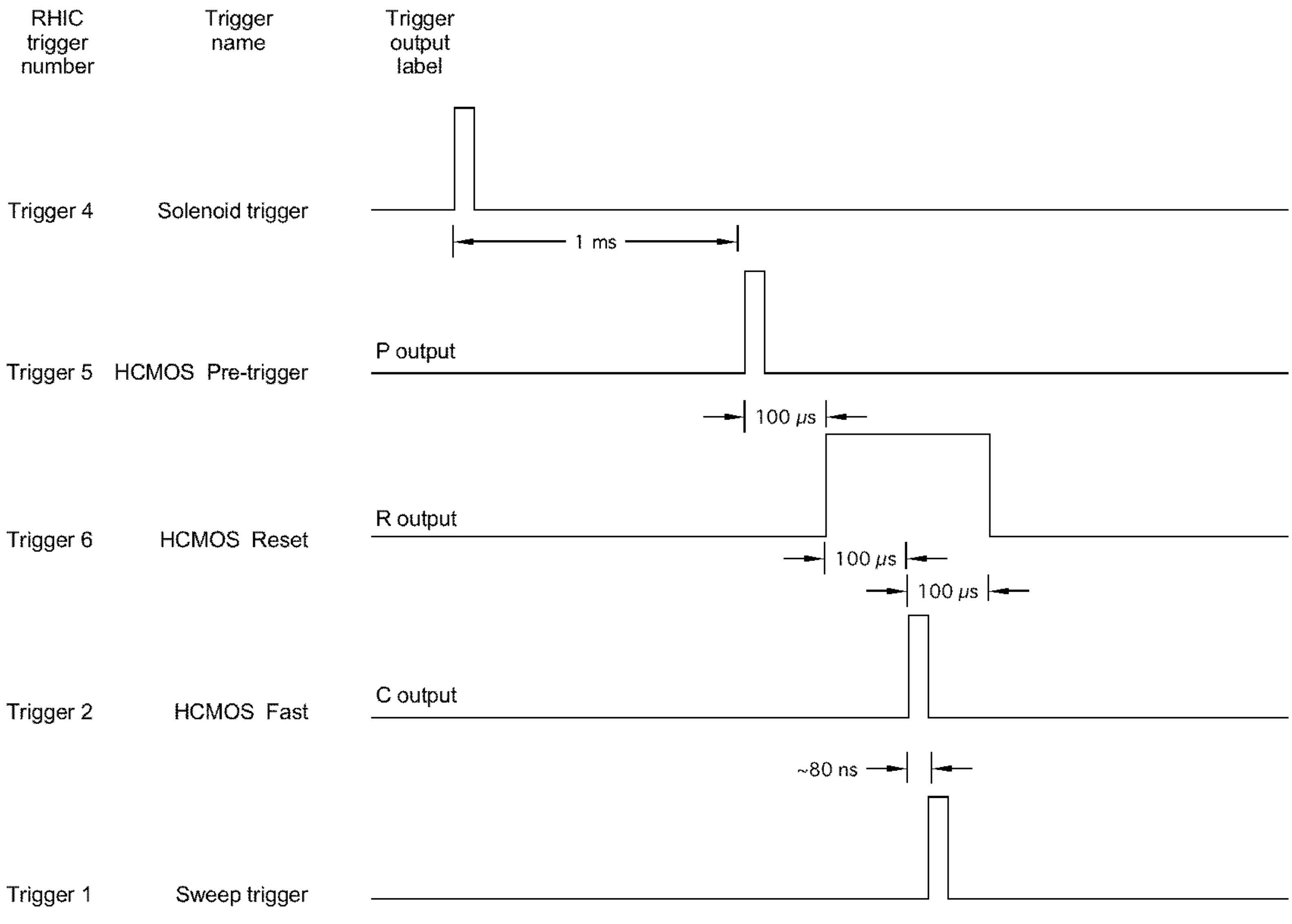


Figure 44 The timing of the trigger required for streaking and driving a HCMOS sensor

18. 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 soldering 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 12 on page 28. 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 19, is a significant repair.

Should the head electronics package require repair, this is probably best sent back to us. Small repairs to the sweep unit may be possible with guidance and diagnosis from Kentech.

The focussing module is mostly a potted unit and repair of potted parts will require the unit to be sent back to Kentech.

Repair of the RHIC should also be sent back to Kentech, but we would assist in local repairs if we thought that they were feasible.

Cable repairs are not difficult. No cable is stressed beyond normal parameters. Cable specifications are available on request.

19. PACKING LIST

Packing List for J17xxxxx HDISC

Main Components

1 x Tube assembly, includes LLNL free issue Photocathode package.
1 x RHIC
1 x Head package including high voltage output leads.

Cables for testing

1 x dual FO St to ST lead
1 x 8 way control cable
1 x 28 VDC Power cable
1 x trigger lead
1 x power lead US style
3 x HCMOS trigger output leads
1 x HDISC interlock lead

Cables for final use

2 x Sweep lead
2 x Sweep monitor lead
1 x blanking trigger lead
1 x corrector supply output lead

Miscellaneous items

1 x CD with manual, test data and STEP files.
1 x free issue Fiducial FO assembly

20. HSLOS MANUAL

The HSLOS manual is included here for information on the RHIC, in particular on how to connect to it via RS232 and Ethernet.