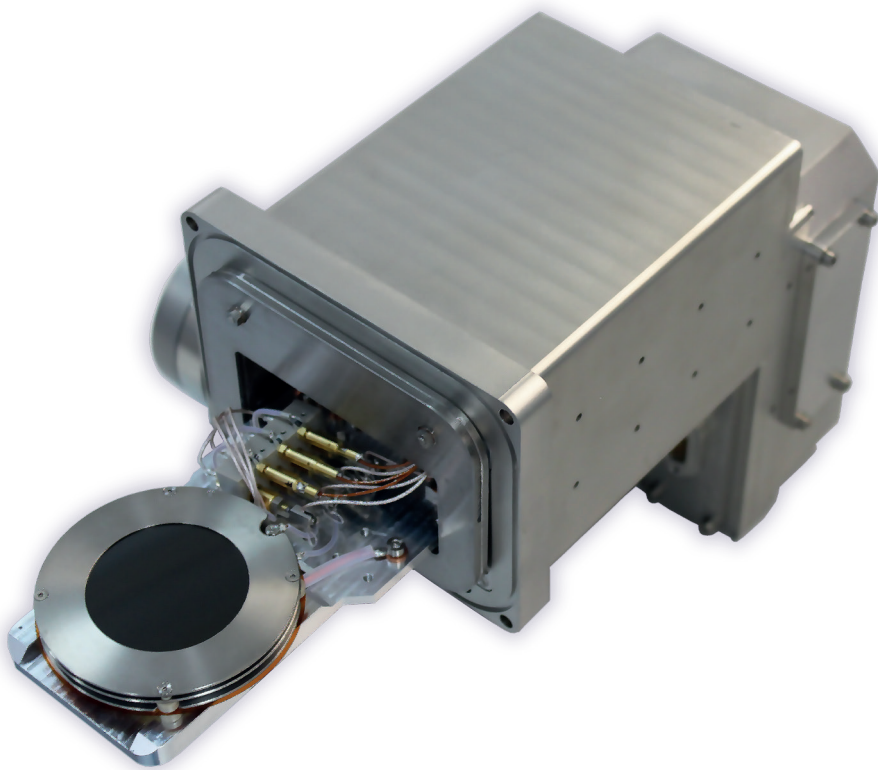


Delayline Detector DLD4040 (Release 9.10)



Manual



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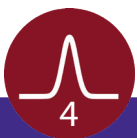
User Manual for the
Delayline Detector DLD4040
Release R9.10
Manual Version 2.0
Printed on 2022-02-17



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2 Introduction

2.1 General Information

This manual is intended to assist users in the installation, operation and maintenance of Release Version 9.10 of the Delayline Detectors DLD4040. It is divided into 11 chapters. The chapter "Introduction" contains a brief description of the DLD. The chapter "Installation" refers to installation and cabling, while the chapter "Principle of Operation" explains the theory of operation of the DLD. 3 chapters describe the technical details of the detector readout package and chapter "Operation of the DLD" describes the operation of the DLD. The final chapters contain amongst others technical details about the microchannel plates and the delayline detector in general.

2.2 Safety Instructions

Please read this manual carefully before performing any electrical or electronic operations and strictly follow the safety rules given within this manual. Surface Concept declines all responsibility for damages or injuries caused by an improper use of the module due to negligence on behalf of the User. Please also respect the Surface Concept Device Safety Instructions Manual in addition and all given safety rules within it.

The following symbols appear throughout the manual:



The "note symbol" marks text passages, which contain important information/hints about the operation of the detector. Follow these information to ensure a proper functioning of the detector.



The "caution symbol" marks warnings, which are given to prevent an accidentally damaging of the detector or the readout system. Do **NOT** ignore these warnings and follow them **strictly**. Otherwise no guarantee is given for arose damages.



The "high voltage symbol" marks warnings, given in conjunction with the description of the operation/use of high voltage supplies and/or high voltage conducting parts. Hazardous voltages are present, which can cause serious or fatal injuries. Therefore only persons with the appropriate training are allowed to carry out the installation, adjustment and repair work.

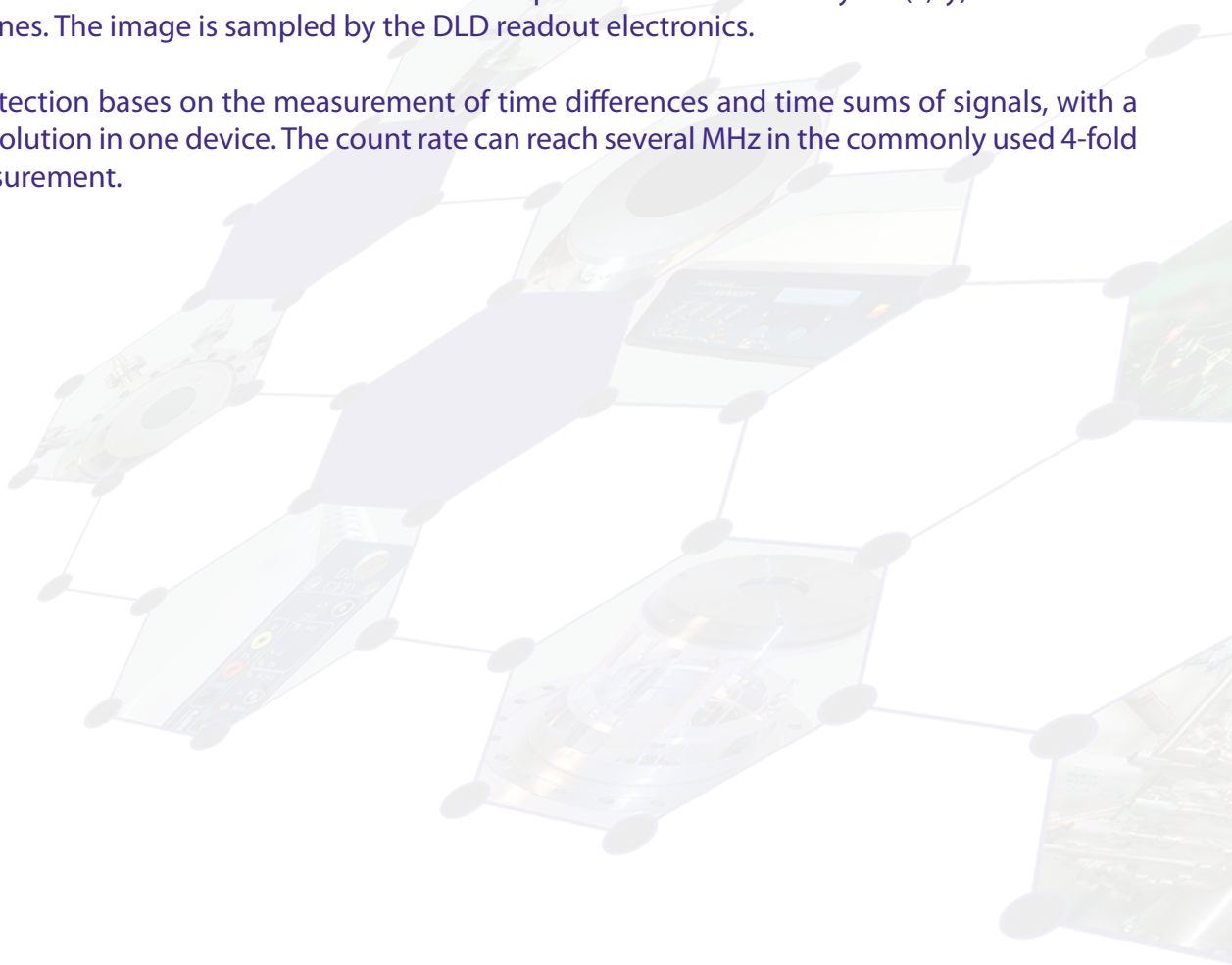
2.3 General Overview of the System

The Surface Concept delayline detectors are particularly developed for the needs of 1D(x), 2D(x,t), 2D(x,y) or 3D(x,y,t) area and time detection of electrons, ions, x-ray and UV-light.

