Kentech Instruments Ltd.

X-Ray Streak Camera for NIF
DISC

Units 2 & 3

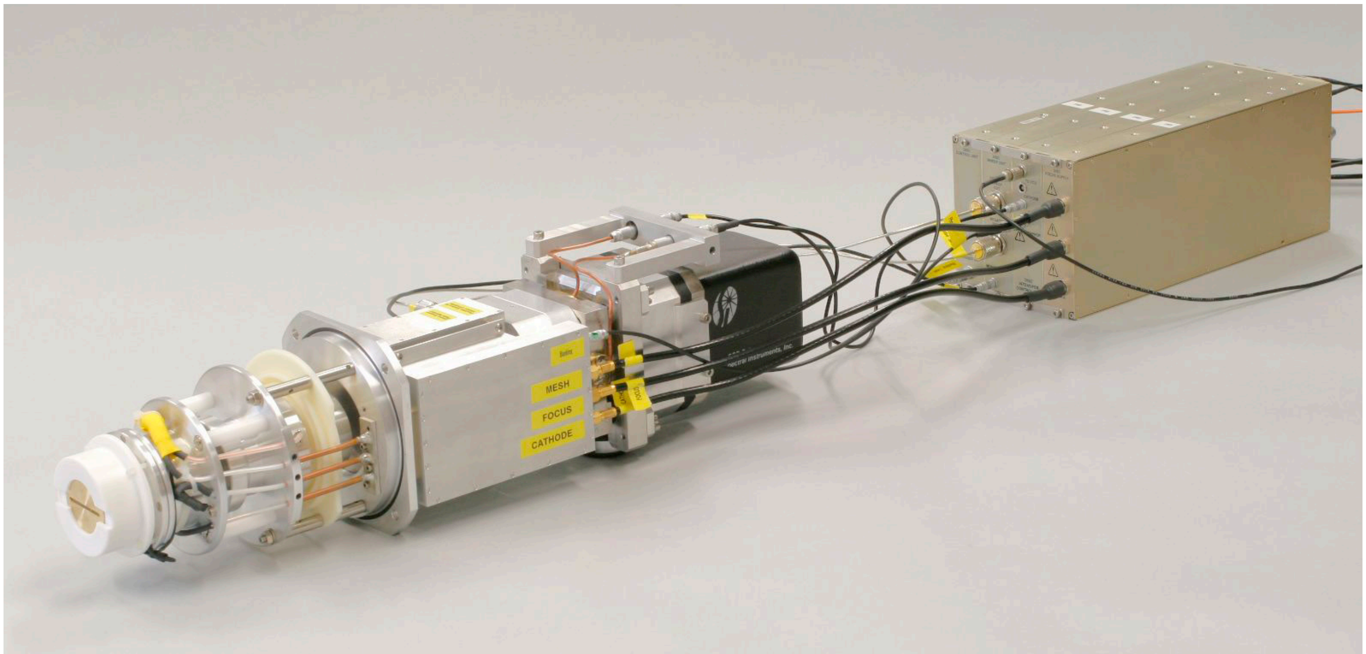
Version 3

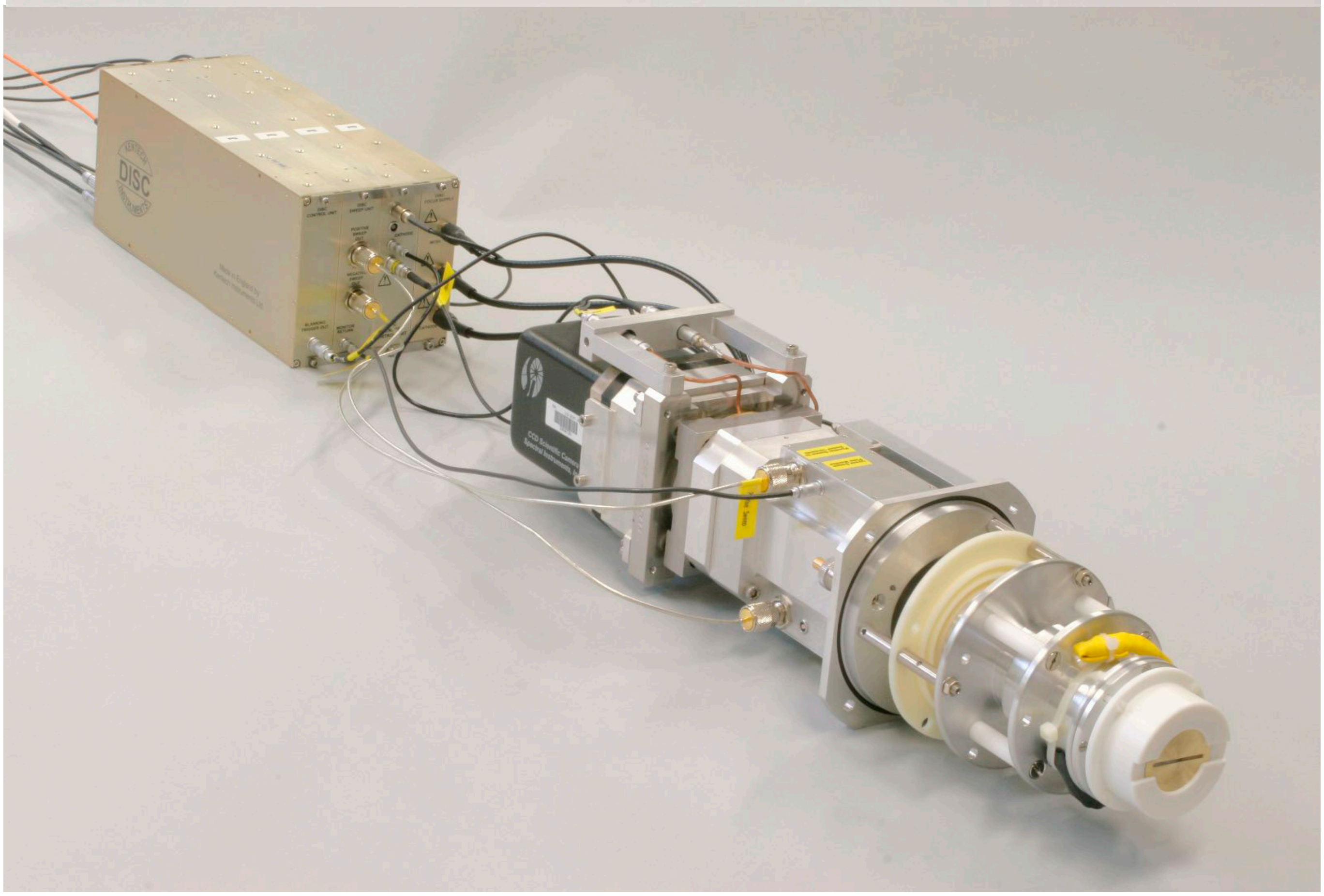
Serial Numbers J00902271-1 & J0902271-2

8th. November 2009

PLEASE READ THIS MANUAL CAREFULLY BEFORE USING THE CAMERA.

Kentech Instruments Ltd.,
Isis Building, Howbery Park, Wallingford, Oxfordshire, OX10 8BA, U.K.
Tel: +44 (0) 1491 82 1601 Fax: +44 (0) 1491 82 1602
E-mail info@kentech.co.uk
Web http://www.kentech.co.uk/


MESH
FOCUS
CATHODE


DISC

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. ABBREVIATIONS

ADC or adc	Analogue to Digital Convertor
CPLD	Complex programmable logic device
CCD	Charge Coupled Device (camera)
cr	carriage return
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
GXD	Gated X-ray Diagnostic at LLNL
hw	hardware
INT	Intensifier
lf	line feed
LFC	Large Format Camera, Gated X-ray Imager used at NIF
LLNL	Lawrence Livermore National Laboratory
MAX	A phosphor and MCP combination made by LLNL
MCP	Micro Channel Plate
MCU	Main Control unit
mv	measured value
NIF	National Ignition Facility, LLNL
PCD	Photo Conductive Detector
PSU or psu	power supply unit
RAM	Random access memory, volatile.
ro	read only
rw	read and write
SW	sweep
sw	software
UCS	Users Control System (to be provided by the user)
W/E	Write Enable
wo	write only

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CORRECTIONS FROM V2

incvcathode	**5**
s_@hst	**40**
stop	**5**

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3. INTRODUCTION

This manual describes the operation and use of the DISC streak camera. The camera is based upon a standard Kentech Low magnification tube design which has been customised to fit into a NIF DIM housing. The electronics package has been built to have a similar form factor to the GXD unit but somewhat shorter to accommodate the extra length that a streak tube has over a GXD head. The software control interface uses similar techniques to the GXD for control of the unit, however, the DISC is a more complex device and the controls are more numerous.

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

3.1 CHANGES SINCE MANUAL V2

3.1.1 SWEEP UNIT

In order to improve the ease of sweep set up and linearity the sweep circuit now has more adjustable parameters. This is a hardware change. Consequently there are software changes also and the sweep table has wo extra parameters per sweep speed entry.

3.1.2 FOCUS MODULE INTERLOCK BEHAVIOUR

The CPLD code has been modified to overcome a problem whereby the interlock lead could turn on the focus unit. This error has been fixed. An update is available for the earlier unit but it requires the visit of Kentech personnel or the return of the item to our factory.

3.1.3 DISC TUBE

In order to make the attachment of a MAX module easier the rear end of the drift tube has been redesigned to give access to mounting screws.

Various minor changes have been made to the position of holes to facilitate the insertion of a fibre optic for the fiducial system

The two cameras supplied with this manual J0902271-1 and J0902271-2 are fitted with LLNL supplied cathode packs.

3.2 SPECIFICATIONS OF THE PACKAGE

Streak tube	Low magnification Kentech design
Overall tube voltage	-15kV
Cathode length	>25mm
Cathode to extraction grid spacing	1 to 5 mm dependent upon spares and vacuum quality
Electron detector	The unit can be fitted with a standard Kentech phosphor or a LLNL MAX module.
Sweep speeds	The duration of the sweep can be set from ~1ns to ~50ns
Power requirements	typically 28 volts DC at ~ 1 amp

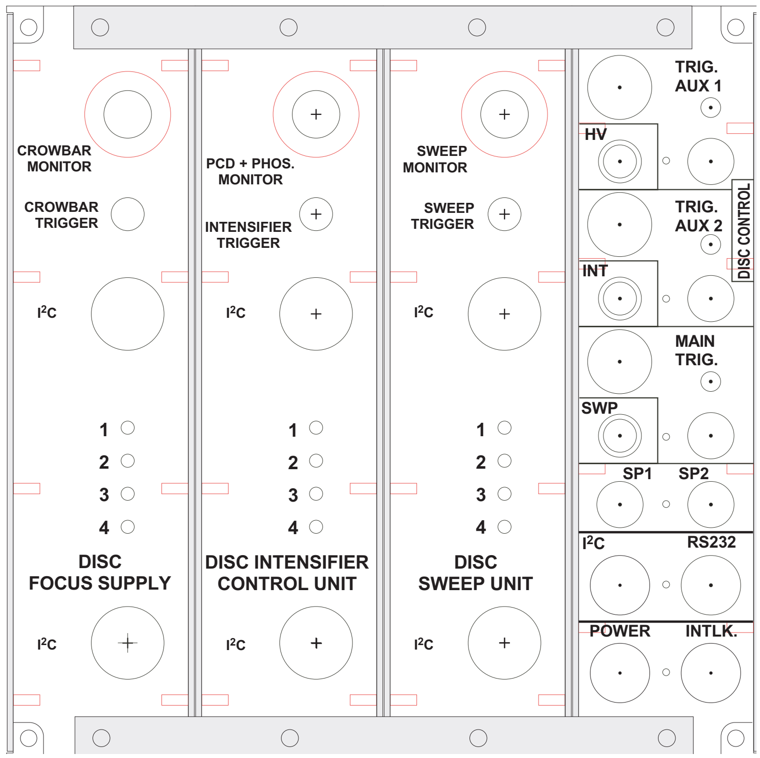


Figure 1 Rear Panels

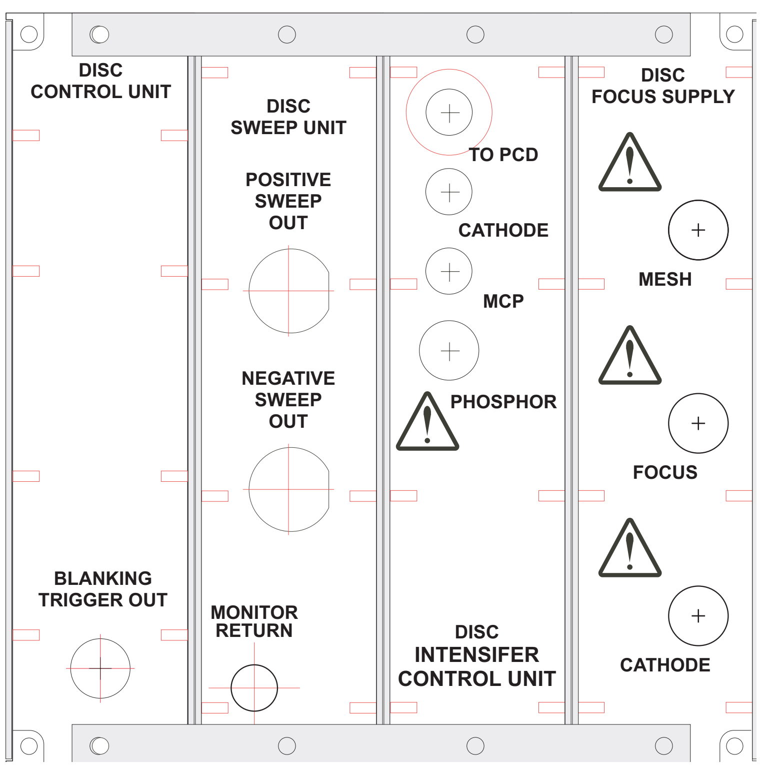


Figure 2 Front panels

Input voltage range	18 to 36 volts, minimum power consumption is near 28 volts.
Dimensions, drive electronics	279 mm (10.984 inches) plus connectors long by 114mm (~4.49 inches) square.
Vacuum compatibility	The electronics has **NOT** been designed for operation under vacuum conditions.
Sweep bias voltage on each plate	Up to -1kV to +1kV nominal
PCD voltage range	0 to > 900V nominal
Intensifier Phosphor Voltage	DC 0 to +5kV
	Pulsed 0 to +6kV
Focus Current trip	User settable through software (0 to 4095) in the range 0 to 8.7μA. Level 3 command.
Maximum repetition rate	Sweep unit >10Hz
	The blanking and crowbar circuits are limited by the rate of switch on of the focus voltages. These are ramped up over many seconds.
Triggers	Main
	Aux 1
	Aux 2
Electrical trigger requirements	5 volts into 50Ω rising in < 5ns for all triggers.
Optical triggers	Optical trigger signal input from NIF
	Wavelength 820-900 nm
	Optical power (on) -15dBm (min), +3 dBm (max)
	Optical power (off) -30 dBm (max)
	Width (50% level) 100 ns (min), 250 ns (max)
	Rise time <2 ns

Each of the three triggers may be either optical or electrical independently.

The main trigger triggers the sweep unit.

The Intensifier/Max module trigger may be Aux 1 or Aux 2

The blanking and crowbar triggers are normally derived from the main trigger internally but can be configured to be triggered from either of the aux triggers.

Connectors:-

Power	Lemo	FGA.0B.302.CTA.D42
Interlock	Lemo	FGB.0B.302.CTA.D42
RS232	Lemo	FGG.0B.302.CTA.D42
Sweep output	TNC x 2	
Sweep monitor	QMA	
Crowbar monitor	QMA	

PCD + phosphor monitor output	QMA
Trigger Lemo	FFA.00S.250.CTA.C22 x 3
Opto trigger	Fibre optic ST jack x 3
Trigger distribution	Lemo PSS.01.250.DLLE24
I^2C/power distribution	Fischer WS102A54 to WS102A054
Phosphor output	Lemo PSA.0S.403.CTA.C27
MCP output	
Photocathode output	
Blanking drive	
PCD (to sensor)	QMA
SP1 (Configurable spare output)	Lemo FFA.00S.250.CTA.C22
SP2 (Configurable spare output)	Lemo FFA.00S.250.CTA.C22

Streak tube high voltages customer in house connector x 3

3.3 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 Static focussing for checking that the image on the cathode is in focus.

2 Camera focussing, for checking that the image of the cathode on the detector is in focus.

3 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.

4 Sweep modes, apart from a normal sweep mode the sweep can also be run in reduced scan mode so that both start and end finish on the detector. This is useful for timing. Alternatively the bias can be configured so that the start position is on screen but the end position is off screen, (normal synch. mode).

As supplied the reduced scan and synch. modes are accessed by using specific sweep settings (of the 32 available) but none has been set up for reduced scan or Synch. mode. Level 3 software commands will be needed to implement these features.

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, ~100μs. This will also cause the high voltage supplies to turn off which they do in ~1ms. They turn on in ~ 20s. This is intentionally slow to protect the cathode and mesh.

7 Various single or multi-sweep shot modes. Blanking and crowbarring can be linked into the timing sequence. Note that repetitive modes will not work with crowbarring because of the slow turn on of the focus potentials.

8 Electrical or optical triggering

9 Image intensification is either by means of a Max module (not supplied) or an external intensifier (not supplied).

For a Max module the intensifier module supports both DC and gated phosphor voltage. In gated mode the MCP voltage is also gated as a constant fraction of the phosphor pulse, however, a DC bias can be added/subtracted to it.

For an intensifier the cathode can be gated, the phosphor and MCP are run DC.

Figure 4 Split modules showing the mounting pins.