The DLD4040 R9.10 is mounted on a motorized transfer stage within a metal housing with a GATAN flange. It is laid out to be installed on transmission electron microscopes parallel with other detectors. The transfer stage is used to move the detector into the beam when being operated. The housing has a tungsten core for x-ray shielding and holds feedthroughs for high voltage supply and signal transfer.

The delayline detector itself consists of a microchannel plate stack and two layers (x, y) of meander structured delaylines. The image is sampled by the DLD readout electronics.

The 3D (x, y, t) detection bases on the measurement of time differences and time sums of signals, with a high temporal resolution in one device. The count rate can reach several MHz in the commonly used 4-fold coincidence measurement.



3 Installation

3.1 Initial Inspection

Visual inspection of the system is required to ensure that no damage has occurred during shipping. Should there be any signs of damage, please contact your provider immediately. Please check the delivery according to the packing list (see **Table 1**) for completeness.

- Delayline Detector Unit (delivered in a vacuum container)
- 1x Pulse Processing Unit ACU
- 1x SHV Termination Plug
- 1x DLD Readout Cable (HDMI) with Strain Relief
- Storage Medium with Documentation and Software

Table 1: Packing list for the delayline detector.

3.2 Installation

3.2.1 Mounting the Delayline Detector

The detector is transported under vacuum. Proceed as follows, to install it into your vacuum chamber:

- Vent the transport container **carefully and slowly (use N2 for venting if possible)**.
- Remove the transport container **carefully**.
- Before installing the detector to your chamber, check the front side of the MCP stack for particles.



The microchannel plates in front of the detector should be protected from exposure to particle contamination. Particles that stick to the plate can be removed by using a single-hair brush carefully and/or with dry nitrogen. Reading the instructions “microchannel plates” in **Chapter 8** is strongly recommended.

- Install the detector into your vacuum chamber.
- Keep the vacuum container in case that the detector must be sent back for repair. It can also be used to store the detector when not installed in a vacuum chamber.





The detector should be kept under vacuum all the time.
The best long term storage environment is an oil free vacuum in the 1E-2mbar range or better. The transport container is not designed for a long term storage of the detector. A storage time of one month should not be exceeded.
The transport housing should be evacuated regularly with a period of at least one month, in case that the transport housing must be used for a longer storage time.

3.2.2 Detector Orientation

The red dot in **Figure 1** mark the 0/0 position of the DLD image which corresponds to the upper left corner of the image in the software.

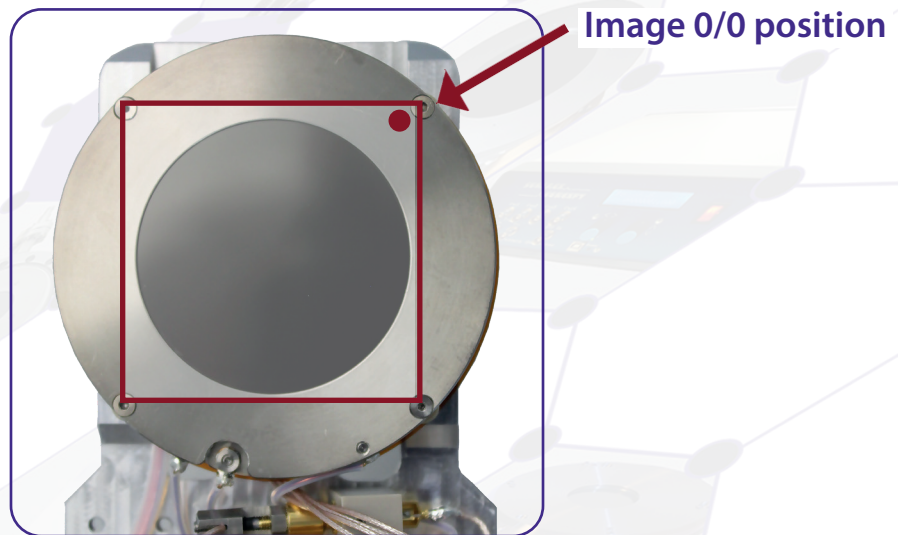


Figure 1: 0/0 position of the DLD R9.10 image (red dot).

3.2.3 Cabling and High Voltage

The general connection scheme of the delayline detector R9.10 including its readout package is shown in **Figure 2**.

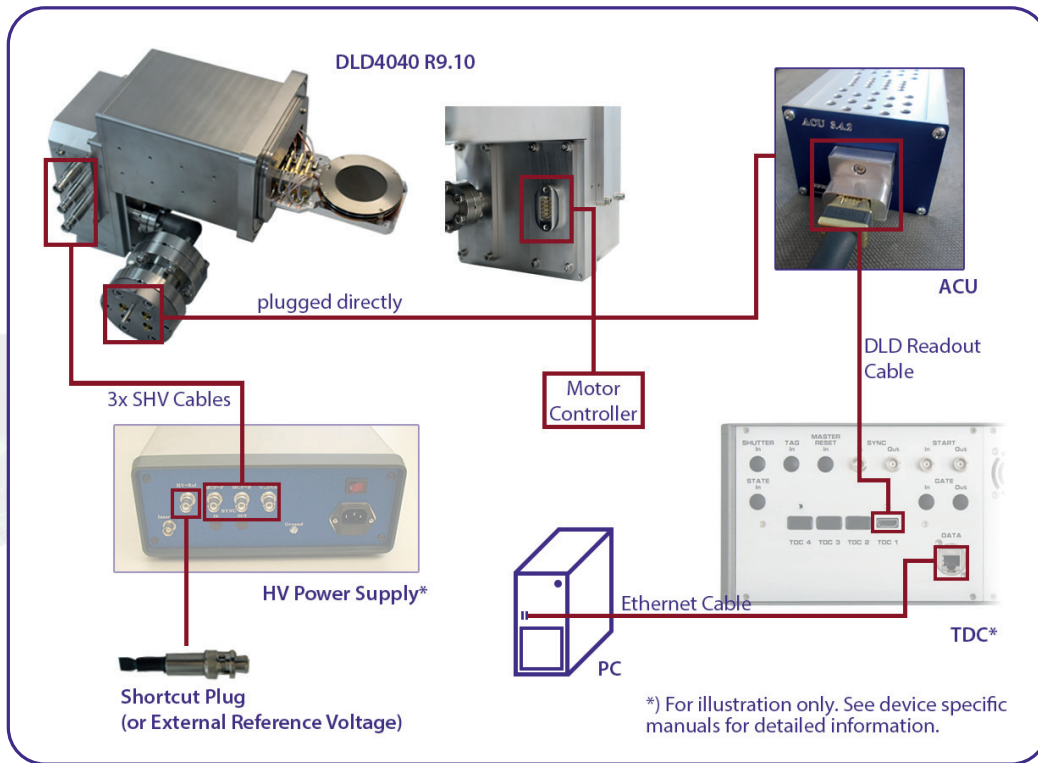


Figure 2: Connection scheme of the delayline detector R9.10 and readout package.

- The pulse processing unit ACU can be connected directly to the DLD 4-fold SMB feedthrough. The metal pin gives the orientation. Fasten the ACU with the two clips on the housing.



Hold the ACU straight and plug it very carefully.
The middle pins of the SMB connectors in the 4-fold SMB feedthrough can be damaged when holding the ACU not straight while plugging.

- Use the DLD readout cable to connect the “Lines Out” socket on the front of the ACU with the “TDC Input” socket at the rear panel of the TDC (see the TDC manual for the specific connection scheme of the TDC).
- The housing holds three SHV feedthroughs for the high voltage supply of the detector named “MCP-F”, “MCP-B” and “U_DLD”. The naming can be found directly engraved on the housing. “MCP-F” is the contact to the front side of the MCP stack, “MCP-B” is the contact to the back side of the MCP stack and “U_DLD” is connected to the detector anode.





Be sure that all voltages are settled to zero before connecting the high voltage cables to the detector, otherwise serious damage to the detector can occur due to high voltage sparks.

- Use the SHV cables to connect the corresponding outputs of the high voltage power supply (“MCP-F”, “MCP-B”, and “U_DLD”) to the corresponding feedthroughs of the detector.
- Terminate the external reference input “HV Ref. In” of the high voltage power supply with the SHV termination plug (part of the delivery). Later on also a reference voltage (e.g. the column potential in an electron microscope or the Herzog potential in an electron spectrometer) can be applied to the front side of the MCP stack of the detector as well as to the high voltage power supply (see the manual for the high voltage power supply for more details).
- In case that a Surface Concept HV Supply is part of the delivery, the MCP-F potential is connected to the external reference input “HV Ref. In” of the HVPS. In this case the SHV termination plug is used to terminate the external reference input. See the manual for the high voltage power supply for more detailed information.



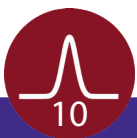
In cases that no reference voltage is applied to the MCP front, the termination plug must be used to ground the MCP front. Otherwise the MCP stack is not functioning as the reference potential is missing.

The exact operation voltage of the detector is given in the specification sheet. It is given in reference to the “MCP-F” (= “HV Ref. In”) potential.



HV power supplies always produce some noise level on the HV lines. An increased noise level can lead to a significant loss of spatial and time resolution. In such a case an appropriate noise filter between the HV power supply and the DLD HV connectors is highly recommended. HV power supplies as part of the DLD delivery have been explicitly tested for the DLD operation.

For the use with a customer HV supply there are noise filters available from Surface Concept. They are not necessarily part of each detector delivery.



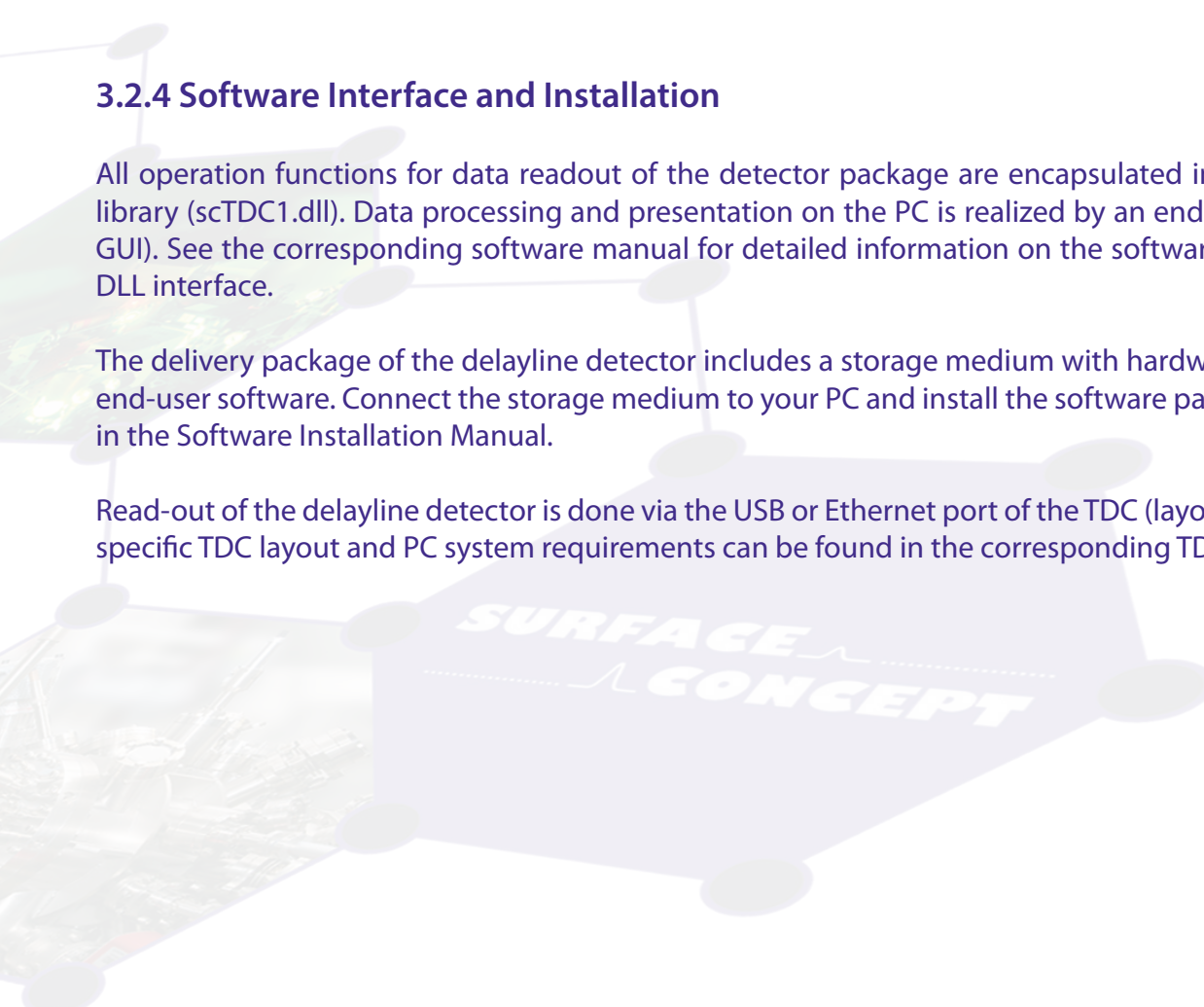
- Further information about detector operation voltages can be found in **Chapter 4**.
- Install the hardware drivers (where necessary) and the GUI – DLD software. See the GUI – DLD Software Installation manual for further details.
- Connect the power cable to the main connector of the TDC and use the USB/ Ethernet cable to connect the TDC to the PC. Do not use PC front panel USB connectors in case of USB connection as they are often restricted in performance.
- To perform time measurements with respect to an external clock, provide start pulses to the start input of the TDC. Use the corresponding BNC socket of the TDC (see the TDC manual for the specific connection scheme of the TDC).

3.2.4 Software Interface and Installation

All operation functions for data readout of the detector package are encapsulated in a dynamic linked library (scTDC1.dll). Data processing and presentation on the PC is realized by an end-user software (e.g. GUI). See the corresponding software manual for detailed information on the software package and the DLL interface.

The delivery package of the delayline detector includes a storage medium with hardware drivers and the end-user software. Connect the storage medium to your PC and install the software package as described in the Software Installation Manual.

Read-out of the delayline detector is done via the USB or Ethernet port of the TDC (layout depending). The specific TDC layout and PC system requirements can be found in the corresponding TDC manual.



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4 Operation of the DLD

Mistakes, which lead to complete wrong measurement results, can happen very easily while taking the detector to operation. Therefore it is strongly advised to read the following sections completely before taking the detector to operation and to strictly follow all given advices within it.

Note

All operation voltages for the detector are given within the detectors specification sheet.

Due to gain degradation it will become necessary to increase the operation voltage from time to time. Please refer to **Chapter 8.5** for detailed information.

4.1 Getting Started

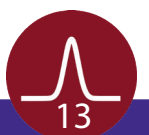
4.1.1 "Start Up" Procedure

Follow this procedure when taken the detector to operation the first time and after every venting.

- Finish the complete cabling as described in **Chapter 3** and as described in the manual of the HV Power Supply.
- Turn on the TDC.
- Start your end-user software (e.g. GUI software) and within this software the rate meter, if available. For details see your end-user software manual.
- Be sure, that the vacuum pressure at the detector is remarkably below $1E-6$ mbar, otherwise the microchannel plates might be damaged by a local discharging (in general: the lower the pressure, the longer the lifetime of the MCPs).
- Turn off all sources for electrons, ions, light or X-rays that might hit the detector.



Ion gauges and ion pump are both sources for electrons and ions. Ion pumps can also be a source for X-rays. They can produce so many particles/ X-rays that the detector is in a complete overload, even when they are not facing the detector directly. This will wear out the MCPs very fast. Turn off ion pumps and ion gauges before turning on the high voltage of the detector.



- Turn on the high voltage carefully. The voltage increase should not exceed 400V per minute. A schematic sketch on how to ramp the voltages during the “Start-Up” procedure is given in **Figure 3**. The starting operation voltage is specified in the specification sheet of the detector.
- Watch the vacuum pressure while increasing the high voltage; turn the voltages back, if an unusual increase is observed in the pressure (indicator for high voltage sparking).