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

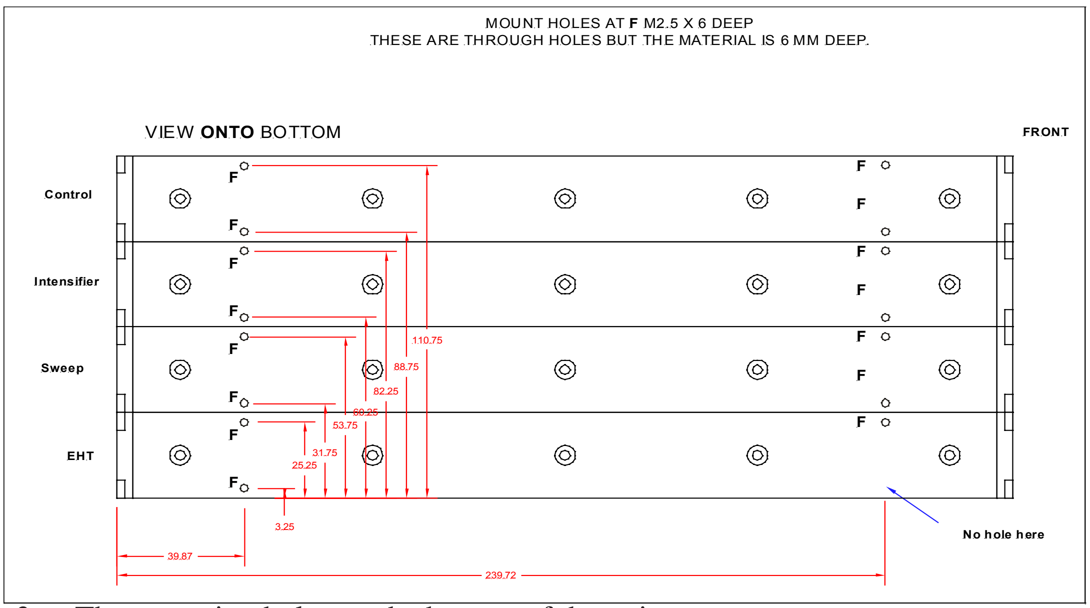


Figure 3 The mounting holes on the bottom of the unit.
Do not screw in fuurther than 6mm.

4. OVERALL DESCRIPTION

4.1 MECHANICS OF THE ELECTRONICS PACKAGE

The electronics package consists of 4 modules strapped together, see Figure 5, a control module (MCU), a sweep (SW) module, an intensifier (INT) module and a high voltage (Focus) module. The modular structure allows the easy replacement of one and the ability to screen fully each part of the system to ensure that cross talk is minimised. Mounting holes on the bottom of each module are provided, see Figure 3.

The screws should not penetrate more than 6 mm into the holes.

The holes are not blind and the use of excessively long screws could easily result in damage or electrical problems.

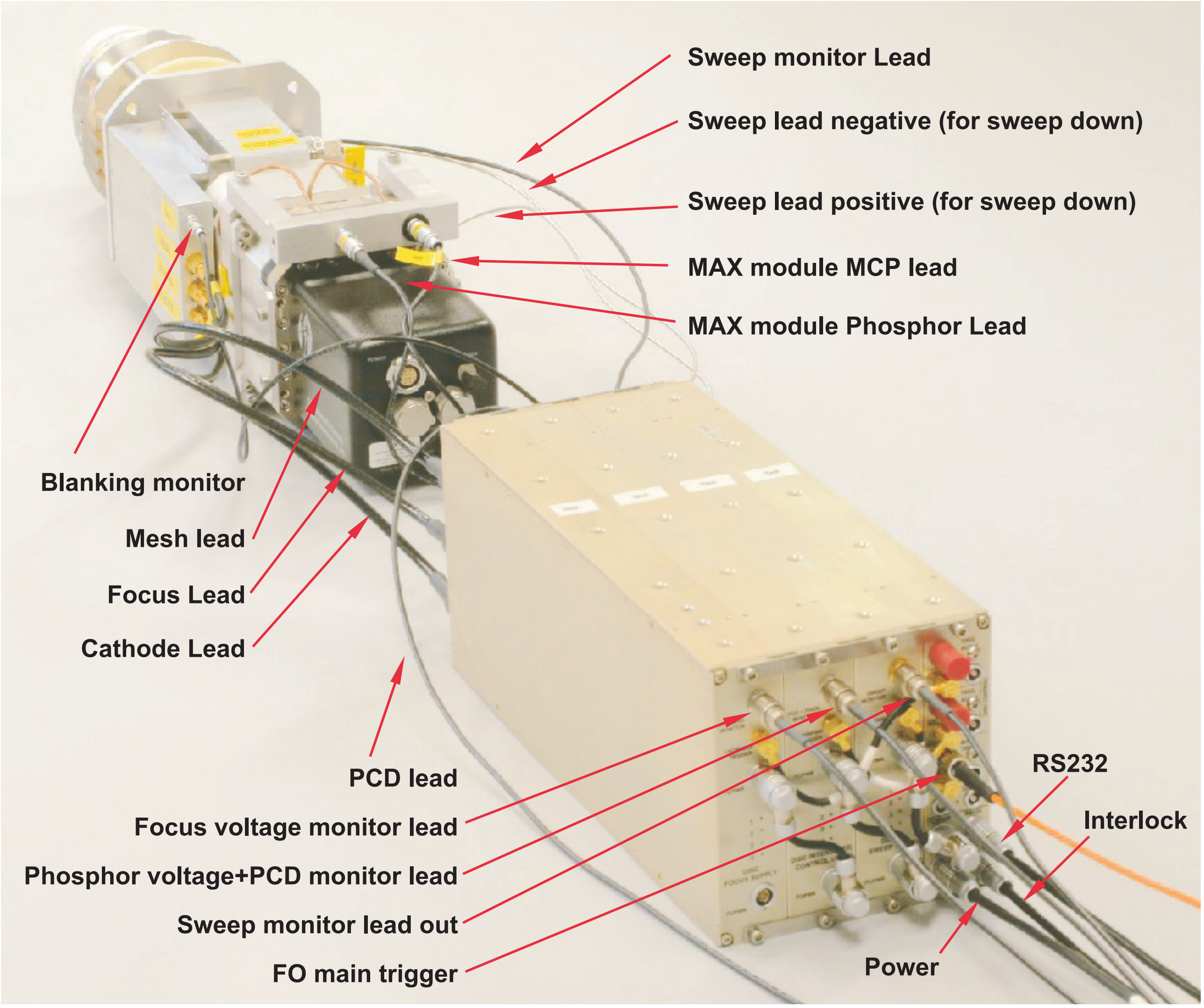


Figure 5 The cabling of the system

4.2 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 is the Clamp Box which contains the blanking circuit. The circuit short circuits the cathode and extraction grid when triggered effectively shuttering the tube. This is a fairly fast circuit, (tens of ns).

The clamp box may be removed or partially removed to make fitting of a MAX module easier. See section 5.1

4.3 ELECTRICAL CONNECTIONS

4.3.1 CONNECTIONS BETWEEN THE MODULES

The unit is supplied with the internal trigger and I^2C leads in place. The following will help in the event that they have been removed. See Figure 7.

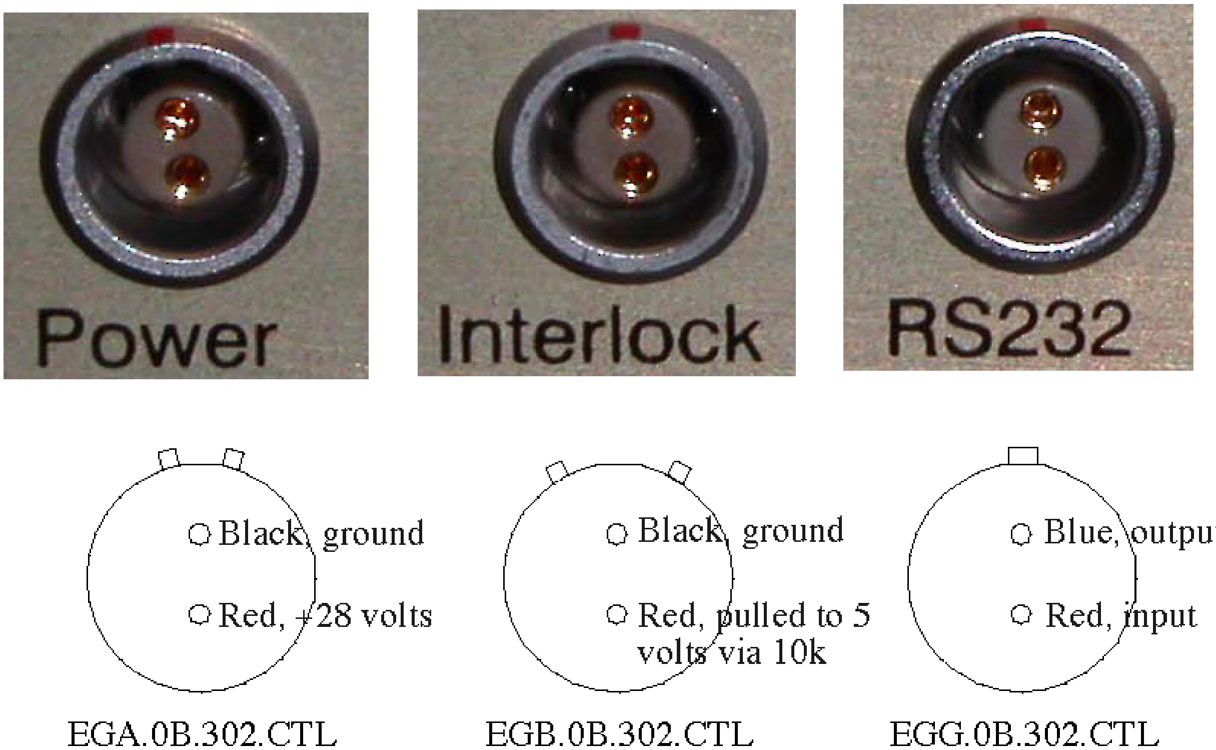


Figure 6 The three Lemo connectors for Power, Interlock and RS232.
The connectors cannot be mis-mated.

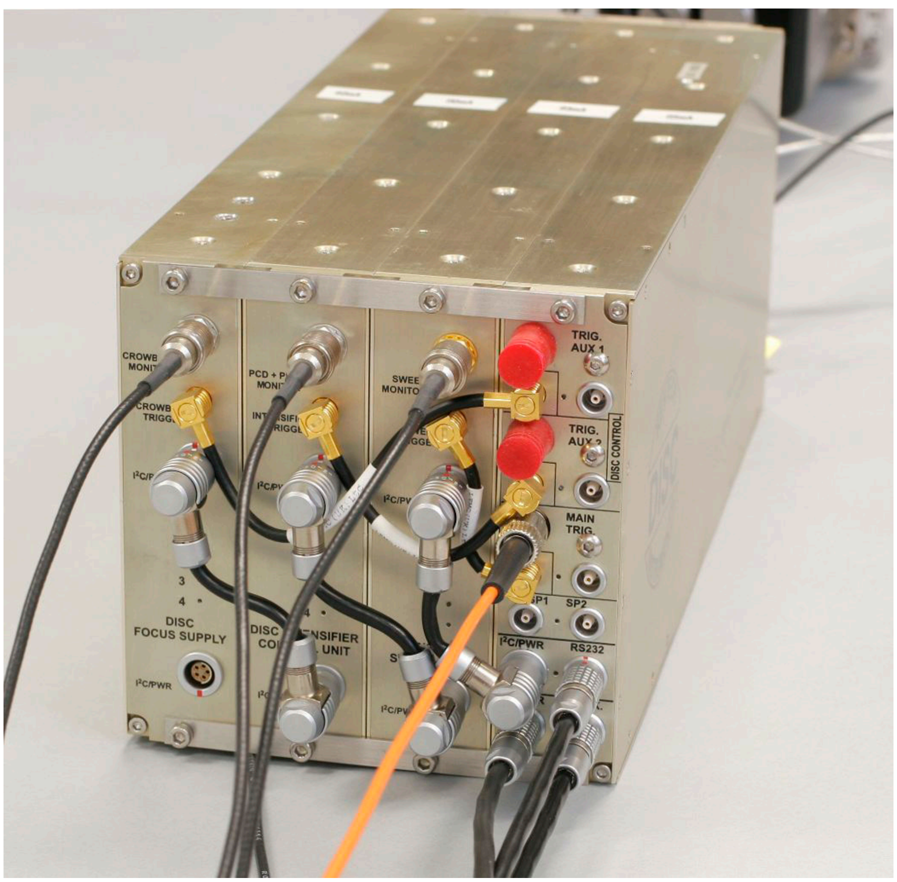


Figure 7 Rear Panel Connectors and Straps

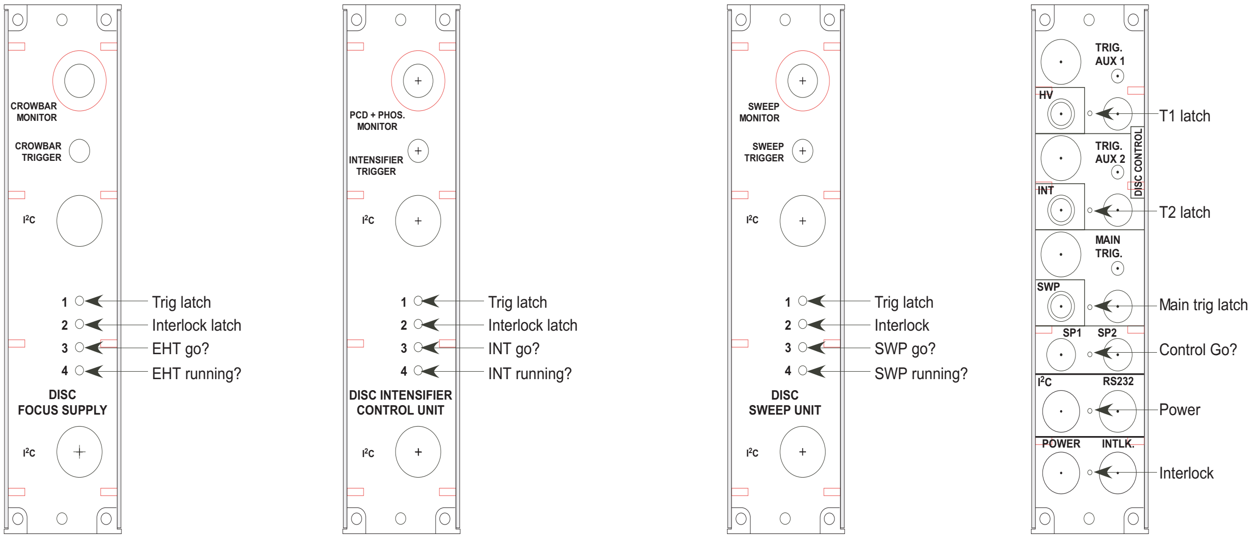


Figure 8 The LEDs on the rear panels indicate the current status of the units.

The communication between the units is via I²C. This is a two lead bus plus ground. One lead is for a clock signal and the other for data. The data can be bidirectional. In addition to the I²C there is power distribution of the incoming 28 volts. These are all contained within a 5 way cable between the control unit and each pulser module. The other three wires are: power (28 volts unregulated), ground and interlock. Note that the power is distributed unregulated and moderately isolated from the system ground, i.e. there is a separate power return.

The I²C connection is daisy chained across the rear panels. Note that all the connections between the units and the control module are nominally identical and any module can be connected to the communications port on the control module. The order of the modules is not important electrically.

If any of the I²C leads is disconnected and reconnected the MCU should be rebooted, failure to do this can result in unexpected measurements and sometimes a MCU crash.

In addition there is one trigger from the MCU to each of the other modules.

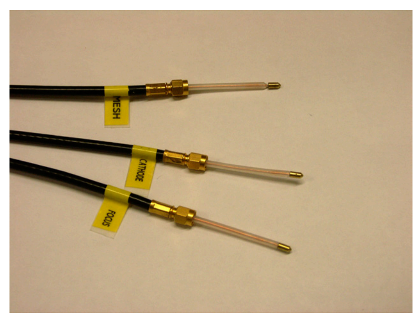


Figure 9 Focus leads. When removing pull gently and carefully

4.3.2 CONNECTING THE STREAK TUBE

The following needs to be connected to the streak tube:

1 Two sweep leads, TNC plug to TNC plug. The sweep will be towards the positive sweep cable. The sweep can be made to go either up or down and in addition the tube can be operated on its side.

2 Sweep monitor lead. This can be connected to either sweep plate. There is only provision to feed on back to the rear panel of the sweep electronics.

3 Blanking drive lead from the MCU to the “Clamp Box”

4 Focussing high voltage leads. These three leads, cathode,mesh and focus are fixed into the high voltage module. 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 clamp box. The leads use

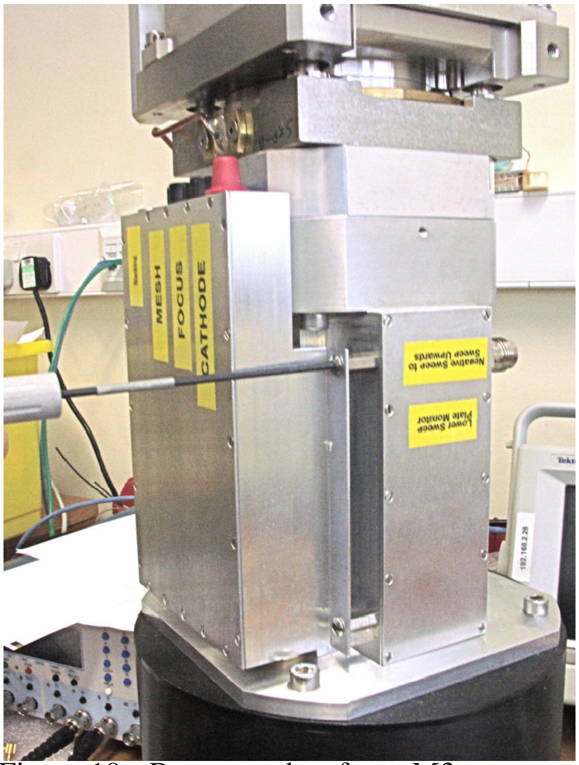


Figure 10 Remove the four M3 screws to loosen the Clamp box. Then lift the clamp box off the three high voltage leads very carefully and without tugging.

Figure 11 Tighten the four M5 screws to clamp the MAX module

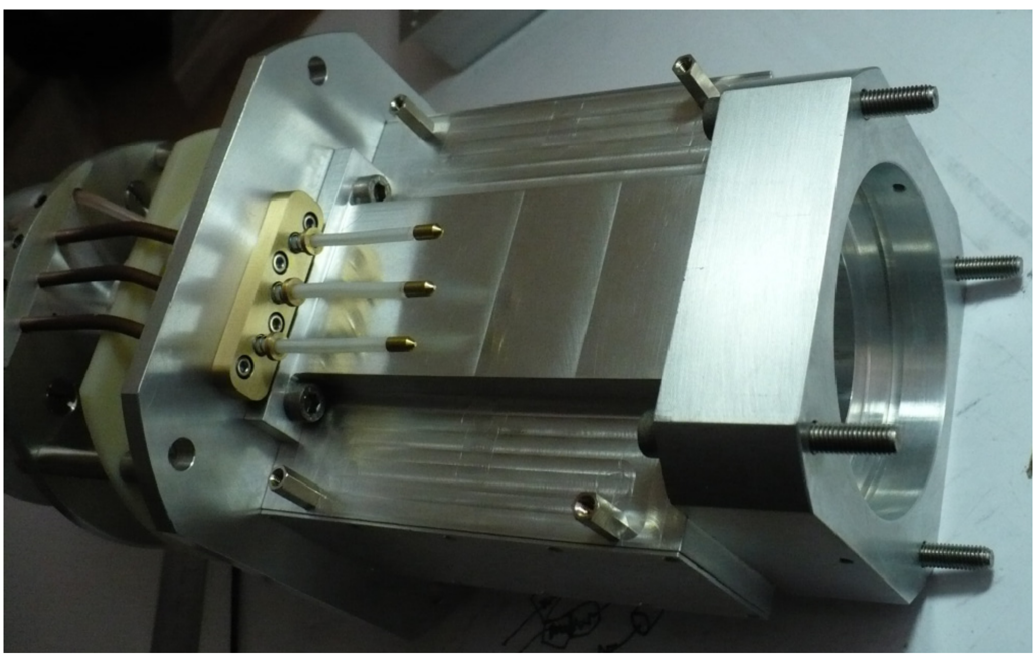


Figure 12 With the Clamp box removed take care not to damage the three high voltage leads or to loose the three washers and springs. Check that the tree brass end connections are in good order and well soldered to the cables. Note that these cables have copper inner conductors and are not as robust as most semirigid cables.

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 clamp box and the streak tube. The tube is supplied with these connected. If the clamp box is removed 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.

5 The intensifier or MAX module also needs to be connected.

If an external intensifier is used there are three connections, photocathode, MCP and Phosphor. If a MAX module is used then only the phosphor and MCP connections need to be made. Note that the intensifier photocathode uses a Lemo FGG.00.302.CTA30. This is a 2 pin connector with the pins are connected together. This connector is used to prevent accidental cross connection of the MCP and photocathode.

4.3.3 CONNECTIONS TO THE OUTSIDE WORLD

There are up to 9 leads which connect the unit to the outside world.

1 Power Red, +28 volts, Black/Blue Local ground.

2 Interlock, Red pulled high to 5 volts via 10kΩ, Black/Blue ground.

3 RS232, Black/Blue is output from DISC, Red is input to DISC

4 Main trigger Trigger

5 Auxiliary 1 Trigger

6 Auxiliary 2 Trigger if needed.

7 Focus monitor

8 Intensifier and PCD monitor

9 Sweep monitor

Leads 1 through 3 are covered in the specification.

The connectors are specified in the specifications, see section. Figure 6 indicates the pin out of connectors 1 through 3.

The power required is 18 to 36 volts with the polarity as per figure Figure 6. Up to 1.2 amps should be available if running at 28 volts, lower voltages may require more current. The interlock is hard wired into the modules.

The interlock is active low, with a pull up resistor to a 5 volt rail (~2k5). A ground connection is provided on the socket also. The software has no means of overriding this hardware interlock but it can sense its state.

The RS232 runs at 9600 baud, 8 bit with 1 stop and 1 start bit, no flow control. Normally a regular PC serial port will communicate without difficulty. Only three lines are used in the RS232, TXD, RXD and ground.

The trigger is positive on the centre pin.

4.4 RUNNING THE ELECTRONICS

The electronics can run in air at atmospheric pressure. 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 should decide if and when to shut down the unit, see section 4.7.

4.5 POWERING UP

On power up the LEDs in each module are flashed and then the unit awaits commands from the UCS. It does not send information to the UCS unless requested to do so. The unit may appear unresponsive but it will respond to valid commands.

4.6 LEDS

On the control unit there are 6 LEDs. On the other three modules there are 4 on each, as shown in figure Figure 8 The figure also indicates their function.

4.7 THERMISTOR POSITIONS

The thermistors are labelled r1 through r5 for use by the software. These correspond to 5 thermistors, 2 in the MCU, 2 in the Sweep unit, 0 in the intensifier module and 1 in the Focus module.

The item being monitored is as below:

- r1 IC10 in control unit (DC DC power supply)
- r2 IC7 in control unit (DC DC power supply)
- r3 Sweep unit Sweep FET
- r4 Sweep unit high voltage PSU
- r5 Focus DC DC converters (thermistor on heatsink covering 3 DC DC converters)

4.8 MAIN CONTROL UNIT

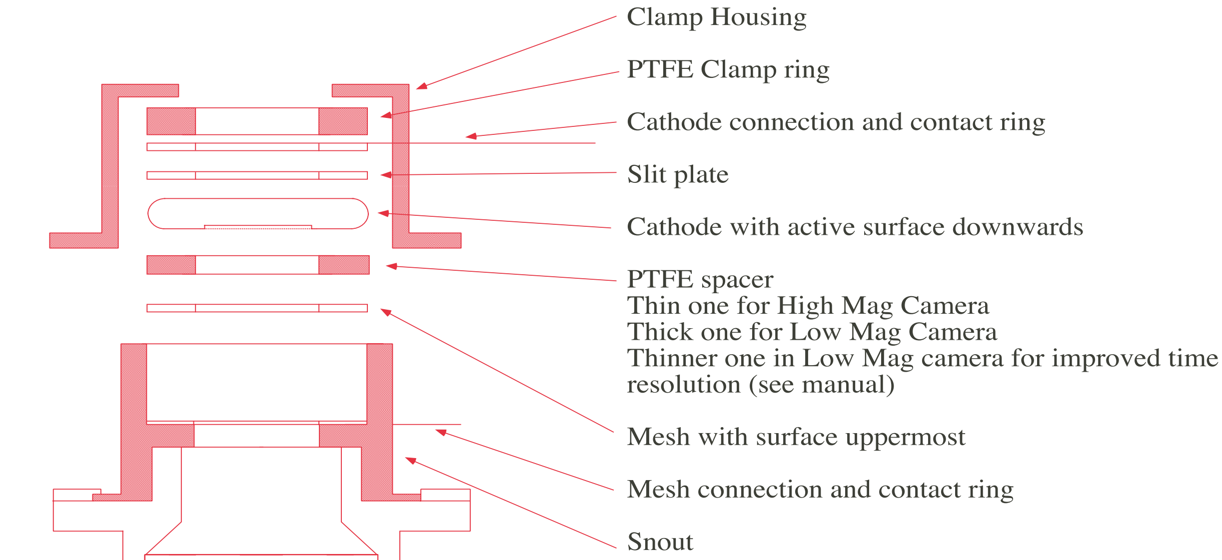
The MCU contains the interface to the outside world, the μProcessor, the high voltage blanking trigger pulse and the trigger routing.

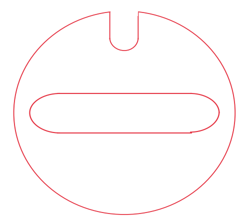
4.9 DISMANTLING THE MODULES

The electronics unit is simply split into its 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 M3 screws)
3. With a soft bladed tool ease the modules apart. They are pinned together, 4 pins between each module.

If it is necessary to access the insides of a module then the side covers are removed by undoing the 18 M1.6 screws around the edge of the unit. Most connections and large components are on the right hand side of each module and so the right hand cover should be removed. It is possible to remove the





cathode and mesh outline

Figure 13 Cathode/mesh assembly

right hand cover of the control module without separating the modules. The sweep unit has heat sinks that are screwed to the right and cover. The screws holding these should be removed before taking the cover off, so as to preserve the heat sink material between the cover and the power supplies. The side covers of the control unit cannot be interchanged with those of the other three units.

5. FITTING THE MAX MODULE TO THE STREAK TUBE

The Max module (not supplied) is fitted into the rear end of the streak tube. It contains an MCP and phosphor. These are driven by the electronics package, (intensifier module).

The MAX module is designed to seal with an “O” ring in the end of the MAX module. When the streak tube is used with a phosphor the seal is made with a Wilson seal in the wall of the drift tube. This “O” ring should be removed (if present) when the MAX module is installed.

In order to fit the MAX module it is no longer necessary to remove the Clamp box.

5.1 REMOVAL OF THE CLAMP BOX

Remove the three high voltage focus leads if fitted. The clamp box is attached with four M4 screws. Remove these (see figure Figure 10) and then gently ease off the Clamp box to reveal the three high voltage leads that go into the streak tube. Do not tug on the clamp box if it catches during removal. Just gently wriggle it until it slides off the three leads. Make sure not to lose the washers and springs on the high voltage leads.

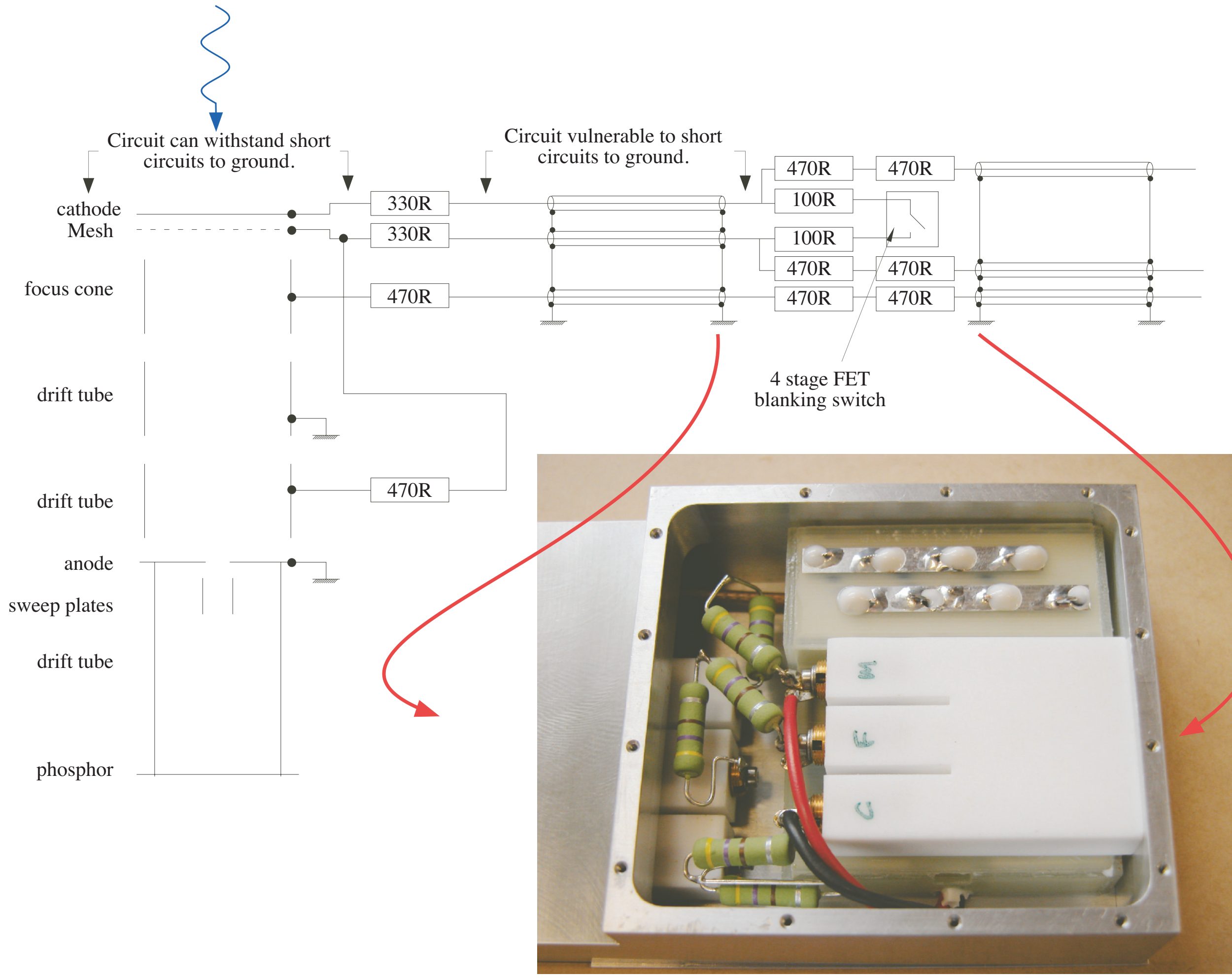


Figure 14 Tube wiring and Clamp Box

5.2 FITTING THE MAX MODULE

If the tube has a blanking piece fitted over the rear end of the drift tube, remove this and retain as a future transit cover. Check that the “O” ring is fitted to the end of the MAX module and that the mating surface is clean. Lower the MAX module into the drift tube and tighten the four M5 screws into the MAX module.

5.3 REPLACING THE MAX MODULE MOUNT SCREWS

If it is necessary to replace either of the two screws on the right side of the streak tube it will be necessary to move the sweep connections out of the way.

Remove the nuts on the outside of the connectors and partially push the connector into the sweep connection box. This will give access to the screws and allow replacement. The connectors may then be pulled out of the sweep connection box and the nuts refitted. The connectors have anti rotation flats and the nuts can easily be done up tightly without twisting the cables fitted to their rear. It is not necessary to remove the cover from the sweep connection box.

5.4 REPLACING THE CLAMP BOX

Gently ease the Clamp box down over the three high voltage leads until the gap between it and the brass vacuum seal clamp is zero. Then refit the four M3 screws that hold the clamp box in place. Refit the three focus leads as required.

6. 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 8

The tube fits into a DIM assembly. The vacuum seal is made on the grounded anode of the electron lens. Figure 14 shows the internal parts and connections to the camera.

6.1 VACUUM REQUIREMENTS

The camera can only be used under a reasonable vacuum. The camera is not pumped but relies on the vacuum of the chamber it is connected to, 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 2mm) pump to under 10^{-5}mBarr. If using a MAX module pump to under 10^{-5}mBarr.

6.2 PRINCIPAL OF OPERATION

The X–rays to be investigated, are incident on the photocathode and produce photoelectrons. The photoelectrons are imaged by the focusing electrodes, passing through the hole in the anode and form an image on the phosphor/MAX 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 onto the phosphor. The direction normal to this corresponds to time. There is an image inversion in the electron optics.

6.3 THE ELECTRON OPTIC FOCUSING

Before the high voltage focusing supply is switched on the vacuum chamber must be at a suitably low pressure, see section 6.1 In order to obtain higher time resolution it will become necessary to increase the extraction field to >30kVcm^{-1} and under these conditions we recommend that the pressure be below 10^{-5} mBarr. The extraction field is adjusted 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, mesh or MAX module. The voltages applied to the focusing electrodes are given in the data section 12. The cathode is nominally at -15kV and users should be aware not to place metallic objects near to the front end of the camera.

The focusing power supply is set to produce these voltages during the factory test of the camera, (see data section 8), however, these tests should be repeated if a MAX module is fitted as the distance from the cathode to the electron detector will be different.

Focussing is achieved most easily with the camera unswept and a 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 (phosphor or MAX module). The software has a mode of operation for doing this.

The cathode should be set to ~15kV and then the focus and mesh potentials adjusted for good focus. 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 other method is to check that the magnification near the tube axis is close to 1.2 and that the image is in focus. This combination will automatically put the cross over in the right place.

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 UCS. 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 UCS.

Note that any new focus voltages that are set as above will be lost when the power is cycled unless a "saveuser" command is issued. This will place the new data into EEPROM for use at the next power up. The factory settings are also available if necessary (see section ≈)

6.4 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 "Clamp Box" attached to the side of the drift tube, see figure Figure 10

The clamp box contains 4 high voltage FETs that are triggered by a signal from the control unit.

The trigger signal is sent at the end of the sweep. One of the set up parameters for a sweep is the delay for the blanking trigger.

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.

6.5 CROWBAR

The unit is also fitted with a crowbar. This short circuits the three high voltage connections to ground and also turns off the focus unit. Normally this would be used in conjunction with the blanking.

The repetition rate of crowbarring is very slow because the focus supply takes around 10 seconds to come on.

This is designed for single shot use.

6.6 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. See figure Figure 54 for specifications.

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 11 sweeps have been preset to the optimum values for best sweep linearity. The system is capable of storing up to 32 sweep settings.

The sweep unit has several modes of operation, see software section ≈ These enable the user to do the following:

i nothing

ii normal sweep

iii normal sweep with modified start position for timing

iv short sweep for timing (both start and end points should be visible on screen

v flat fielding, a slow sweep for calibrating the area sensitivity of the CCD camera.

A sweep monitor is provided. A fraction of the sweep signal to each plate is available to monitor the sweep signal. This is routed back through the sweep unit to the rear panel. Only one plate may be monitored at a time. The connections between the front panel of the sweep unit and the sweep monitor outputs on the of the streak tube determine which. 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.

Sweep modes iv and v need to be set up in the sweep settings table. This requires level 3 commands and is not intended for use via the UCS.

6.7 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 may be needed. The user is to provide this.

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 screws clamping the cathode snout should be of nylon. The cables carrying the focus potentials to the electrostatic lens have copper inner conductors.

6.8 CATHODE AND MESH ASSEMBLY

The system has been provided with a standard Kentech cathode assembly. Should the user wish to switch to an alternative some care should be taken, see section .A suitable cathode and mesh need to be inserted before the camera can be used.

The instructions that follow refer to components shown in Figure 13. In order to access the photocathode assembly four nylon screws around the periphery of the holder should be removed. The clamp may then be removed. Always take extreme care at this stage. The photocathodes are delicate, subject to contamination and very expensive. The meshes (underneath) are also very fragile and expensive. With the mesh and photocathode removed there is a direct line to the output phosphor (although there is only a small aperture in the lens assembly), hence particular care must be taken not to drop small screws or other items into the camera.

The items to be placed into the snout of the camera are as follows and must be in the sequence and orientation specified. It is assumed that the camera is orientated with the snout looking upwards.