High voltage sparks may seriously damage the detector anode/meander or the MCPs. Observe the chamber pressure carefully every time the high voltage is turned on. Switch off the high voltage immediately in case of a temporary pressure rise by an order of magnitude or more. This indicates high voltage sparking.



If sparking occurs, turn down the high voltage immediately and wait some time (up to 5 min.). Start the “Start-Up” procedure again with an increased ramp time. Turn off the high voltage completely, stop the procedure and call your provider for further assistance, if it is not possible to reach the operation voltage without sparking.

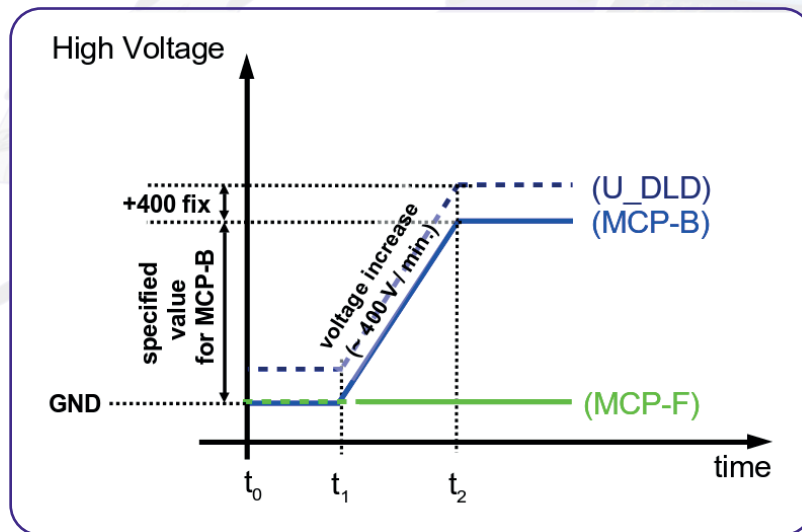


Figure 3: Schematic sketch on voltage ramping during “Start-Up” procedure.

The detector starting operation voltage for “MCP-B” is given in the specification sheet. The voltage for “MCP-B” is always given in reference to the MCP front voltage “MCP-F” (which corresponds to the external reference voltage of the Surface Concept HV Power Supply).



The voltage for “U_DLD” is typically “MCP-B” + 400V and it is increasing/ decreasing together with the voltage for “MCP-B” when using the Surface Concept HV Power Supply (for detailed information check your manual of your HV power supply).

Depending on the detector setup the voltage difference between “U_DLD” and “MCP-B” can be different than 400V.

Example: Assume the following operation voltage for "MCP-B": +1800V and "U_DLD": +400V. "MCP-F" is terminated to GROUND. First ramp "U_DLD": to +400V, then a ramp time of approx. 5min. should be used to increase ""MCP-B" and U_DLD" parallel to +1800V and +2200V ("MCP-B" + 400V) respectively.



The analogue readout electronics have been adjusted to optimized detector voltages. The starting operation voltages are given in the specification sheet of the detector. Please note that one cannot compensate a voltage lower than the specified operation voltages by increasing the intensity to the detector. This will only lead to complete false measurement results.

4.1.2 Dark Count Rate Measurement

- Check the detector output by means of your end-user software (e.g. GUI software) after ramping to the operation voltage (the use of the rate meter where available is recommended).
- The dark count rate without any source should be as given in the specification sheet.
- Accumulate the dark counts for several minutes (e.g. 15 minutes). The DLD image should appear homogeneous and sharply bounded. See **Figure 4** for an example (your specific DLD image can differ in size, shape and segmentation).

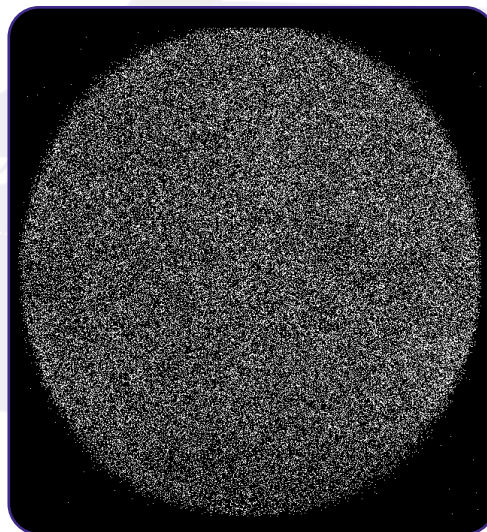


Figure 4: Example for DLD image of accumulated dark counts.

4.1.3 Standard DLD Measurement

- After finishing the dark count rate measurement with a satisfying result, you may now start carefully with an electron or light source observing the detector output.



Keep in mind the description about the important operation details in **Chapter 5**.



Turn off the high voltage, close the software and turn off the TDC before performing any changes of the cabling.

4.2 Standard Operation Procedure

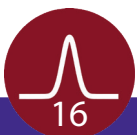
4.2.1 Operation with MCP Front Side terminated to GROUND

Use this procedure later on for all operations when the detector has already been operated in vacuum before and has not been vented in between.

- Finish the complete cabling as described in chapter 3 and as described in the manual of the HV Power Supply.
- Connect the termination plug to the “MCP-F” connector to ground the front side of the MCP stack.
- Turn on the TDC.
- Start your end-user software (e.g. GUI software) and within this software the rate meter (if available). For details see your end-user software manual.
- Be sure, that the vacuum pressure at the detector is remarkably below 1E-6mbar, otherwise the micro channel plates might be damaged by a local discharging (in general: the lower the pressure, the longer the lifetime of the MCPs).
- Turn off all sources for electrons, ions, light or X-rays that might hit the detector.
- Increase the detector voltage for “MCP-B” to the specified operation voltage stepwise within a couple of minutes. **The starting operation voltage is specified in the specification sheet of the detector.**
- Watch the vacuum pressure while increasing the high voltage; turn the voltages back, if an unusual increase is observed in the pressure (indicator for high voltage sparking).



High voltage sparks may seriously damage the detector anode/meander or the MCPs. Observe the chamber pressure carefully every time the high voltage is turned on. Switch off the high voltage immediately in case of a temporary pressure rise by an order of magnitude or more. This indicates high voltage sparking.





If sparking occurs, turn down the high voltage immediately and wait some time (up to 5 min.). Start the “Start-Up” procedure again with an increased ramp time. Turn off the high voltage completely, stop the procedure and call your provider for further assistance, if it is not possible to reach the operation voltage without sparking.

- Check the detector output with your end-user software (e.g. GUI software) after ramping to the operation voltage (the use of the rate meter is recommended).
- Now you may start carefully with an electron source observing the detector output.



Keep in mind the description about the important operation details in **Chapter 5**.



Turn off the high voltage, close the software and turn off the TDC before performing any changes of the cabling.

4.2.2 Operation of the Detector with the MCP Front Side connected to a Reference Voltage

Follow this procedure for all later operation starts, when operating the detector with the front side of the MCP stack connected to an external high voltage potential

- Finish the complete cabling as described in **Chapter 3** and as described in the manual of the HV Power Supply.
- Connect the external reference voltage to the “MCP-F” connector. DO NOT APPLY ANY HIGH VOLTAGE yet.
- Turn on the TDC.
- Start your end-user software (e.g. GUI software) and within this software the rate meter (if available). For details see your end-user software manual.
- Be sure, that the vacuum pressure at the detector is remarkably below 1E-6 mbar, otherwise the microchannel plates might be damaged by a local discharging (in general: the lower the pressure, the longer the lifetime of the MCPs).
- Turn off all sources for electrons, ions, light or X-rays that might hit the detector.
- Increase the detector voltage for “MCP-B” to the specified operation voltage stepwise within a couple of minutes. **The starting operation voltage is specified in the specification sheet of the detector.**
- Now increase the external reference voltage until reaching the desired voltage for “MCP-F”. (Important: Respect the maximum reference voltage for “MCP-F”. It is given within the specification sheet.) The voltage increase should not exceed 400V per minute, when operating the detector with an external high voltage applied to “MCP-F” for the first time. Otherwise turn up the high voltage carefully and stepwise within a couple of minutes to the operation voltage.