1. Mesh contact ring (not actually removable without unsoldering from lead) solder contact side downwards. The contact ring must seat evenly with solder of the connection being in the rebate of the housing.
2. Mesh with mesh side upwards, [also called grid or accelerator grid]
3. Spacer. There are two standard spacers. Normally the 3mm one should be used. The 1.5mm one is used to obtain greater time resolution but a better vacuum may be required to prevent breakdown. If the vacuum and cathode quality permit, a 1.5mm spacer may be used. The voltage across this gap is about 4.5kV giving extraction fields from 15 to 30 $kVcm^{-1}$.

   The spacer may be reduced even further. We have worked with and 1mm spacers (not supplied here) on low magnification cameras but only after gaining confidence at larger spacings and establishing a good vacuum. Make sure that when using very high extraction fields that the condition of both the mesh and cathode is good and that there are no spikes protruding. **In addition the spacers and snout must be very clean and free from contamination or burn marks.** If burn marks occur they must be removed completely. This usually involves machining the damage away or replacement. Solvent cleaning does not work well enough.
4. Photocathode with photocathode side downwards i.e. nearest the mesh.
5. Slit, providing that the cathode is not made on a slit substrate.
6. Photocathode contact ring with solder connection upwards away from the photocathode.
7. Remaining spacer(s). Must be placed in so that the rebate covers the solder connection to the photocathode contact ring. If reduced thickness spacers have been used between the mesh and cathode more spacers may be necessary here to give enough height to the stack of components so that they are compressed by the outer clamping piece.

If using a low angle of incidence option it will be necessary to use a top spacer with a cut out. This is a non-standard option.

Note 1:- Cathodes come in two main formats, normally for slow sweep speeds the cathode and slit are separate items. In this case the slit should go in after the cathode. For faster work we have made the cathode on the slit assembly. This eliminates two main problems, firstly if a laser beam is focused onto the slit the beam may well have expanded again by the time it reaches the cathode. Secondly, multiple reflections between the cathode and slit may give rise to spurious results. By using a single slit/cathode unit these are overcome, however, at the expense of losing independent control of the slit and cathode.

6.9 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 focusing supply must not be turned on if the pressure is higher than 10-4 torr. At extraction fields greater than ~15kVcm-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 (3mm 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 will usually occur as a result of absorbed gas released under the influence of high electric fields. The normal procedure, after the vacuum chamber has been evacuated, is to turn the camera on with the intensifier removed while watching the phosphor in semidarkness. At the first application of power there will probably be a slight flash of light. The focusing supply should be switched on and off a few times, such that no light is visible on the phosphor and the fault does light not flash. It may be necessary to wait for the pressure to improve before this test is passed. Only after this test is passed satisfactorily should the intensifier be mated and powered up. 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. LED 3 on the focus unit will come on once the voltages are up to the normal values. This state can also be interrogated from the UCS.

It is not a good idea to leave the camera powered up for long periods while waiting for shots as an unexpected rise in the chamber pressure due to accidental venting or possibly pump failure could result in destruction of the cathode and/or the mesh.

6.10 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 1.7ns)

(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.

(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 “SYNCH” mode and then switch to the “OPERATE” mode. On DISC there are up to 32 possible sweep conditions and some should be set up to be of the “Synch” type, i.e. either with the sweep start on screen or with reduced scan so that both sweep start and finish are on screen.

The camera deflection sensitivity is ~18V/mm. 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 of the CCD sensitive area.

At the time of writing the camera has no “Synch” type sweeps set up. Level 3 software commands will be needed to set up some suitable ones. See section ≈

In “SYNCH” 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 intensifier trigger or no focus voltage, also a stationary image can be caused by a loss of sweep signal.

With the reduced sweep mode these ambiguities are overcome. One should always see a signal. If the trigger comes early the image will be at the end of sweep position, if too late and the start of sweep position. Note

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 (especially with the regular sweep unit) it may be necessary to trigger a little earlier to see the image on screen in “OPERATE” mode. See the timing data in section 8.2.

6.11 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 pattern may be needed. We can supply cathodes made onto resolution charts to do this. [Dynamic focusing effects are unlikely to be an issue on DISC due to the relatively slow sweep speeds.]

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 torr. A suitable window and cathode must be provided for UV use. (Kentech can advise on the supply of such a cathode, being either 10nm gold or 100nm 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 the 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 -15kV and that the lamp is probably grounded. In normal (swept or short exposure) operation an intensifier should always be used in order to maintain a low electron current in the tube and still obtain a recordable image. 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 software commands, see section≈

With the DC source, the focusing supply and the intensifier (if used), switched on, the focus should be set for optimum image quality. The two potentials are interdependent and the optimum image quality is obtained by iterating between the two settings. The cathode voltage should first be checked to be –15kV. Then a best image should be found by adjusting the mesh potential and then the focus voltage should be changed slightly. The mesh voltage should be again set for a best image and the image compared with that obtained with the previous focus setting. The greatest effect of the focus voltage will be on those parts of the image furthest from the axis. The focus should be chosen to give the best edge image quality while always maintaining the mesh potential at a best image position. 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 focusing 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.

If DC tests are performed with a CCD readout system it is important that the exposure is maintained at a constant time for image comparison. It may be advisable to trigger the intensifier also or it can be used DC.

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.

6.12 POSSIBLE FAULTS

6.12.1 NO DC IMAGE

Focusing 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 (this should result in the focus unit tripping out).

6.12.2 BAD FOCUS.

Poor connections to cathode/mesh.

Old/damaged cathode.

Poorly mated high voltage connector.

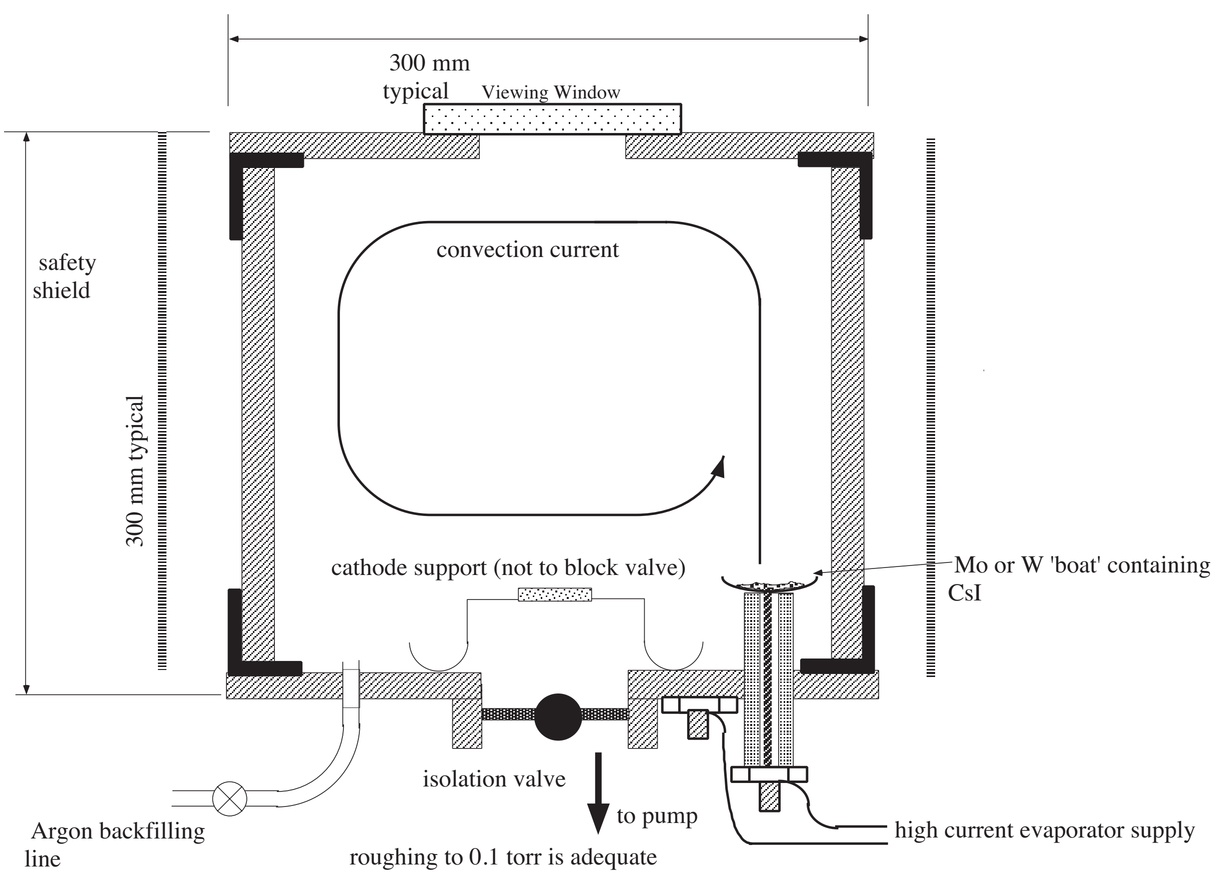


Figure 15 Low Density cathode manufacture

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 focusing unit switched off. If necessary block the direct X-ray path.

.

6.12.3 NO STREAKED IMAGE.

Intensifier triggering at wrong time, possibly from noise.

CCD camera triggering at the wrong time.

Sweep unit triggering at wrong time from noise.

Sweep feeds incorrectly connected.

Inadequate trigger signal causing jitter.

6.12.4 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.

6.12.5 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.

6.12.6 JITTER PRESENT IN IMAGE.

Inadequate or irreproducible trigger signal. The electronics has a jitter of about 20ps 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 focusing as the electrodes charge up.

7. CATHODES

The cathode materials normally recommended for X–ray use are cæsium iodide and gold but for high time resolution the energy spread from these 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 AS SOON AS POSSIBLE AFTER RECEIPT OF THE CAMERA

7.1 CATHODE MANUFACTURE

The most sensitive cathodes we have used are low density cæsium iodide. This material is made by thermal evaporation in a background atmosphere of argon. The cathode is in the form of a foam, with a structure scale length of a few microns. The voids in the material allow electrons to escape from a greater depth. Furthermore the presence of a large electric field in the material causes a cascading effect resulting in a small amount of gain. Ironically the low density material, with a very large effective surface area, is most tolerant of atmospheric water vapour. We believe this is because the absorbed water is quickly lost under vacuum, as a result of the large surface area. Low density cathodes are, however, not very mechanically robust.

A suitable "recipe" for the production of such cathodes is to evaporate approximately 1-2ccs of powdered cæsium iodide in a background of 5 mBarr of argon. The layout of the deposition chamber should be roughly as shown in figure Figure 15. The cæsium iodide is carried in the form of a smoke by convection currents in the background gas. A very uniform cathode can be made by rotating the substrate during the deposition.

8. DISC SOFTWARE INTERFACE

8.1 VERSIONS

The software has undergone several revisions before shipping and is likely to undergo more before final fielding. The current status of the revisions are as follows:

0.0 26 June 2009 PK	initial software version
0.1 30 June 2009 PK	add go flag to intensifier and camera status commands
0.2 09 July 2009 PK	add system commands, miscellaneous mods
0.3 14 July 2009 PK	remote command names revised

8.2 CAUTIONS

1 There is no internal thermal shutdown, temperature sensors must be regularly checked by the UCS and the DISC should be shutdown if they become excessive. It is assumed that the unit will be mounted on a heat sink.

3 The DISC will accept a wide range of desired voltage settings for the intensifier system. It is the users' responsibility to ensure that the various voltage settings are compatible with the intensifier. The use of the wrong voltages may destroy the intensifier/MAX module.

8.3 COMMAND LEVELS

There are currently three command levels. Level 1 is for general use. Level 2 for setting up by experienced users. Level 3 for more fundamental setting up, recalibration etc. by expert users who are thoroughly familiar with the device.

Level 3 commands are not covered by this manual. Contact Kentech Instruments Ltd. for details if required.

8.4 INTRODUCTION

The DISC software provides a comprehensive set of commands using a robust protocol similar to the GXD.

The DISC uses a Forth operating system similar to the GXD which is flashed into the H8 processor ROM. It will not be possible to reflash the processor without dismantling the control unit to make a hardware link.

The program in the DISC is stored in a serial EEPROM on the I2C bus which will is read into RAM and executed at power up. The program EEPROM is write protected by a momentary push button. It is possible to download upgraded software in the form of Forth source code to the DISC but it is recommended that this is done off line using a PC or Mac.

Calibration data are stored in a further serial EEPROM. This is write protected by the same momentary push button as the program memory. Again it is recommended that any modifications are done off line.

A further EEPROM contains non-volatile user data which is not write protected. This data consists primarily of cathode, mesh and focus voltages and trigger mode definitions. Changing the user data is a level 2 or engineering procedure. Level 2 commands are covered by this manual.

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

8.5 ARCHITECTURE

The DISC electronics hardware consists of 4 modules, these are:-

Module	*Module no.*
Control	0
EHT	1
Sweep	2
Intensifier	3

For software purposes the DISC system is subdivided into the Camera system consisting of modules 0 through 2 and the Intensifier system consisting of module 3.

Each system has a RUN and a STOP state, and each has a number of operating modes.

Note that the PCD supply is generated by the hardware in the intensifier module and therefore is part of the intensifier system.

8.6 INTENSIFIER SYSTEM

The intensifier is controlled at level 1 by sending values for 5 operational variables and switching the unit between RUN and STOP states. Operational variables are always reset on power up, i.e. they are volatile data. The intensifier will always power up into a STOP condition.

Note that the intensifier system can be in the RUN state but not operational because of an interlock or shutdown (i.e. one shot latch tripped) condition.

8.6.1 INTENSIFIER MODES

Mode#	*Mode*
0	Inhibit
1	MAX module, pulsed, no shutdown
2	MAX module, pulsed with shutdown
3	MAX module, dc operation, no shutdown
4	MAX module, dc operation with shutdown
5	Optical intensifier, pulsed cathode, no shutdown
6	Optical intensifier, dc operation, no shutdown

8.6.2 INTENSIFIER OPERATIONAL VARIABLES

Vphosphor	Amplitude of the pulsed or the DC voltage to be applied to the phosphor
Vmcp	MCP voltage, this can be used to DC bias the MAX module in pulsed mode. In an optical intensifier it will be the MCP DC voltage.
Vpcd	PCD voltage
PCwidth	Pulse width to be used on intensifier photocathode
Intensifier Mode	A number defining the operating mode as above

The pulse width setting affects only the cathode pulse width in mode 5. In all other modes it is ignored and can be set to zero but must be included. The phosphor pulse used with the MAX module has a fixed pulse width.

8.7 CAMERA SYSTEM

The camera system is controlled at level 1 by sending values for 3 operational variables and switching the unit between RUN and STOP states. Operational variables are always reset on power up, i.e. they are volatile data. The camera will always power up into a STOP condition.

8.7.1 CAMERA MODES

Mode#	*Mode*
0	Inhibit
1	Focus/Flat field
2	Repetitive
3	Single [set up to include crowbar and blanking]
4	User1
5	User2
6	User3
7	User4

8.7.2 CAMERA OPERATIONAL VARIABLES

Sweep#	A number selecting a set of sweep data
Trigger Mode	A number defining the trigger configuration.
Camera Mode	A number defining the operating mode as above.

8.7.2.1 SWEEP#

The sweep data is stored in write protected calibration EEPROM. This can be edited off line using level 3 commands.

16 sweeps have been preconfigured in the calibration EEPROM in the sweep table. See section ≈.

8.7.2.2 TRIGGER MODE

The trigger mode is a set of data controlling the selection of electrical or optical inputs, and the trigger sources for the various modules. Trigger modes can be edited and created using the level 2 commands below. There are 2 trigger modes preconfigured in the calibration EEPROM. Up to 8 modes can be configured with level 3 commands.

The trigger modes are copied into RAM at power up. If modes are edited or created they will be lost at power up unless they are save into the user EEPROM using the level 2 commands provided.

There are 3 potential trigger inputs, Main, T1 and T2. Each can be driven from an optical or an electrical signal. Each trigger mode contains 3 flags to control this.

Main trig optical?
T1 trig optical?
T2 trig optical?

Flag set (= -1) means the input is optical, reset (=0) means electrical.

There is also one channel of delay that can be fed from any of these trigger sources. Generally it is fed from Main trigger.

There are 3 variables to control the trigger source for the intensifier, the crowbar and the spare outputs. Each has several options.

For the intensifier and crowbar the options are:-

0 Main trigger
1 Delayed trigger
2 T1
3 T2

and for the spare outputs:-

0 both main
1 both delayed
2 spare1 from main, spare2 from T2
3 spare1 from T1, spare2 from T2

Two trigger modes are preconfigured and are expected to be the most useful.

Mode 0 has Main, T1 and T2 switched to electrical, intensifier triggered from T1, crowbar and blanking from delayed trigger, spare 1 output from main and spare 2 output from T2.

Mode 1 has Main, T1 and T2 as optical inputs, otherwise identical to mode 0.

The delayed trigger is used for the blanking pulser and the delay value is a parameter in the sweep table. The sweep trigger is always MAIN.

In normal use one would expect to trigger the intensifier first so that it is working in time for the shot. Then the sweep at or near shot time and then the blanking and crowbar after the shot.

The Main trigger is a low jitter signal that is buffered and fed to the Sweep trigger output. The other two trigger inputs are fed to the CPLD where they can be routed to various places. The CPLD also detects the main trigger so that it can use it as an input to the delay channel.

8.7.3 USER VARIABLES

User variables include the trigger mode table and the cathode, mesh and focus voltage settings.

Commands are provided to edit all these variables. Note that any changes will be lost unless they are save into the user EEPROM using the level 2 commands provided.

The EEPROM containing non-volatile user data is ***not*** write protected and can be corrupted or overwritten with inappropriate values. A command is provided to overwrite the user variables in RAM with the factory defaults.

Commands are provided to allow the changing of the cathode, mesh and focus voltages with the camera in the ON state in focus mode to assist with focussing. To avoid tripping the focus supply it is necessary that any step changes are small and the software limits them to 50V.

8.8 MODULE CONFIGURATIONS

Each module will have a number of operating configurations. It is not necessary to manipulate these directly as they are controlled and selected by the intensifier and camera operating modes.

Control module configurations

0	Inhibit
1	Static
2	Swept no blanking
3	Swept with blanking
4	Swept no blanking single sweep
5	Swept with blanking single sweep

EHT module configurations

0	Inhibit
1	Run no crowbar
2	Run with crowbar

Sweep module configurations

0	Inhibit
1	Run normal
2	Bias only

8.9 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 or Mac and are not covered by this manual. Level 3 commands can use level 1 and 2 commands but also include many commands that do not adhere to the protocol.

The protocol is very similar to that used on the GXD and LFC.

The DISC 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 the DISC 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.

The DISC 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, the DISC 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 the DISC 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 than 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.

For example

1) To set up camera in mode 2 (repetitive mode) using trigger mode 0 (default electrical trigger) and sweep# 5, the command would be

0 5 2 !c_mod

and the response would be

{0 5 2 !c_mod;-1}

2) as above but with a missing parameter

0 2 !c_mod

and the response would be:-

{-1 -1 -1 !c_mod;?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

0 500 2 !c_mod

and the response would be:-

{0 500 2 !c_mod ;?param}

Again no execution will result.

8.9.1 COMMANDS

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

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.

8.10 LEVEL 1 OPERATIONAL COMMANDS

Note that level 1 and 2 commands have names as well as formats. If using a level 1 or 2 command within a word definition at level 3 it is best to use the name rather than the format. The name used as a level 3 command will return values onto the stack in the order specified so that the first item to be read on the stack is the last item the function sends. The use of the name at levels 1 or 2 will result in the command being ignored as they are not part of the level 1 and 2 protocol.

8.10.1 INTENSIFIER SYSTEM

Name	**!intmode**
Explanation	write intensifier system mode
Format	p1 p2 p3 p4 p5 i_!mod
parameter 1	p1 = pcd voltage, range 0 to 900 volts
parameter 2	p2 = mcp voltage, range 0 to 900 volts
parameter 3	p3 = phosphor voltage, range 0 to 6000 volts
parameter 4	p4 = cathode pulse width, range 252 to 30,000, us
parameter 5	p5 = intensifier mode, range 1 to 6
returned value 1	r1 = command completed?, true or false
Notes	will execute only if intensifier system is in STOP state
	r1 = false implies system in RUN state

Name	**@intmode**
Explanation	read intensifier system mode
Format	i_@mod
returned value 1	r1 = pcd voltage
returned value 2	r2 = mcp voltage
returned value 3	r3 = phosphor voltage
returned value 4	r4 = cathode pulse width
returned value 2	r5 = intensifier mode
Notes	returns values set with !intmode, not measured voltages

Name	**intrun**
Explanation	put intensifier system into RUN state
Format	i_run
returned value 1	r1 = command completed?, true or false
Note	will execute only if intensifier system is in STOP state
	r1 = false implies system in RUN state

Note that after executing an intrun (i_run) command there is a 3 second built in delay before the intensifier/MAX module becomes operational. The operational state can be checked with the @intstatus (i_@sts) command.

Name	**intstop**
Explanation	put intensifier system into STOP state
Format	i_stp
returned value 1	r1 = command completed?, true or false
Notes	will execute only if intensifier system is in RUN state
	r1 = false implies system in STOP state
Name	intarm
Explanation	reset intensifier trigger latch
Forma	i_arm

Notes This currently only resets intensifier trigger latch. There is no inhibit of the intensifier by the latch.

Name	**@intadcs**
Explanation	read intensifier system adcs
Format	i_@adc
returned value 1	r1 = pcd voltage from adc
returned value 2	r2 = mcp voltage from adc
returned value 3	r3 = phosphor voltage from adc
returned value 4	r4 = phosphor PSU voltage from adc
Note	returns are measured values

Name	**@intstatus**
Explanation	read intensifier system status
Format	i_@sts
returned value 1	r1 = int_go?, true/false
returned value 1	r2 = intrunning?, true/false
returned value 2	r3 = intshutdown?, true/false
returned value 3	r4 = intinterlock?, true/false
Notes	operational intensifier system requires
	in_go? = true
	int_go? is true if and only if:-
	intrunning? = true
	intshutdown?= false
	intintlk? = false

8.11 CAMERA SYSTEM

Name	**!cammode**
Explanation	write camera system mode
Format	p1 p2 p3 c_!mod
parameter 1	p1 = trigger mode, range 0 to 7
parameter 2	p2 = sweep#, range 0 to 31
parameter 3	p3 = camera mode, range 0 to 7
returned value 1	r1 = command completed?, true or false
Note	will execute only if intensifier system is in STOP state
	r1 = false implies system in RUN state

Name	**@cammode**
Explanation	read camera system mode
Format	c_@mod
returned value 1	r1 = trigger mode
returned value 2	r2 = sweep#
returned value 3	r3 = camera mode
Notes	returns values set with !cammode, not measured voltages

Name	**camrun**
Explanation	put camera system into RUN state
Format	c_run
returned value 1	r1 = command completed?, true or false
Notes	will execute only if intensifier system is in STOP state r1 = false implies system in RUN state

Name	**camstop**
Explanation	put camera system into STOP state
Format	c_stp
returned value 1	r1 = command completed?, true or false
Notes	will execute only if intensifier system is in RUN state r1 = false implies system in STOP state

Name	**@camtubeadcs**
Explanation	read camera system tube voltage adcs
Format	c_@tua
returned value 1	r1 = cathode voltage
returned value 2	r2 = mesh voltage
returned value 3	r3 = focus voltage
returned value 4	r4 = bias voltage
Note	returns are measured values

Name	**@camtempadcs**
Explanation	read camera system temperature adcs
Format	c_@tea
returned value 1	r1 = temperature 1 degrees centigrade
returned value 2	r2 = temperature 2 degrees centigrade
returned value 3	r3 = temperature 3 degrees centigrade
returned value 4	r4 = temperature 4 degrees centigrade
returned value 5	r5 = temperature 5 degrees centigrade
Notes	returns are measured values

Name	**@campoweradcs**
Explanation	read camera system power supply adcs
Format	c_@psa
returned value 1	r1 = supply voltage millivolts
returned value 2	r2 = supply current mA
Notes	returns are measured values

Name	**@camstatus**
Explanation	read camera system status
Format	c_@sts
returned value 1	r1 = cam_go?, true/false
returned value 2	r2 = eht running?, true/false
returned value 3	r3 = sweep running?, true/false
returned value 4	r4 = control running?, true/false
returned value 5	r5 = EHT shutdown?, true/false
returned value 6	r6 = EHT tripped?, true/false
returned value 7	r7 = EHT steady?, true/false
returned value 8	r8 = control armed?, true/false
Notes	operational camera system requires r1 cam_go? = true camgo? is true if and only if:- r2 eht running? = true r3 sweep running? = true r4 control running? = true r5 EHT shutdown? = false r6 EHT tripped? = false r7 EHT steady? = true r8 control armed? = true EHT voltage stable (i.e. soft start completed)

Name	**camarm**
Explanation	arm control/sweep module
Format	c_arm this arms the control/sweep unit and resets trigger latches. Generally after a shot in single mode it is necessary to restart the EHT power supply module using a camstop and camrun sequence.

8.12 CAMERA AND INTENSIFIER COMBINED

Name	**arm**
Explanation	arm system
Format	s_arm this arms the control/sweep unit and resets trigger latches. Generally after a shot in single mode it is necessary to restart the eht power supply module using a stop and run sequence.

Name	**@trigstatus**
Explanation	read trigger latch status
Format	s_@tst
returned value 1	r1 = T1 input triggered?, true/false
returned value 2	r2 = T2 input triggered?, true/false
returned value 3	r3 = Main input triggered?, true/false
returned value 4	r4 = EHT module triggered?, true/false
returned value 5	r5 = INT module triggered?, true/false
returned value 6	r6 = SWp module triggered?, true/false
Notes	The triggered flags reflect the state of latches on the relevant trigger inputs.

Triggered flag set indicates only a signal at the input, does not confirm any pulse at the module outputs. These latches are not reset by a stop and run sequence, reset using arm.

Name	**@healthstatus**
Explanation	read health status
Format	s_@hst
returned value 1	r1 = ?ehtfound, true/false
returned value 2	r2 = ?intfound, true/false
returned value 3	r3 = ?swpfound, true/false
Notes	Returns the results of the power up hardware tests. A true value indicates the relevant module was found. A false value indicates a problem with the I2C connector or other hardware fault.

Name	**@sysstatus**
Explanation	read system status
Format	s_@sst
returned value 1	r1 = ?sysgo, true/false
returned value 2	r2 = ?camgo, true/false
returned value 3	r3 = ?intgo, true/false
Notes	Returns the state of the system go flag. Sysgo = true implies the system is ready for the next shot. This is the logical and of the camera and intensifier go flags.

Name	**run**
Explanation	put combined system into RUN state
Format	s_run
returned value 1	r1 = command completed?, true or false
Notes	r1 = false implies the camera and/or the intensifier system was already in

RUN state. Will leave both camera and intensifier in RUN state regardless.

Name	**stop**
Explanation	put camera system into STOP state
Format	s_stp
returned value 1	r1 = command completed?, true or false
Notes	r1 = false implies the camera and/or the intensifier system was already in

STOP state. Will leave both camera and intensifier in STOP state regardless.

Name	**@version#**
Explanation	read software version no.
Format	s_@ver
returned value 1	r1 = version number, currently 0.

Name	**@serial#**
Explanation	read software version no.
Format	s_@ser
returned value 1	r1 = serial number

8.13 LEVEL 2 ENGINEERING COMMANDS

Name	**@camuservolts**
Explanation	read camera system user voltage settings
Format	c_@usv
returned value 1	r1 = cathode voltage
returned value 2	r2 = mesh voltage
returned value 3	r3 = focus voltage
Notes	returns set values, not measured values

Name	**camfocus**
Explanation	setup camera focus condition
Format	p1 c_foc
parameter 1	p1 = bias voltage for focus
returned value 1	r1 = command completed?, true or false
Notes	will execute only in focus/flat-field mode false return implies system in the wrong mode or in STOP state

Name	**camflatarm**
Explanation	Arm the camera system in flat field mode
Format	p1 c_fla
parameter 1	p1 = voltage increment per step for flat field
returned value 1	r1 = estimated time in ms for complete flat field
returned value 2	r2 = command completed?, true or false
Notes	will execute only in focus/flat-field mode false return implies system in the wrong mode or in STOP state restores sweep bias to flat-field start condition

Name	**camflattrig**
Explanation	Trigger the camera system in flat field mode
Format	c_flt
returned value 1	sweep bias voltage on termination
returned value 2	r2 = command completed?, true or false
Notes	will execute only in focus/flat-field mode false return implies system in the wrong mode or in STOP state This command will sent 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	**incvcathode**
Explanation	add an increment to the cathode voltage
Format	p1 c_ivc
parameter 1	p1 = voltage increment, range +/-50V
returned value 1	revised cathode voltage setting
returned value 2	r2 = command completed?, true or false
Notes	will execute only in focus/flat-field mode
	false return implies system in the wrong mode or in STOP state
	Changes only the ram value, will be lost on power up unless saved

Name	**incvfocus**
Explanation	add an increment to the focus voltage
Format	p1 c_ivf
parameter 1	p1 = voltage increment, range +/-50V
returned value 1	revised focus voltage setting
returned value 2	r2 = command completed?, true or false
Notes	will execute only in focus/flat-field mode
	false return implies system in the wrong mode or in STOP state
	Changes only the ram value, will be lost on power up unless saved

Name	**incvmesh**
Explanation	add an increment to the mesh voltage
Format	p1 c_ivm
parameter 1	p1 = voltage increment, range +/-50V
returned value 1	revised mesh voltage setting
returned value 2	r2 = command completed?, true or false
Notes	will execute only in focus/flat-field mode
	false return implies system in the wrong mode or in STOP state
	Changes only the ram value, will be lost on power up unless saved

Name	**!trigmode**
Explanation	store settings to a trigger mode
Format	p1 p2 p3 p4 p5 p6 p7 s_!tgm
parameter 1	p1 = Main trig optical?, true/false
parameter 2	p2 = T1 trig optical?, true/false
parameter 3	p3 = T2 trig optical?, true/false
parameter 4	p4 = Intensifier trig source, range 0 to 3
parameter 5	p5 = Crowbar trig source, range 0 to 3
parameter 6	p6 = Spare trig source, range 0 to 3
parameter 7	p7 = trigmode, range 0 to 7
	Changes only the ram value, will be lost on power up unless saved

Name	**@trigmode**
Explanation	read settings from a trigger mode
Format	p1 s_@tgm
parameter 1	p1 = trigmode, range 0 to 7
returned value 1	r1 = Main trig optical?, true/false
returned value 2	r2 = T1 trig optical?, true/false
returned value 3	r3 = T2 trig optical?, true/false
returned value 4	r4 = Intensifier trig source, range 0 to 3
returned value 5	r5 = Crowbar trig source, range 0 to 3
returned value 6	r6 = Spare trig source, range 0 to 3

Name	**saveuser**
Explanation	save user data to EEPROM
Format	s_sus

Name	**restoreuser**
Explanation	read user data from EEPROM into ram
Format	s_rus

Name	**defaultuser**
Explanation	read factory user data from calibration EEPROM into ram
Format	s_dus
	Changes only the ram value, will be lost on power up unless saved

8.14 LEVEL 3 COMMANDS

Level 3 commands enable one to reconfigure many things and overide safety features etc. They permit controlling trip levels, setting up sweep and trigger parmeters. These commands will not normally be accessed via the UCS but with a terminal programme such as Hyperterminal, Terminal (available from Kentech) or a Forth terminal programme (for use with Macs). A few details are given here for the setting of sweep configurations and changing the focus supply trip levels.

8.14.1 CHANGING THE SWEEP TABLE

This requires the use of level 3 commands. These are accessed by placing the camera in debug mode. Debug mode does not adhere to the protocol. Debug mode is not suitable for use with the UCS. Debug mode should not be used by anyone who is not familiar with the system and its potential vulnerabilities. In debug mode one is talking to the FORTH operating system using the FORTH language.

If the DISC is powered down in debug mode it will power back up in the same mode.

+debug	changes to debug mode
-debug	changes back to standard protocol mode

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 must be operated by inserting a small screw driver or similar object into the labelled hole on the control unit see Figure 16.

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 32 different

Figure 16 The boot enable access hole is located on the top of the control unit

sweeps, numbered 0 to 31.

Currently defined sweeps are

0	1ns
1	2ns
2	3ns
3	4ns
4	5ns
5	8ns
6	10ns
7	20ns
8	30ns
9	50ns
10	100ns
11	special1
12	special2
13	special3
14	special4
15	special5
16 - 31	not defined

Each sweep entry consists of 12 fields.

The first field “time” is intended to hold the physical sweep speed but is not used at present.

The ramp circuit works by adding several stages together. This gives a degree of arbirtrary waveform generation ability that helps when the sweep duration is similar to the round trip time of the cabling. There is a hold up circiut 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.

There are 12 fields to control the sweep module hardware. The fields do the following things:

swp_time	for reference, not used
swp_bias	the optimum bias voltage for this sweep speed, measured empirically.
swp_hold	delay for firing hold up circuit (0 to 63, 63 = short delay)
swp_60v	controls the slope of a stage
swp_18v_0 through _4	controls the delay of a stage
swp_diode	if set to true turns on a diode to increse the speed slightly Only used on the fastest sweep.
swp_short	Set true if the ramp is to be fully on screen, used for timing see speed 11.
swp_bldel	Sets the delay for the blanking pulser. This is set to fire at the end of the ramp.

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

Word	Stack effect
@swp_time	(swp# -- n)
@swp_bias	(swp# -- n)
@swp_hold	(swp# -- n)
@swp_60v	(swp# -- n)
@swp_18v_0	(swp# -- n)
@swp_18v_1	(swp# -- n)
@swp_18v_2	(swp# -- n)
@swp_18v_3	(swp# -- n)
@swp_18v_4	(swp# -- n)
@swp_diode?	(swp# -- n)
@swp_short?	(swp# -- n)
@swp_bldel	(swp# -- n)

e.g.

```
3 @swp_bias .
```

Will print the bias field for sweep 3

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

Word	Stack effect
!swp_time	(n swp# --)
!swp_bias	(n swp# --)
!swp_hold	(n swp# --)
swp_60v	(n swp# --)
!swp_18v_0	(n swp# --)
!swp_18v_1	(n swp# --)
!swp_18v_2	(n swp# --)
!swp_18v_3	(n swp# --)
!swp_18v_4	(n swp# --)
!swp_diode?	(n swp# --)
!swp_short?	(n swp# --)
!swp_bldel	(n swp# --)

e.g.

```
3500 1 !swp_60v
```

will set the 60v dac field for sweep 1 to 3500.

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.

E.g. if you type or download the following, sweep 16 will be set up similarly to exisiting sweep 1

```
2000 16 !swp_time
610 16 !swp_bias
false 16 !swp_short?
false 16 !swp_diode?
63 16 !swp_hold
3500 16 !swp_60v
2500 16 !swp_18v_0
2700 16 !swp_18v_1
2300 16 !swp_18v_2
2300 16 !swp_18v_3
2300 16 !swp_18v_4
0 16 !swp_bldel
```

Note that true is -1, and false is 0, the interface can accept either format.

Once ther table is modified it must be save to EEPROM as shown earlier in theis section.

8.15 CONTROL EXAMPLES

1) Repetitive

0 5 2 !c_mod {cr}
set up camera in mode 2 (repetitive mode) using trigger mode 0 (default electrical trigger) and sweep# 5,

{ 0 5 2 !c_mod; -1} executed ok

250 450 5000 0 !i_mod {cr}
set up intensifier in mode 6 (optical intensifier , dc operation)
450v on mcp
250 v on pcd
5000v on phosphor

{250 450 5000 0 !i_mod; -1}
executed ok

c_run Camera to RUN state

{c_run;-1} executed ok

i_run Intensifier to RUN state

{i_run: -1} executed ok

Wait till ready for shot then

@c_prs camera pre shot check

{@c_prs; -1 15010 11005 104990 0 5 2}
(camera is go, volts and modes look good)

@i_prs intensifier pre shot check

{ @i_prs; -1 251 449 4995 6}
intensifier is go, volts and mode look good

Do shot

Going to be a long time till next one so

c_stp Camera to STOP state

{c_stp;-1} executed ok

i_stp	Intensifier to STOP state
{i_stp: -1}	executed ok

Nearly ready for next shot so back to RUN

c_run	Camera to RUN state
{c_run;-1}	executed ok
i_run	Intensifier to RUN state
{i_run: -1}	executed ok

Wait till ready then

@c_prs	camera pre shot check
{@c_prs; -1 15010 11005 104990 0 5 2}	
	(camera is go, volts and modes look good)
@i_prs	intensifier pre shot check
{ @i_prs; -1 251 449 4995 6}	
	intensifier is go, volts and mode look good

9. CURRENT TRIPS

There is no current trip on the intensifier supply.