- Increase the external reference voltage until reaching the desired voltage for “MCP-F”.
- A schematic sketch on how to ramp the voltages is given in **Figure 5**.
- Watch the vacuum pressure while increasing the high voltage; turn the voltages back, if an unusual increase is observed in the pressure (indicator for high voltage sparking).



High voltage sparks may seriously damage the detector anode/meander or the MCPs. Observe the chamber pressure carefully every time the high voltage is turned on. Switch off the high voltage immediately in case of a temporary pressure rise by an order of magnitude or more. This indicates high voltage sparking.



If sparking occurs, turn down the high voltage immediately and wait some time (up to 5 min.). Start the “Start-Up” procedure again with an increased ramp time. Turn off the high voltage completely, stop the procedure and call your provider for further assistance, if it is not possible to reach the operation voltage without sparking.

- Check the detector output by means of the rate meter of your end-user software (e.g. GUI software). The dark count rate without any source should be as given in the specification sheet.
- Now you may start carefully with an electron source observing the detector output.



Keep in mind the description about the important operation details in **Chapter 5**.

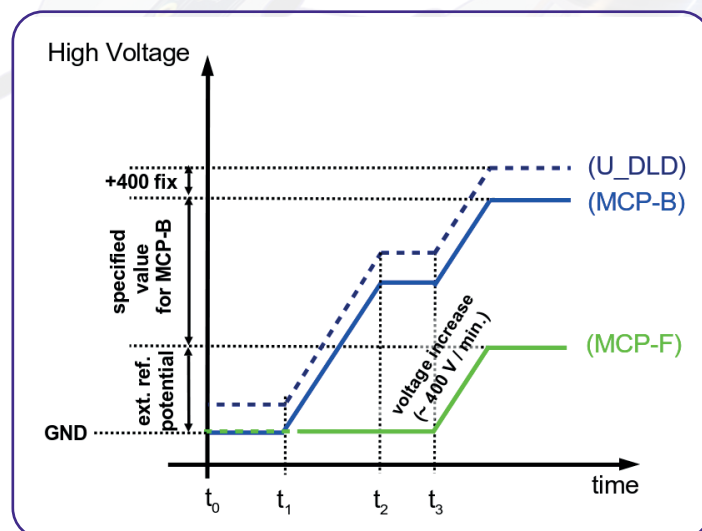


Figure 5: Schematic sketch on voltage ramping with external reference voltage.



The detector operation voltage “MCP-B” is given in the specification sheet. It is always given in reference to the MCP front voltage “MCP-F”. The maximum reference voltage for “MCP-F” is also given in the specification sheet.

Note

The Surface Concept HV Power Supply is a floating HV device. The reference voltage must not explicitly be added to the operation voltage. See the manual of the HV Power Supply for further information.

Example for voltage ramping: Assume the following operation voltage for “MCP-B” in respect to “MCP-F”: +1,900V and a reference potential for “MCP-F” of +1,000V. A ramp time of a few minutes should be used to increase “MCP-B” to +1,900V. Then a ramp time of approx. 3 min. should be used to increase the external reference voltage from 0V to +1,000V. Now the actual output voltage of the Surface Concept HV Power Supply in reference to the GND potential would be for “MCP-B”: +2,900V (1,900V + 1,000V) and for “U_{DLD}”: +3,300V (“MCP-B” + 400V), because the HV Power Supply is floating on the reference voltage.



Note

Keep in mind the description about the important operation details in **Chapter 5**.



Turn off the high voltage, close the software and turn off the TDC before performing any changes of the cabling.

4.3 Bake Out Procedure



The DLD4040 R9.10 is not made for bake out. All flanges are sealed with o-ring gaskets made from viton which are no laid out to withstand higher temperatures for a longer time.

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5 DLD - Principle of Operation

5.1 Basics of Delayline Detection

The delayline detector (DLD) consists of a microchannel plate stack (required to amplify incoming electrons) and the detector anode. The DLD anode (for quadranted and segmented DLDs: each single quadrant and segment) consists basically of two meander structured delaylines; one rotated by 90° with respect to the other and both isolated from each other. The electron cloud from the MCP stack output is drawn to the detector anode by a positive potential difference between anode and back side of MCP stack, where it induces electrical pulses into the delayline by capacitive coupling. The pulses are traveling to the both ends of the meander within a time determined by the hitting position.

Each hit position is encoded by a fast data acquisition unit, which also may detect the hit time referenced to an external clock in repetitive (stroboscopic) experiments.

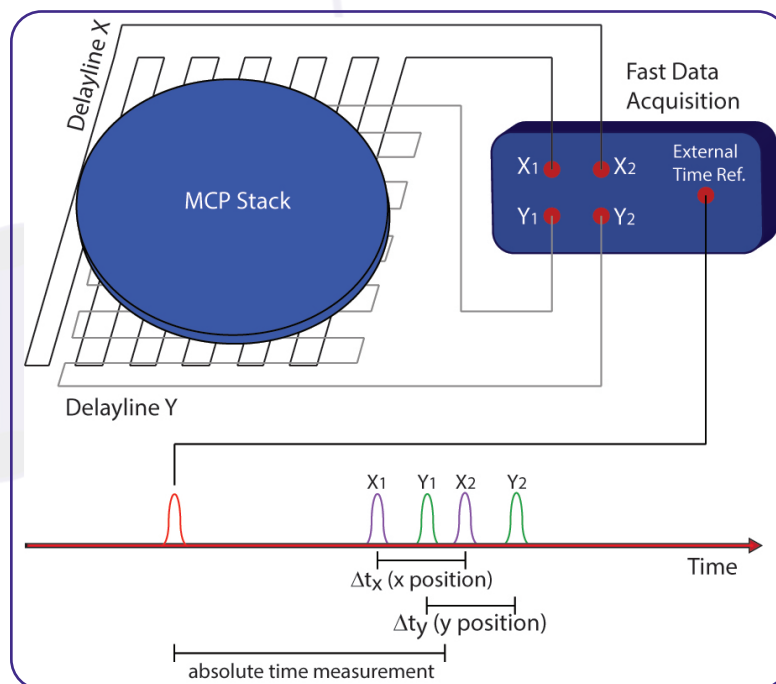


Figure 6: Schematic drawing of the principle of the 3D (x, y, t) delayline operation.

Delayline detectors are single counting devices; therefore the complete device works linearly even at extremely low numbers of incoming electrons. The maximum count rate in the fourfold coincidence measurement is up to a few million counts per second. The exact value depends on the individual DLD layout (e.g. the size of the active area) and is given within the specification sheet of the DLD.



5.2 Basic Operational Modes of the Delayline Detector

5.2.1 2D(x, y) Area Detection

To determine the position in x and y of a single event, it is sufficient to subtract the arrival times of the four pulses from the four ends of the both (x/y) DLD meanders (x: tx1-tx2; y: ty1-ty2). As only relative time information for the four signals are relevant, the TDC doesn't have to measure those signals in respect to a defined external reference clock. It is sufficient to measure in respect of an internal clock, which is provided by the TDC itself.

5.2.2 3D(x, y, t) Time Resolved Imaging

The delayline detector can also measure all events in temporal reference to an external clock. For this mode, the user needs to start the TDC by an external clock, providing a low jitter LVTTTL signal to the start input of the TDC.

The time information of an event is gained by summing up all four arrival times of the four meander pulses. Such time result corresponds to $t(\text{sum}) = t(\text{offset}) + t(\text{hit})$, where $t(\text{hit})$ is the desired time information (e.g. ToF) in a given experiment and $t(\text{offset})$ is a device related constant, which depends on cable lengths, electronics propagation times, experimental setup etc.

The software can group all measured time sums in plain 1D time histograms, which are valid for the chosen region of interest (ROI) with the correct time bin size. The time bin size for each single TDC channel is around 27ps, but due to the summing of 4 single times per event, the time axis is expanded by a factor of 4. This allows to measure the relative time between single events with a time bin size of around 6.75ps.

5.3 Data Acquisition

Each readout line of the detector anode is connected to a fast amplifier followed by a constant fraction discriminator (CFD) for pulse shaping. They are encapsulated inside the pulse processing electronics (ACU = Amplifier-CFD-Unit or AU = Amplifier-Unit). The main function of the CFD is digital pulse discrimination, ideally without any time-walk even at varying pulse heights. A time-to-digital converter (TDC) behind these chains serves as stop-watch for arrival time measurements.

The measurement results, in terms of time differences (space information) and time sums (time information) are fed into the PC via a USB or Ethernet interface and are completed to 2D images (with or without time stamps) by the histogram module of the data acquisition DLL. Data processing and presentation on the PC is realized by the end-user software (see the corresponding software manuals for detailed information on the software package).

5.4 Working with the DLD - Important Details

The DLD is a counting system that works in a laterally resolving sense by detecting four pulses from the four ends of the delayline meanders in a fourfold coincidence. It only works correctly within a certain range of the supply voltage. The MCP voltage has to exceed an operation threshold for the detector otherwise the pulse detection is not possible. This is due to the induced pulses on the delayline which have to reach a certain amplitude to be detected by the electronics, independent on the primary intensity hitting the detector. On the other hand, if the MCP voltage and/or the primary intensity of the electron source are too high, the detector overloads and again pulse detection is not possible. Saturation effects of the MCPs limit the amount of electrons provided by single pulses. An intensity increase of the electron source leads to an increased number of hits on the MCP. The current per bunch and therefore the amplitude for the single pulses decreases. There are two kinds of overloads: local and global. A local overload (locally high intensity on the MCP) leads to reduced count rate within this local area and to “darkened” areas in the images. An intensity too high and homogeneously distributed over the whole MCP first leads to diffuse images and then (with further increasing intensity) to randomly distributed artificial structures up to nearly no count rate at all (global overload).

Single pulse amplitudes are too low to be detected by the electronics, being lost for the fourfold coincidence condition. Randomly fitting pulses from following events can compensate the missing pulse and can result in a theoretically fitting (in terms of boundary conditions) but physically wrong fourfold coincidence.

High intensities on the MCPs always lead to a significant pressure increase. Therefore an observed pressure increase can always be taken as an indicator for an overload of the detector, when problems with the functionality of the DLD occur.

Figure 7 shows examples of a partial and a global overload.

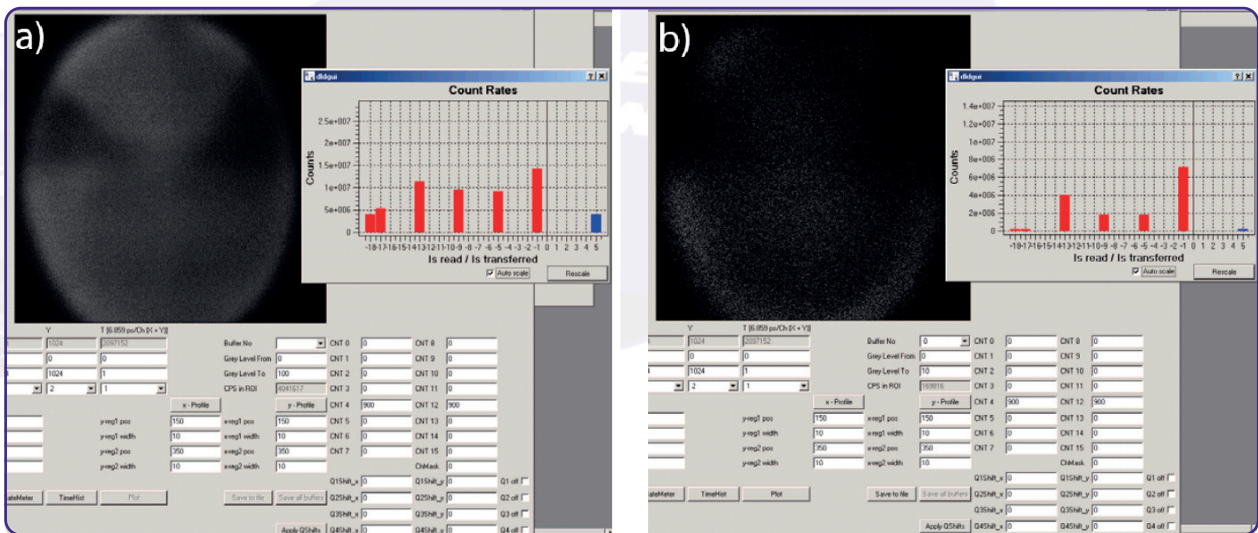


Figure 7: Example of a) a partial overload and b) a global overload.





It is easy to mistake an overload for no signal at all. To distinguish between these two, check the pressure. A pressure increase indicates an overload.

The DLD has been calibrated for an optimized MCP voltage and it is strongly advised to use this optimized voltage value for operation. It is given in the specification sheet. A change of the MCP voltage can lead to artefacts within the images (see **Figure 8**). The MCP voltage should only be increased to compensate a decrease in amplification of the MCP stack due to degradation. MCP degradation is recognizable by a slow permanent decrease of the count rate and happens continuously during the MCP operation.

Therefore it is recommended to regularly determine the correct operation voltage by making a detector voltage scan

For further detailed information on MCP degradation and detector working voltages see **Chapter 8**.

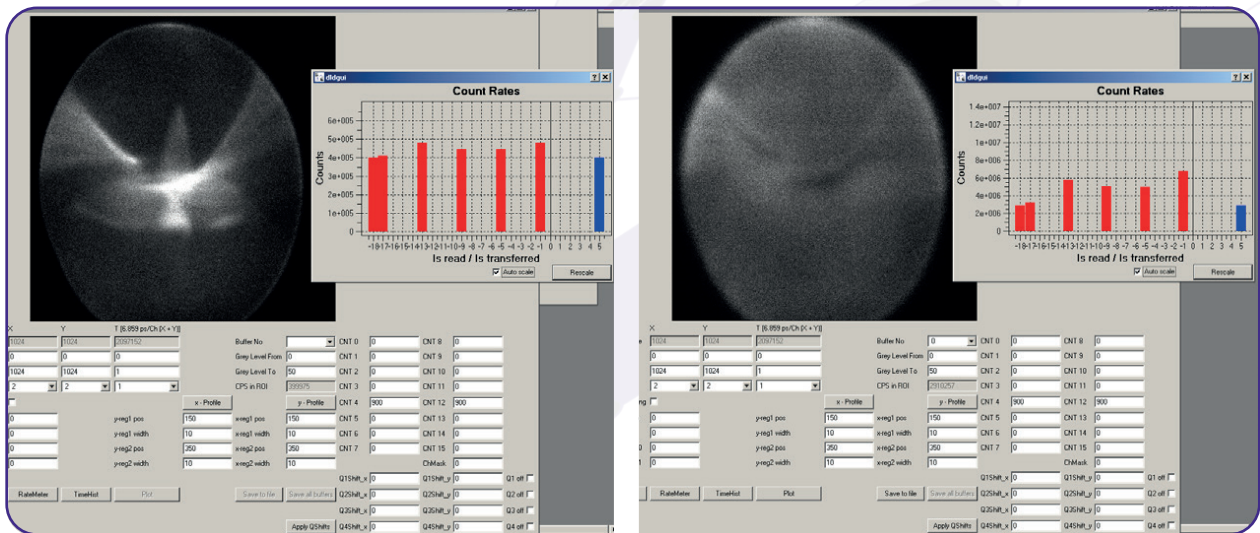


Figure 8: Example of an over voltage on the MCPs (left) and an under voltage at high count rates (right).

5.5 MCP Outgassing during Operation

It is an intrinsic feature of the MCPs that they outgas during operation for quite a while due to desorption of gas molecules which are still available inside the MCP pores. This effect becomes mainly visible at low pressure which is reached after bake out and scales significantly with the size and the load of the MCPs. The increase can easily reach more than one decade starting from the $10E-10$ mbar range for new MCPs being operated with a load of a couple of million counts per second. The effect of outgassing reduces with operation time of the detector in-vacuum. The reduction of the outgassing can also be enforced by running a degas procedure, which consists in the end of the operation of the detector under high load from a homogeneously distributed intensity for a long time period. The degas procedure must be repeated to some extent after each venting. For further information on the degas procedure for MCPs see **Chapter 8**.