There is a trip on the focus unit. The trip uses the currents in the mesh, focus and cathode circuits summed together.

There are two settings:-

ehtrisetrip	- variable containing the value used during soft start.
ehtdctrip	- variable containing the value used after soft start when the eht is steady.

The values are the numbers output to the dac, range 0 to 4095. They work in inverse logic, higher is more sensitive, lower is less sensitive.

Default settings are:-

3000 for ehtrisetrip
3300 for ehtdctrip

The dctrip is more sensitive. These are the most sensitive values that work reliably on the bench (no tube attached).

They are read with the level 3 commands

ehtrisetrip @ .
ehtdctrip @ .

They can be changed by for example

1234 ehtrisetrip !

2345 ehtdctrip !

Newly entered values will be overwritten at power up or reset unless stored with ee!cal.

0cal will restore factory defaults to these and all other calibration variables.

9.1 CORONA

On our standard X-ray streak cameras the electron lens electrodes are fed from a high impedance source. The result is that although the overall voltage is stabilised corona from an electrode can affect significantly the voltage on the electrode leading to a possible defocus.

On the DISC tube the requirement to blank and crowbar the electrodes means that the source impedance is significantly lower. Also each electrode is individually stabilised. This has the failure mode that if one electrode is grounded the relative voltage to another is high. There are zener diodes between lens elements to help protect the cathode and mesh. In addition there is a current trip that will shut down all three voltages. Current leakage via corona can be compensated for up to the current limit level.

10. THE SOURCE CODE

The software inside the DISC is in two sections:-

The Forth operating system resides in the 128kbyte Flash memory of the Renesas H8S/2148F microprocessor.

The application program resides in an I2C serial EEPROM.

Forth Operating System

The Forth operating system uses MPE ROMFORTH. It was produced using the H8/330H and H8S Forth 6 Cross Compiler version 6.2 from:-

MPE Ltd.
133 Hill Lane
Southampton SO15 5AF
UK

Tel +44 2380 631441
Fax +44 2380 339691
http://www.mpeltd.demon.co.uk/

Most of the source code for the Forth development system is proprietary to MPE and we are not allowed to disclose it unless the user purchases a licence for the Forth 6 Cross Compiler. It is not easy or meaningful to supply our modifications to the MPE code without also supplying sections of the original code. However, it is possible to change the application program without changing the Forth operating system so we consider that this is not strictly necessary and that it is beyond the scope of the current contract.

The Forth 6 Cross Compiler generates an image file from the source code which is then put into flash memory. A copy of the GXD image file called “CPU2148.IMG” is supplied on CD. The image file can be transferred to the flash memory on the Renesas H8S/2148F using the “Flash Development Toolkit” which is available from Renesas Technology www.renesas.com. This should be necessary only if the H8S/2148F chip fails and is replaced with a new unprogrammed item.

11. CATHODE PACK

The unit is supplied with a LLNL 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 to be supplied by LLNL.

12. TUBE DATA

Deflection sensitivity +&- 18.9V/mm J0902271-1 and 18.0V/mm J0902271-2

Focus potentials when focussed with a LLNL MAX module.

These are the potentials in volts measured with the built in monitor.

13. SWEEP DATA

In Table 1 on page 49, delays to screen centre w.r.t. speed 0 are shown as well as the total screen duration on a 35 mm MAX module. Speed 11 is a reduced scan speed, the screen duration is made up from the sweep and the time before the tube is blanked but note that the exposure has no set beginning as the sweep starts on screen.

Sweep data is shown in Figure 17 on page 51 and Figure 18 on page 58.

Table 1 Sweep speed delay data.

J0902271-1

Name	Nominal Screen sweep duration ns	relative delay wrt speed 0 ns
0	1.2	0
1	1.8	3.54
2	2.5	3.42
3	3.4	5.48
4	4.4	3.94
5	7.6	8.18
6	9.1	9.5
7	16.8	19.54
8	25	30.9
9	38	36.3
10	80	79.1
11	40/300	28.3

J0902271-2

Name	Nominal Screen sweep duration ns	relative delay wrt speed 0 ns
0	1	0
1	2	3.18
2	2.8	3.18
3	3.5	5.22
4	4.4	4.68
5	7.6	7.26
6	9	8.44
7	16.8	20.04
8	25.6	33.6
9	42	40.48
10	80	92.08
11	40 / 300	34.88

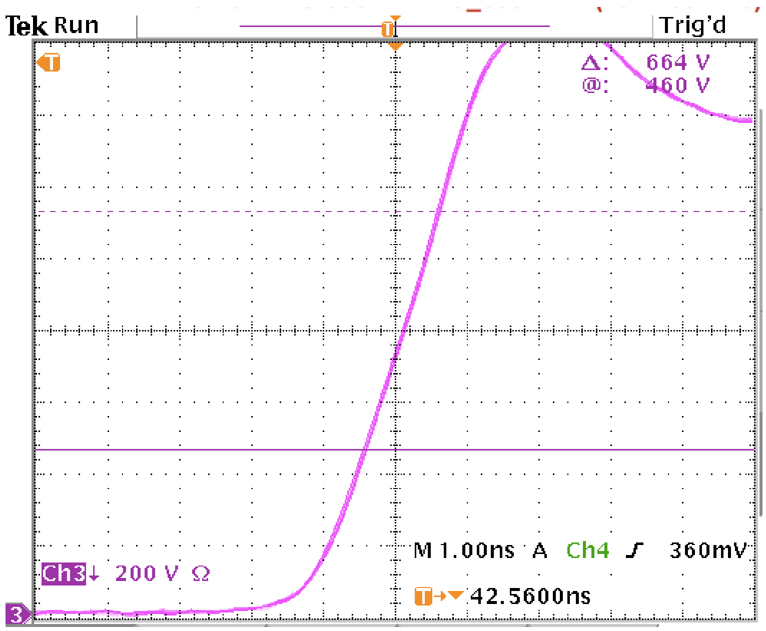
14. CROWBAR AND BLANKING DELAY

The sweep speed table includes a value for the blanking delay for each sweep speed. This is the delay that is added to the main trigger before the signal is fed to both the blanking circuit and the Crowbar circuit (in normal operation).

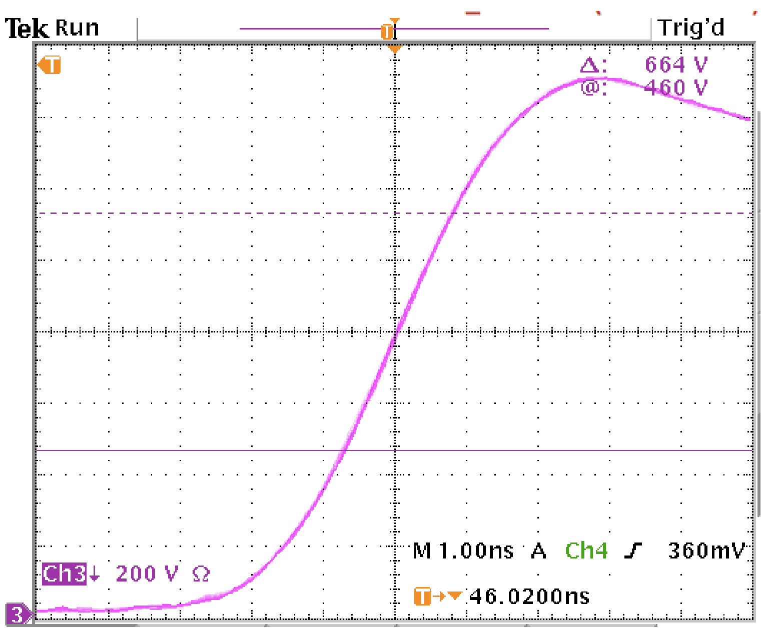
.