6 Delayline Detector Layout

6.1 Delayline Detector - Vacuum Wiring

The delayline detector DLD4040 R9.10 consist of a detection area, defined by the detector cover, the MCP holders and the detector anode. The detector anode consists of two meander structured delaylines (named x and y), which are placed above each other (electrically isolated) and are oriented perpendicular to each other. The one delayline is referred to as the x meander and the other delayline as the y meander. **Figure 9** gives a schematic orientation of the x and y meander. The meander structured delayline is close to ground potential (in respect to the high voltage of the MCPs). A pulse coupling layer is used to isolate the meander from the high voltage of the MCP stack as well as to couple pulses from the electron cloud into the meander.

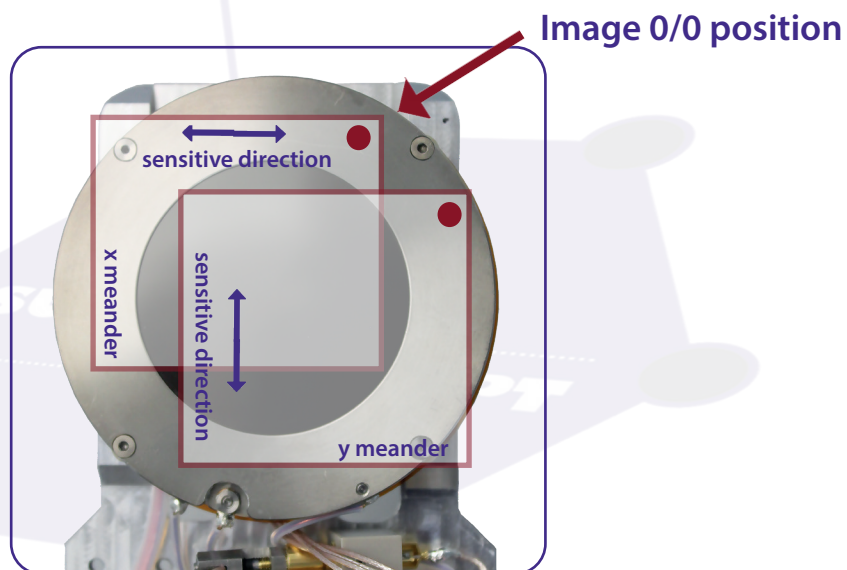


Figure 9: Schematic orientation and naming of delaylines and DLD image.

Signal readout is done via two readout lines (named 1 and 2) for each meander structured delayline. The naming of the readout lines is put together of the naming of the meander structured delayline x and y and the naming 1 and 2 of the individual readout lines per delayline (e.g. X2 for the second line of the x meander).

The 0/0 position of the DLD image (top left corner of displayed image in the GUI software) is marked by a red dot.

6.2 Delayline Detector - Connection Ports

The housing of the delayline detector R9.10 carries three single SHV feedthroughs for the high voltage supply of the detector, a CF40 flange with four SMB feedthroughs for signal transfer and a D-Sub connector feedthrough for the motor control of the transfer stage (see **Figure 10** and **Figure 11**).

The flange for the signal transfer also holds an orientation pin for correct orientation of the ACU. The allocation of the four signal channels X1, X2, Y1 and Y2 on the "SMB flange" can be taken from **Figure 10**.

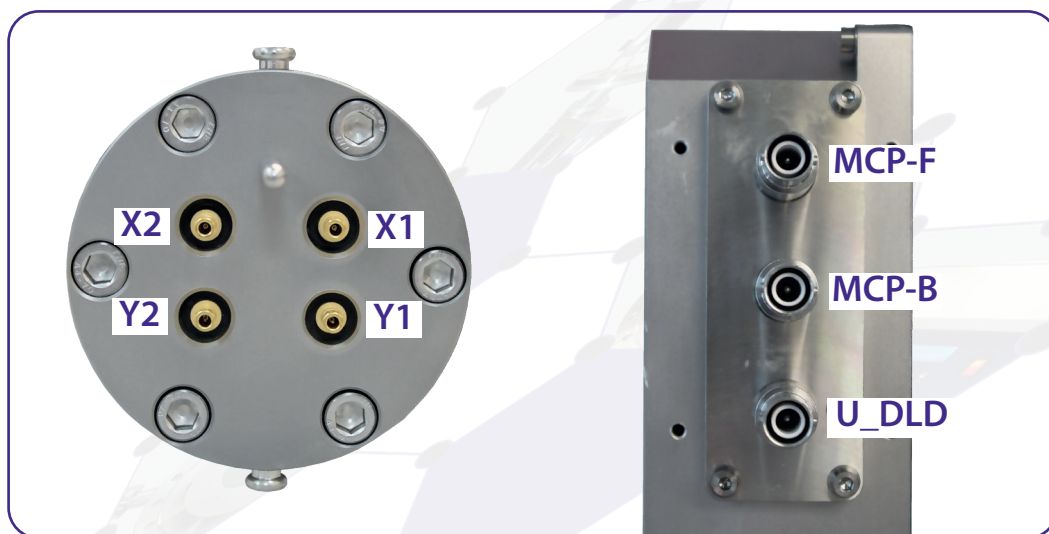


Figure 10: Connection ports of the DLD4040 R9.10 for signal transfer and HV supply.

The naming of the SHV connections are engraved directly on the housing. The internal high voltage connection for the delayline detector is given schematically in **Figure 12**. The housing holds a spare port for future extensions on the detector (e.g. additional pulse readout of the MCP stack directly).

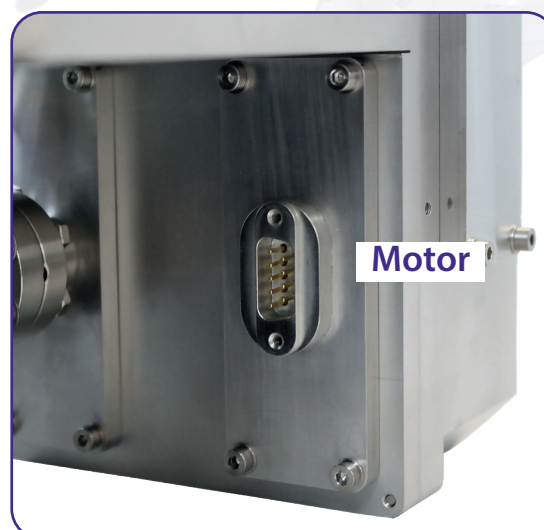


Figure 11: Connection port of the DLD4040 R9.10 for motor control.

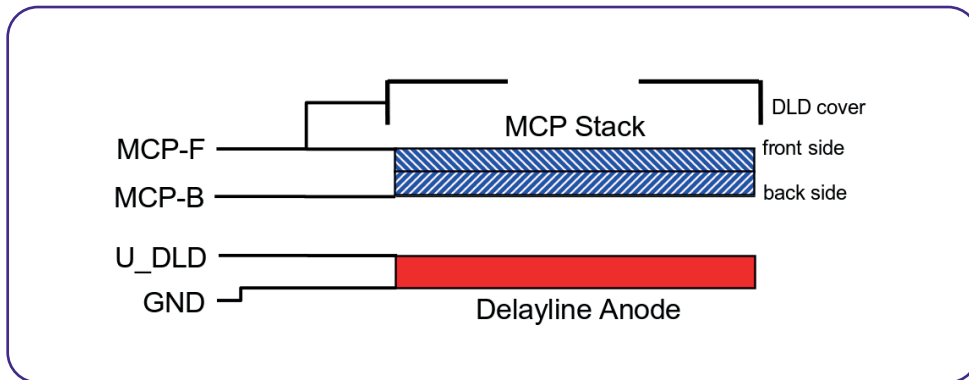


Figure 12: Internal connection of high voltage potentials (schematic).

Note

The resistance between "MCP-B" and "MCP-F" (resistance of MCP stack) should be in the range of 8 – 30M Ω (the exact value is given in the specification sheet of your detector), while the resistance between "MCP-B" and "U_DLD" and "MCP-F" and "U_DLD" respectively should be unlimited. This can be used to verify the position of the "U_DLD" voltage connector.

Caution

Do not disconnect single high voltage cables from the delayline detector as long as high voltage is applied. This will lead to sparks which can damage the very sensitive detector, the MCPs and/or the analogue readout electronics seriously.