Figure 17 Sweep Data J0902271-1

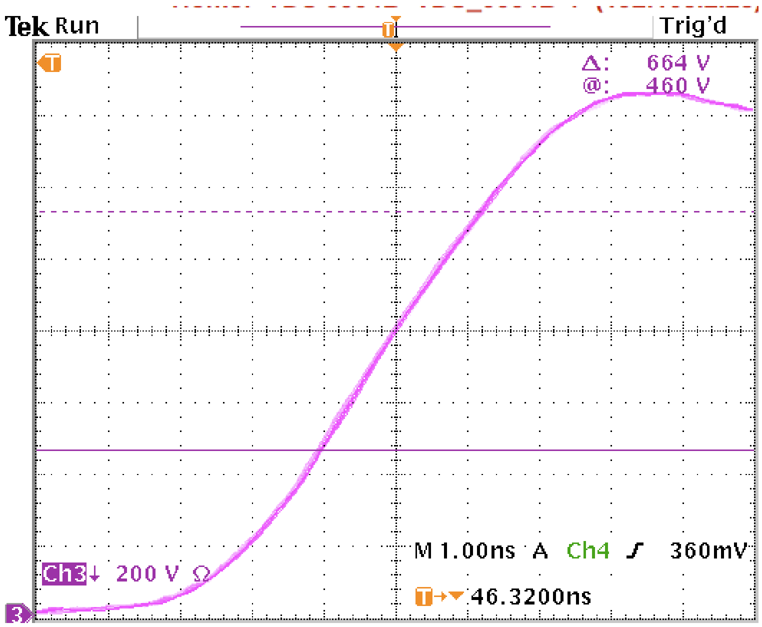
J0902271-1 Sweep 0



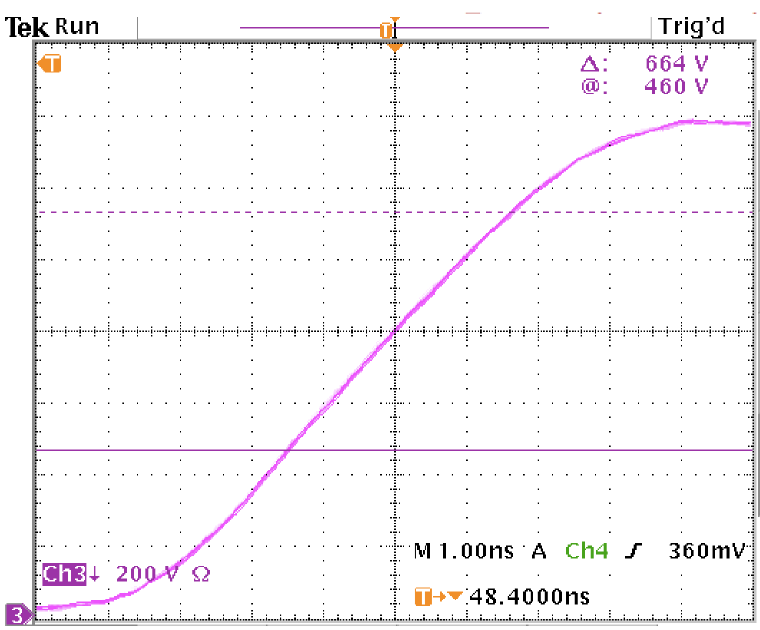
J0902271-1 Sweep 1



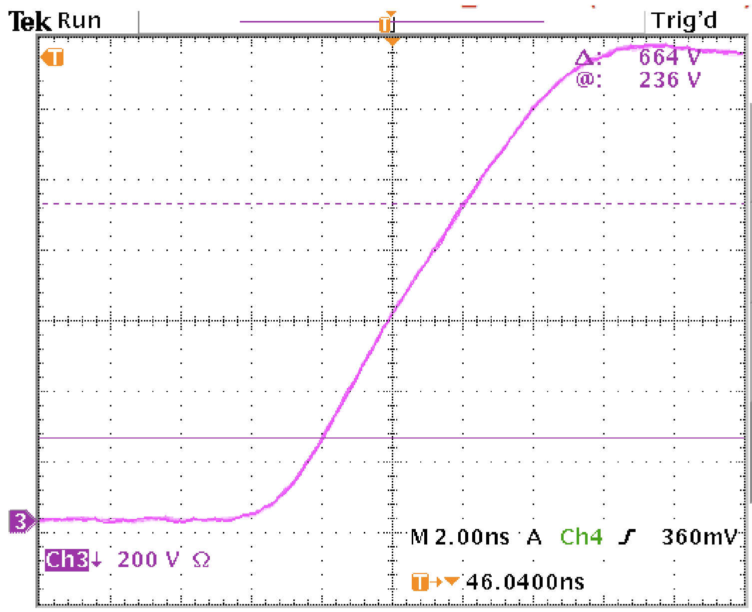
J0902271-1 Sweep 2



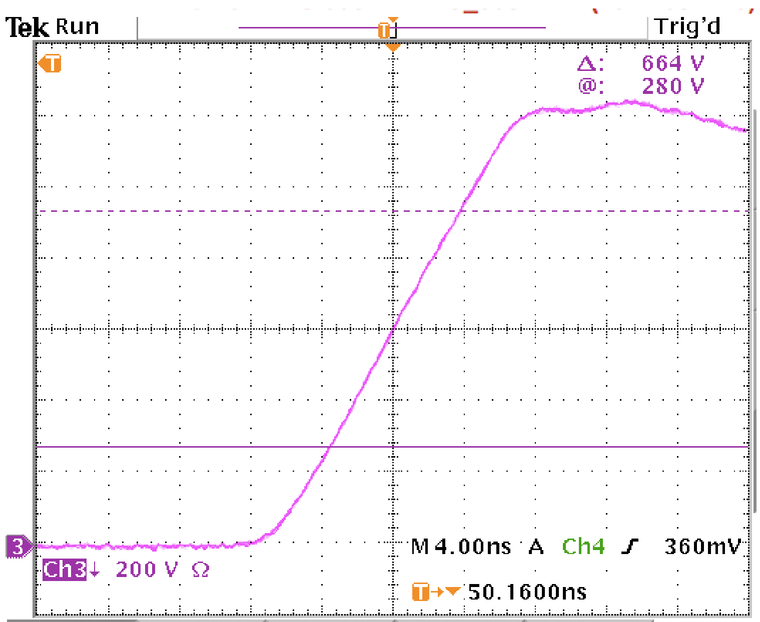
J0902271-1 Sweep 3



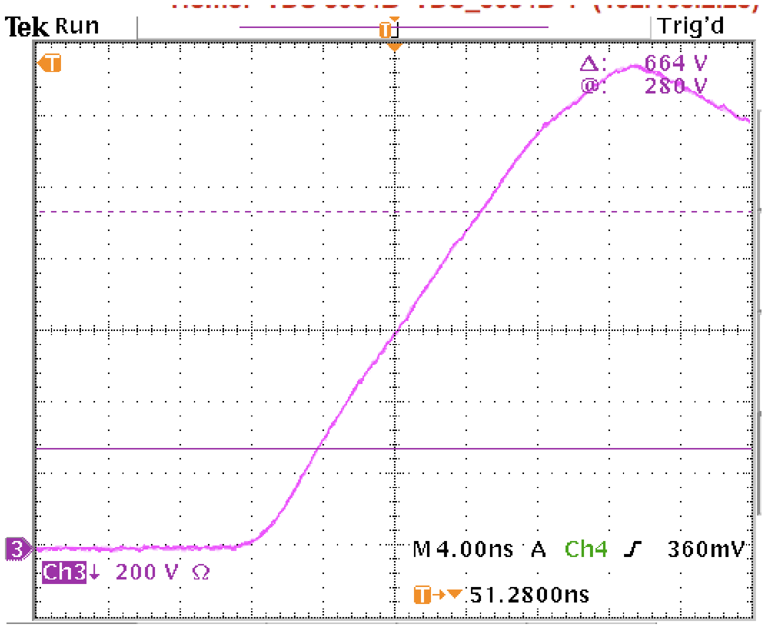
J0902271-1 Sweep 4



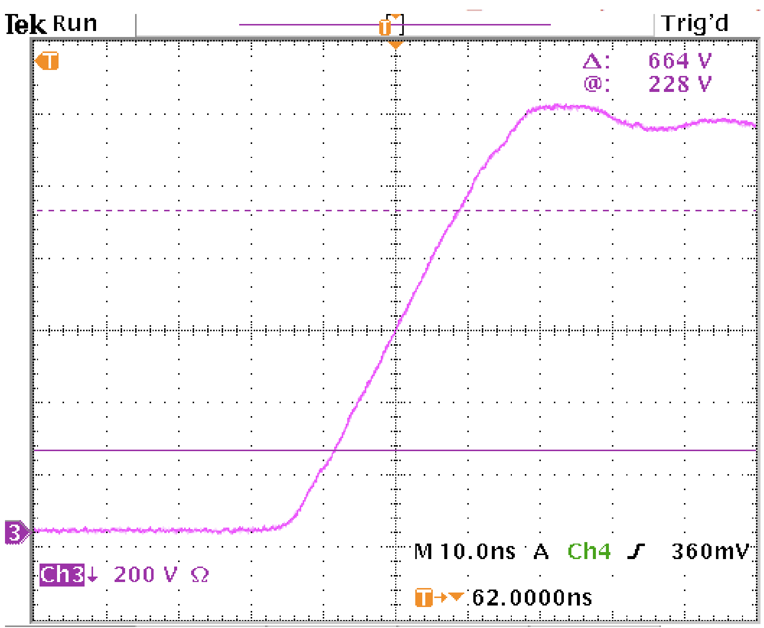
J0902271-1 Sweep 5



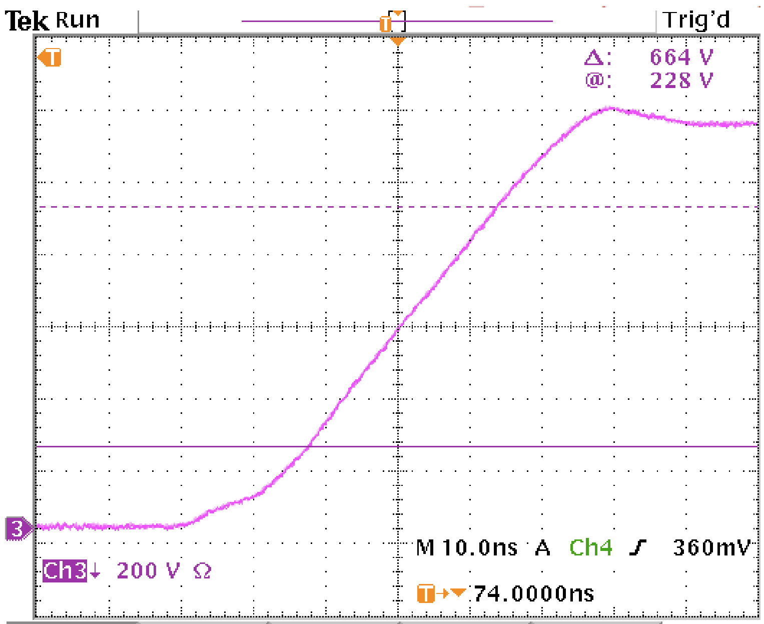
J0902271-1 Sweep 6



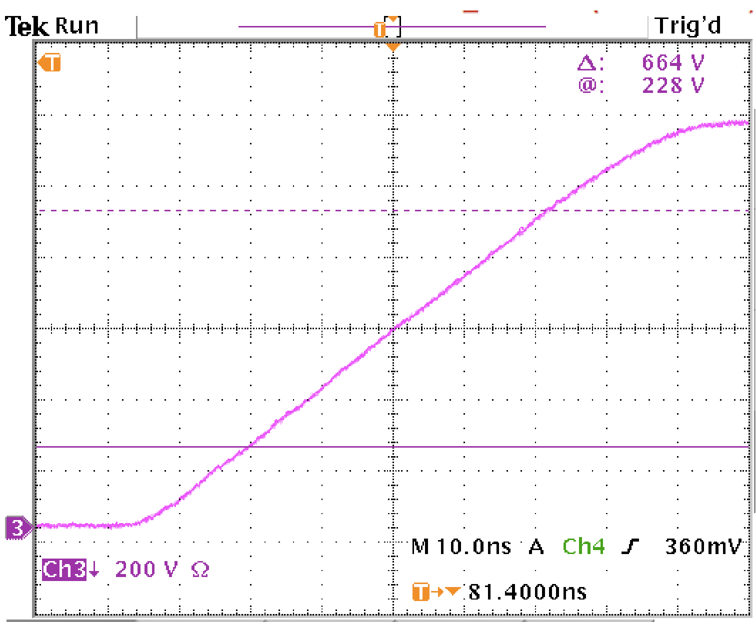
J0902271-1 Sweep 7



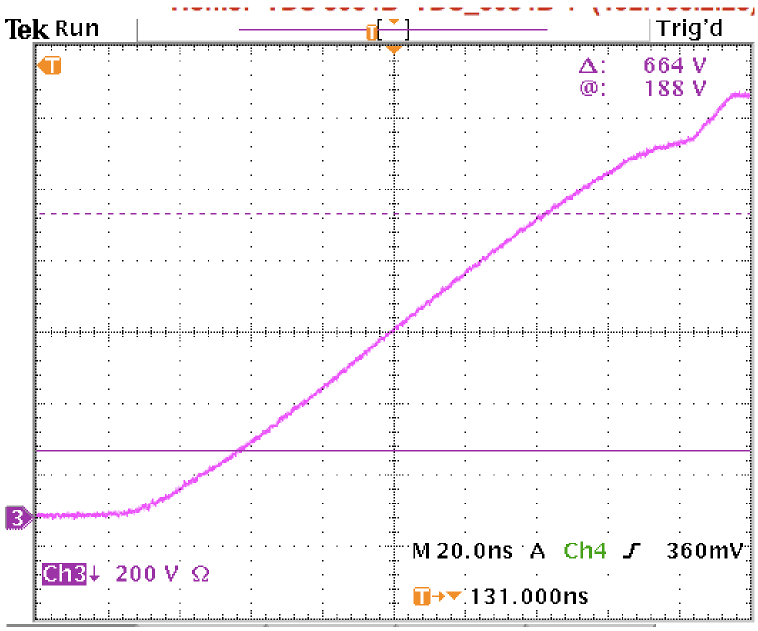
J0902271-1 Sweep 8



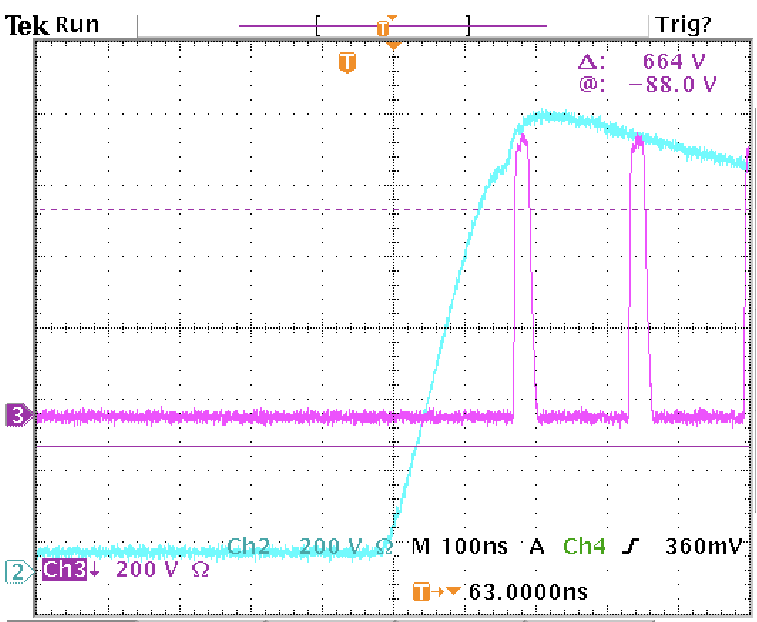
J0902271-1 Sweep 9



J0902271-1 Sweep 10



J0902271-1 Sweep 10 blanking and hold off delays



J0902271-1 Sweep 11 hold off late.
Blanking late but near hold off time

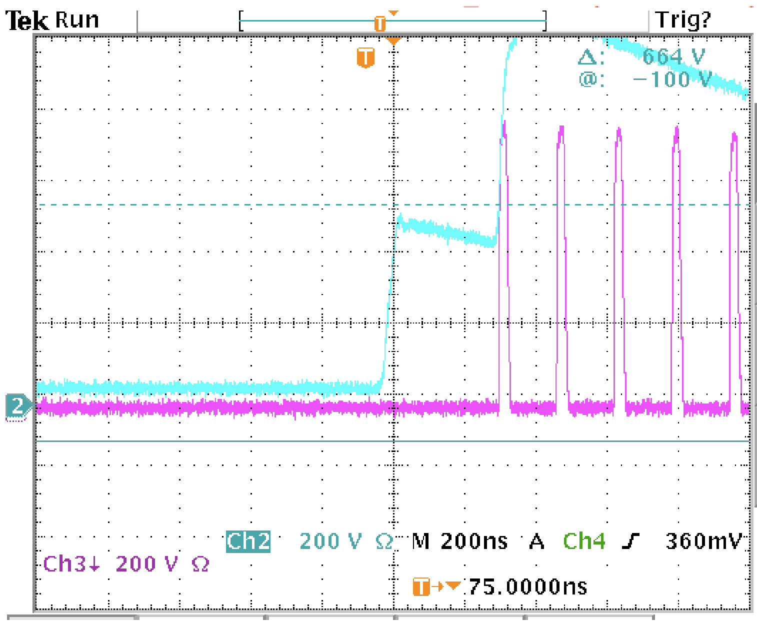
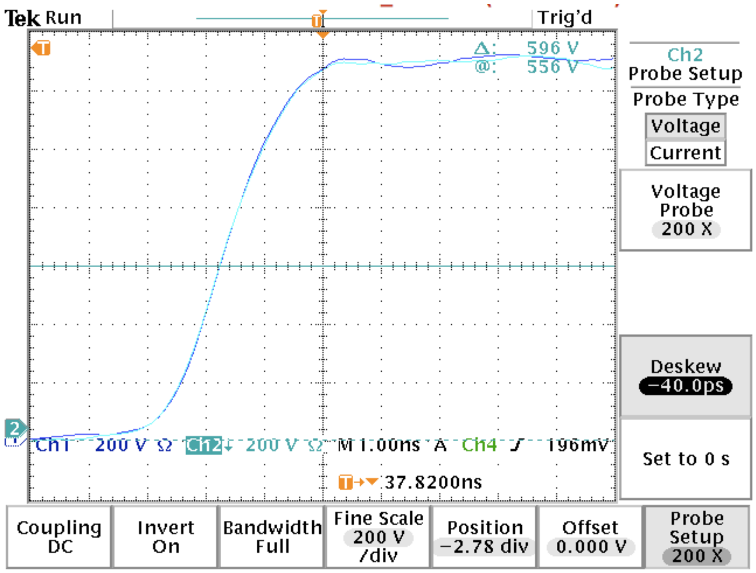
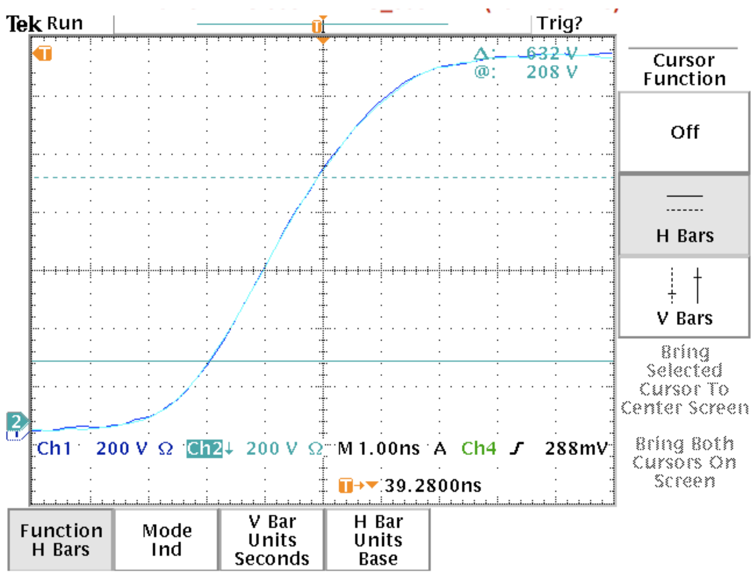


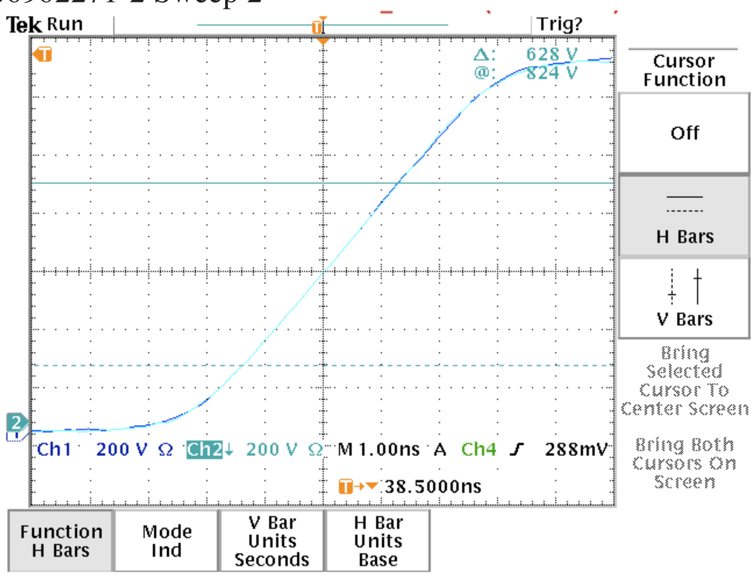
Figure 18 Sweep Data J0902271-2
J0902271-2 Sweep 0



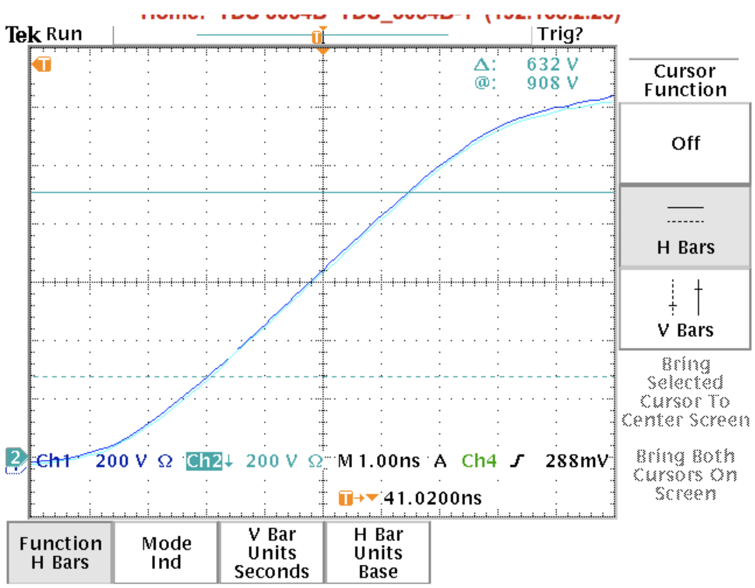
J0902271-2 Sweep 1



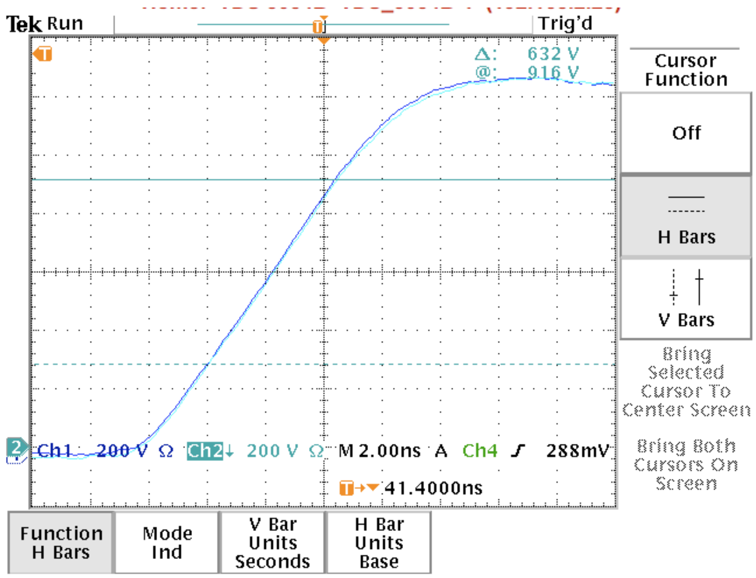
J0902271-2 Sweep 2



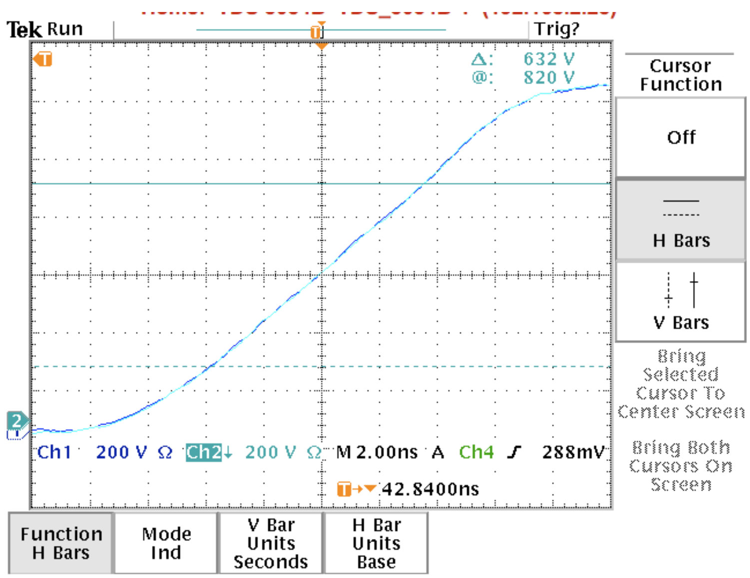
J0902271-2 Sweep 3



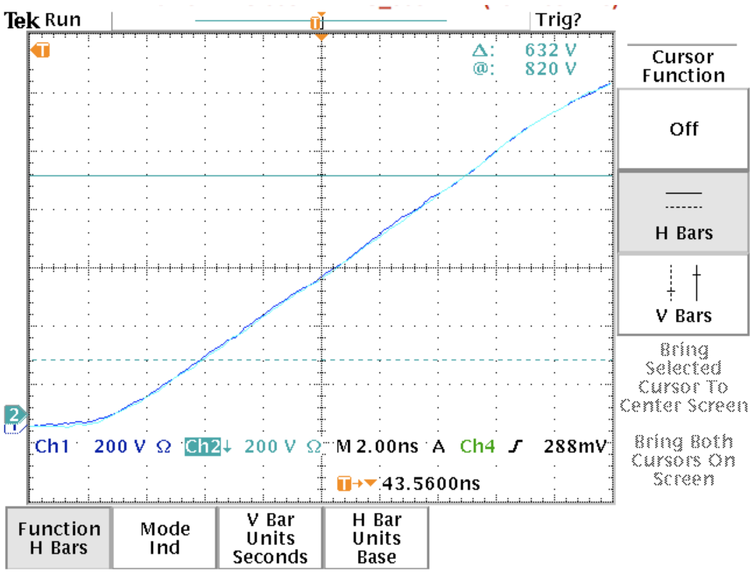
J0902271-2 Sweep 4



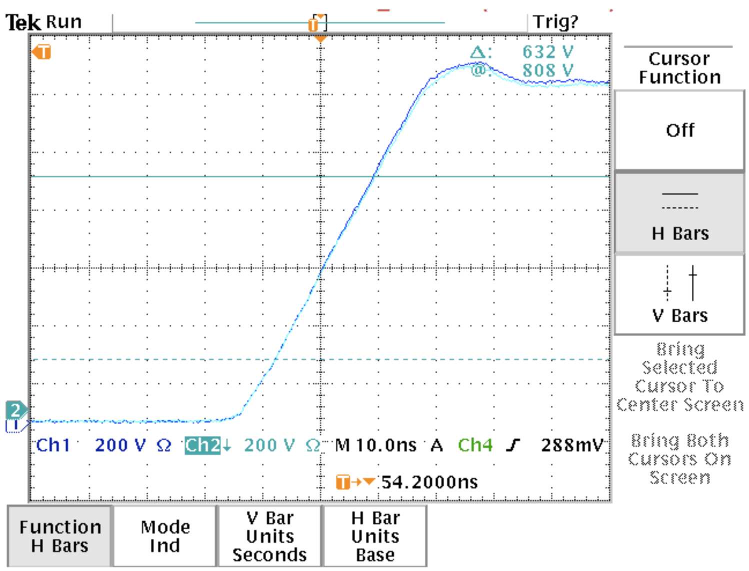
J0902271-2 Sweep 5



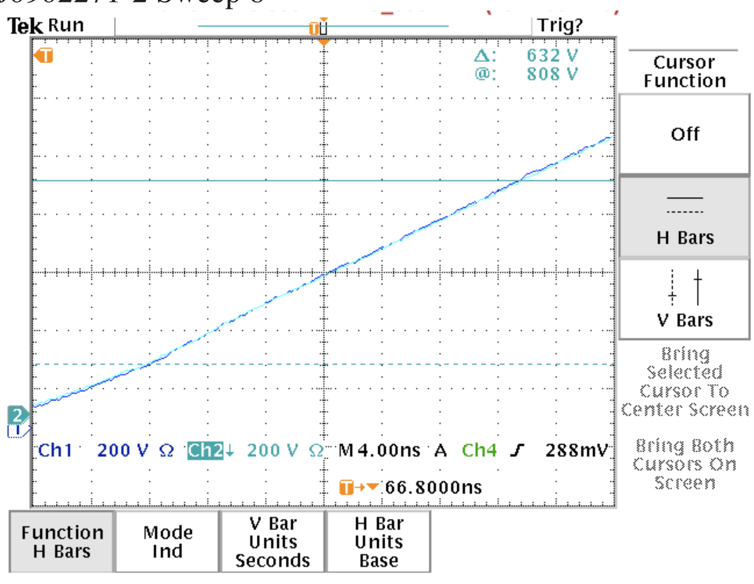
J0902271-2 Sweep 6



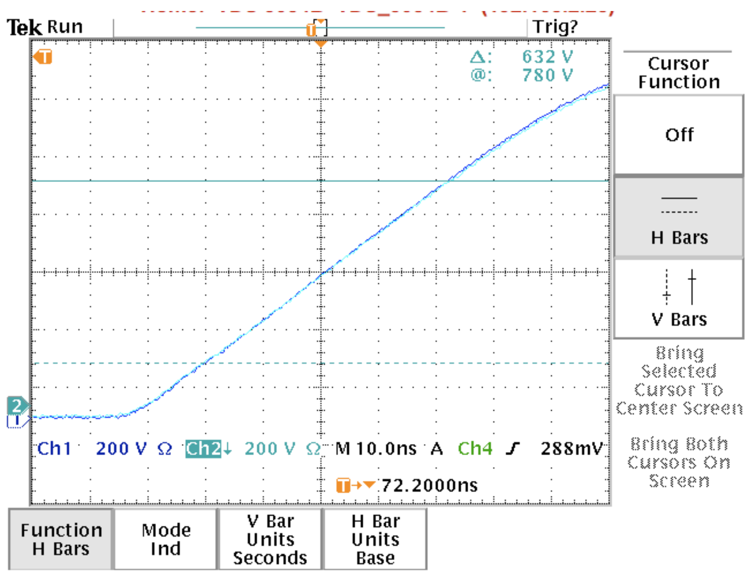
J0902271-2 Sweep 7



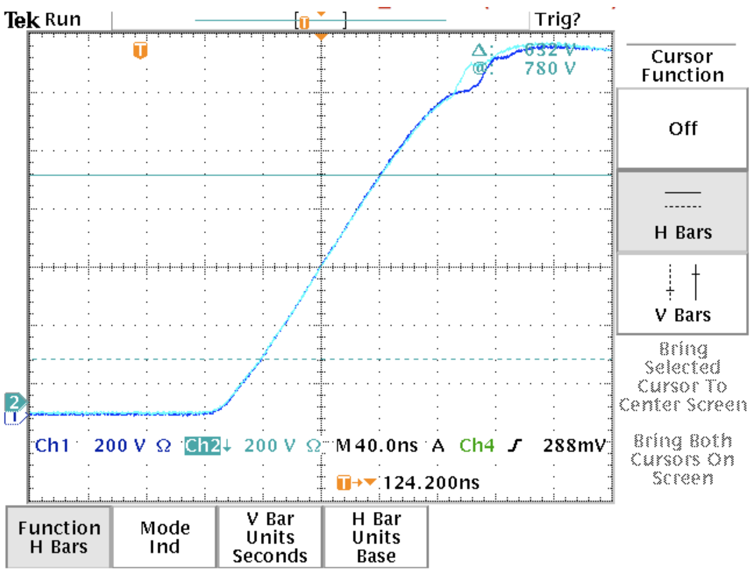
J0902271-2 Sweep 8



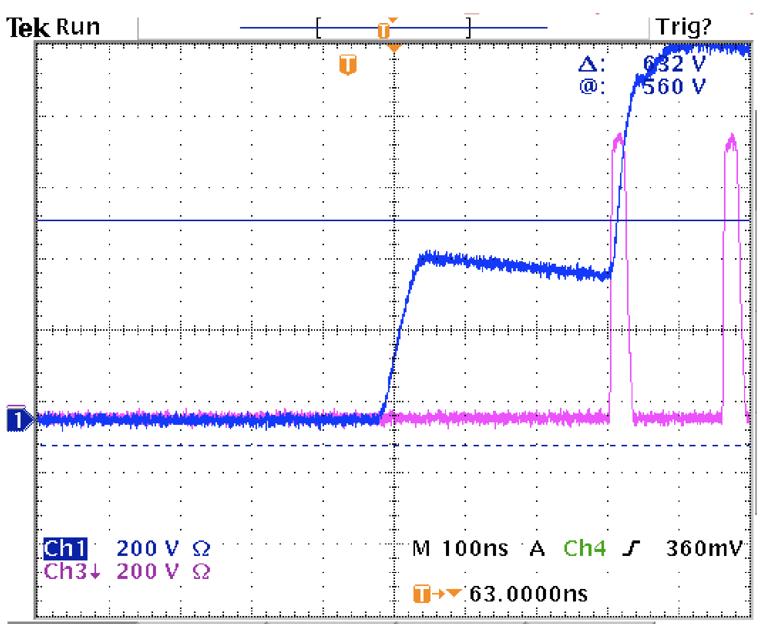
J0902271-2 Sweep 9



J0902271-2 Sweep 10



J0902271-2 Sweep 11 showing hold off and blanking delays.



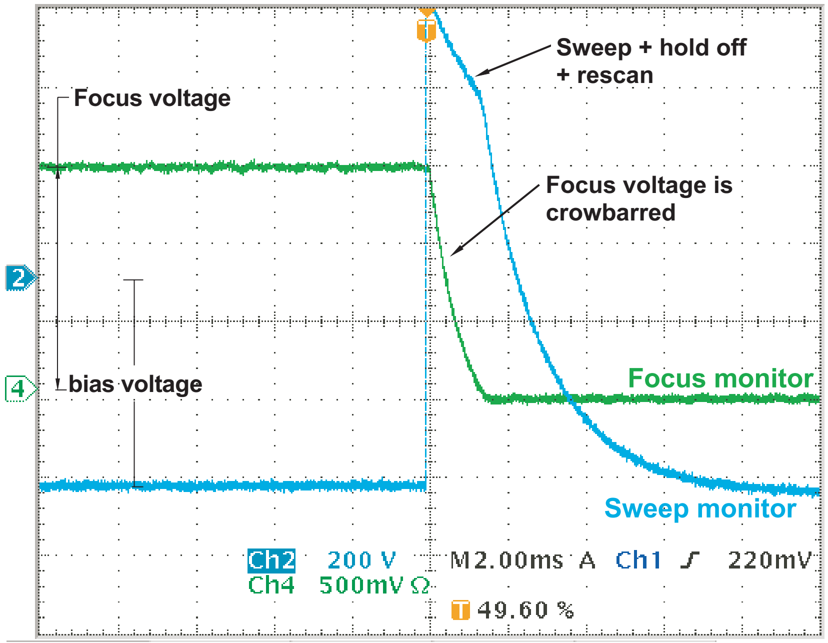


Figure 19 Crowbar and focus voltage timing at 2ms/div

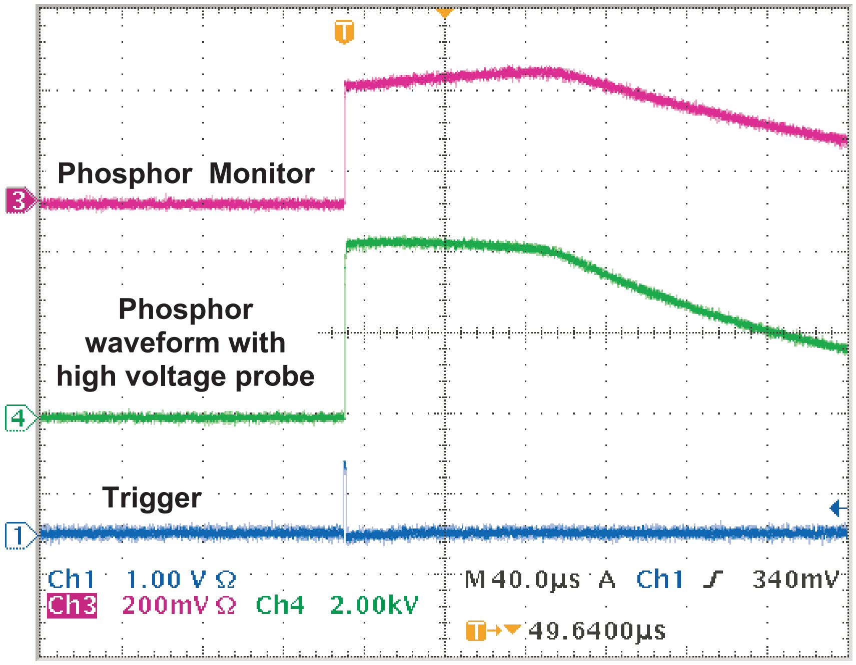


Figure 21 Phosphor monitor and actual signal

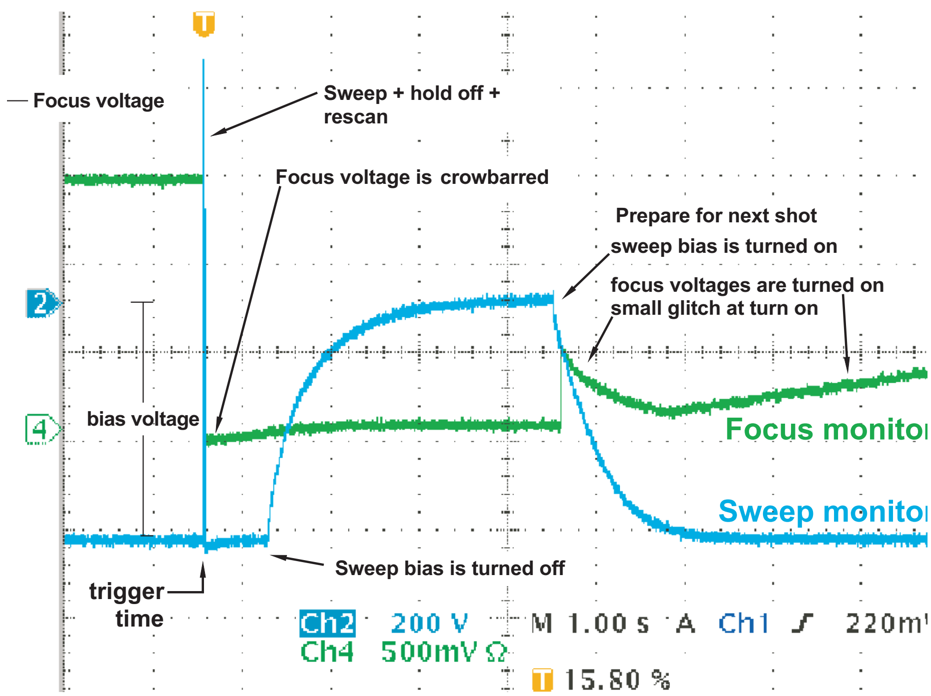


Figure 20 Crowbar and focus voltage timing at 1s/div

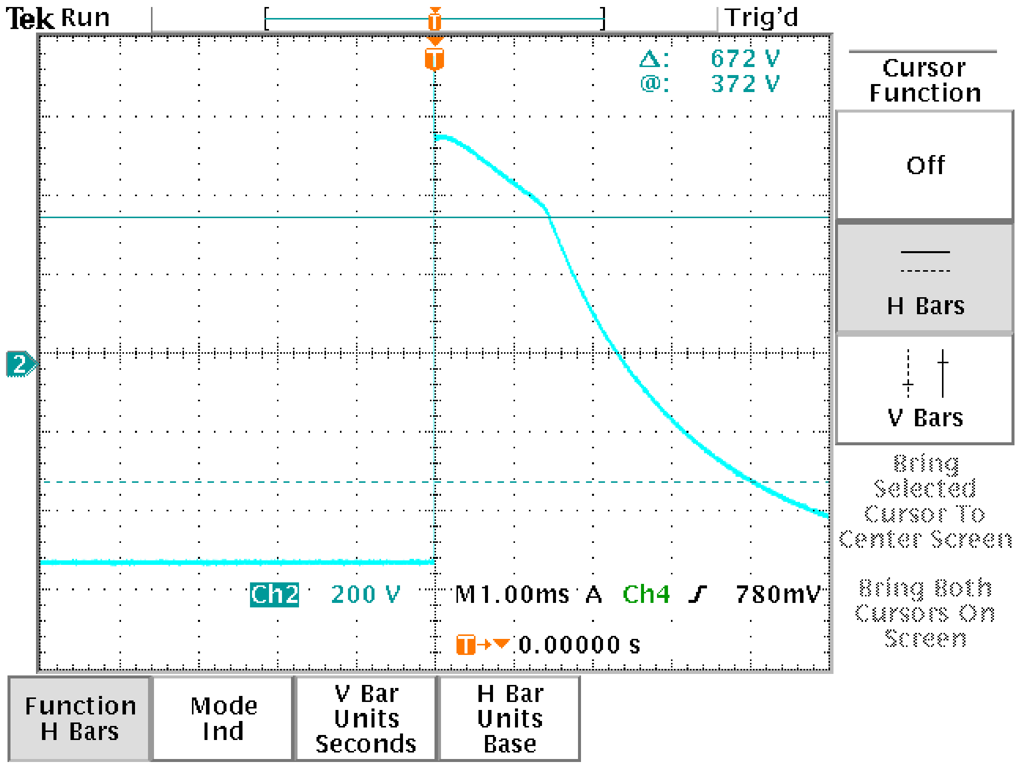


Figure 22 Sweep 0 (1ns) at 1ms/div showing hold off

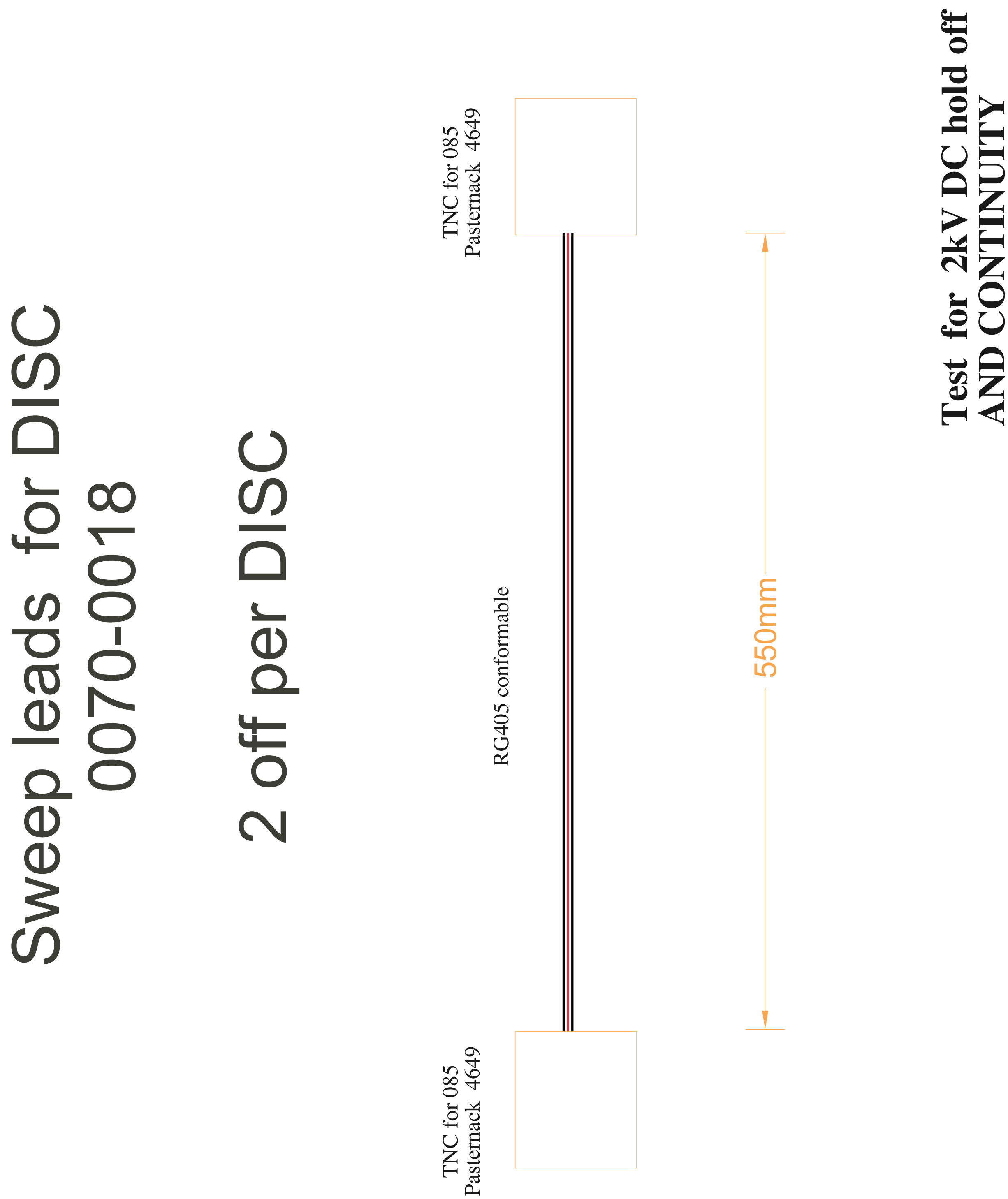


Figure 23 Sweep lead specifiaction
RG405 or RG402 may be used instead of RG405 conformable