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7 Pulse Processing Electronics

The pulse processing electronics ACU (Amplifier-CFD-Unit) and AU (Amplifier-Unit) hold all devices like the amplifiers, pulse shapers, and constant fraction discriminators to turn the analogue pulses from the detector into digital pulses suitable for the Time-to-Digital Converter. Pulse decoupling is either performed within the pulse processing electronics or directly in-vacuum, depending on detector type and layout. Some pulse processing electronics also contain an integrated high voltage power supply for the complete detector. This also depends on the layout of the detector as well as the pulse processing electronics.

7.1 Pulse Processing Electronics ACU 3.4.2

The ACU 3.4.2 contains the amplifiers, pulse shapers and constant fraction discriminators for signal processing.

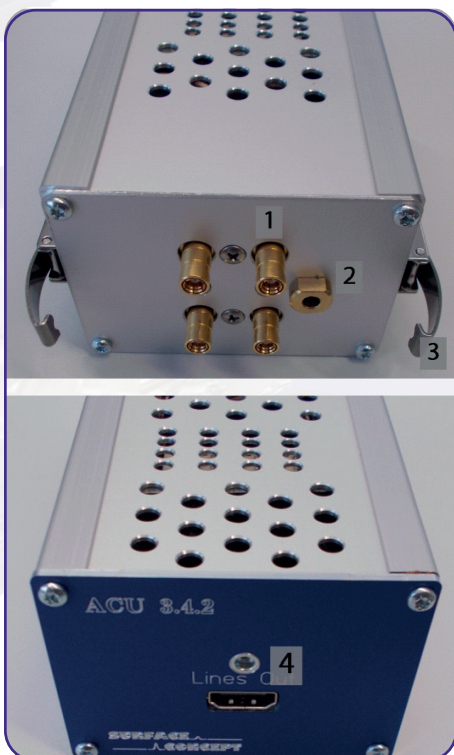


Figure 13: Layout of ACU 3.4.2.

1. 4x SMB sockets for signal transfer from SMB feedthrough
2. Hole for orientation pin from SMB feedthrough
3. Clip for fastening ACU to detector flange
4. Connection socket for DLD readout cable

The ACU can be plugged directly onto the 4-fold SMB feedthroughs. Fasten the two clips of the ACU to fix it to the detector. **Figure 13** shows the layout of the ACU 3.4.2.



Hold the ACU straight and plug it very carefully.
The middle pins of the SMB connectors in the 4-fold SMB feedthrough can be damaged when holding the ACU not straight while plugging.

7.1.1 Positions of the Discriminator Threshold Regulators

Discriminator threshold regulators of the 4 DLD channels as well as potentiometers for an additional adjustment can be found on the corresponding boards inside the ACU 3.4.2. They can be reached through the holes on the top side of the ACU housing (see **Figure 14**).

The adjustment of the readout electronics goes hand in hand with the detector voltage. In fact there is only a small “window” for an optimum setting of the readout electronics for a given operation voltage. Changes of the detector voltage, other than to compensate loss in the amplification of the MCP stack due to degradation effects, will directly lead to a loss in performance of the readout electronics (artefacts within the image, increased dark count rate etc.). The readout electronics is adjusted to its best performance to the starting operation voltage of the detector when delivered. A new adjustment should not be needed. The starting operation voltage is given in the specification sheet. The operation voltage is not fixed but must be re-adjusted over time to compensate gain degradation of the MCPs. See **Chapter 8.5** for further details.

The sensitivity of the CFD is increased (threshold decreased) by turning the screw of the potentiometer clockwise and vice versa for decreasing the sensitivity of the CFD.



The readout electronics is adjusted to its best performance to the operation voltage of the detector when delivered. The settings for the threshold positions and the zero offsets are given in the specification sheet. **Do not change the adjustment of the thresholds and/or zero offsets.** Changing the adjustment can easily end up with a status, where a readjustment must be made by Surface Concept.



Figure 14: Labelling of discriminator threshold and amplification regulators.

8 Microchannel Plate

8.1 Specifications

Please check the specification sheet of the DLD for the exact MCP specifications.

8.2 Storage

Because of their structure and the nature of the materials used in manufacture, care must be taken when handling or operating MCPs. The following precautions are strongly recommended:

- The most effective long-term storage environment for an MCP is an oil-free vacuum.

8.3 Handling

- Shipping containers should be opened only under class 100 Laminar flow cleanroom conditions.
- Personnel should always wear clean, talc-free, class 100 clean-room compatible, vinyl gloves when handling MCPs. No physical object should come into contact with the active area of the wafer. The MCP should be handled by its rims, there is no solid glass border! Use clean degassed tools fabricated from stainless steel, Teflon™ or other ultra-high vacuum-compatible materials. Handling MCPs should be limited to trained, experienced personnel.
- MCPs without solid glass border should be handled very carefully with great care taken to contact the outer edges of the plate only.
- The MCP should be protected from exposure to particle contamination. Particles which become affixed to the plate can be removed by using a very pure and low pressure air flow such as from a clean rubber bellows.
- The MCP should be mounted only in fixtures designed for this purpose. Careful note should be taken of electrical potentials involved.





Voltages must not be applied to the device while at atmospheric pressure. The pressure should be 1E-6mbar or lower at the micro channel plate before applying voltage. Otherwise, damaging ion feedback or electrical breakdown will occur.

8.4 Operation

- A dry-pumped or well-trapped/diffusion-pumped operating environment is desirable. A poor vacuum environment will most likely shorten MCP life or change MCP operating characteristics.
- A pressure of 1E-6mbar or better is preferred. Higher pressure can result in high background noise or even to damaging due to ion feedback or to an electrical breakdown.
- Apply voltages as defined in **Chapter 4**. If fluctuations appear, damage or contamination should be suspected and the voltage should be turned off. The assembly should then be inspected before proceeding.
- Voltage across single MCPs should not exceed the maximum voltage given in the specification sheet of the detector. Higher potentials may result in irreversible damage.
- MCPs can be degraded by exposure to various types of hydrocarbon materials which raise the work function of the surface, causing gain degradation.
- Operation at higher temperatures ($> 50^{\circ}\text{C}$) will cause gain degradation.
- MCPs can degas for quite a while during operation. The pressure increase also depends on the number of initial particles given to the MCP (e.g. pressure increase from 5E-10mbar up to 1E-8mbar for a new chevron MCP stack and DLD count rates of a few Mcps). A degas procedure for MCPs is described in **Chapter 8.6**.

8.5 MCP Lifetime and Operation Voltage

The lifetime of the MCPs is determined by the MCPs gain degradation over time, whereas the gain degradation is a function of the extracted output charge. Therefore the lifetime of the MCPs strongly depends on the count rate applied to the detector over time.

The typical gain degradation of a MCP is shown in **Figure 15** as a function of extracted output charge in terms of coulombs per square centimetre.

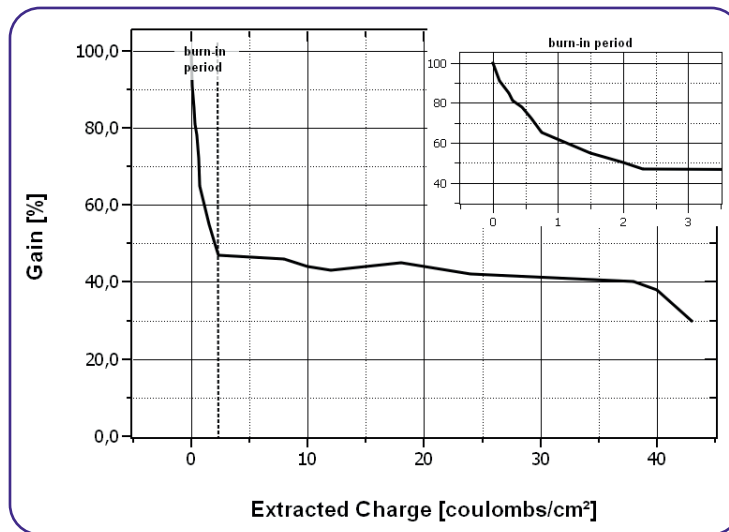


Figure 15: Typical gain degradation of MCPs as function of the extracted output charge.

After an initial burn-in period, in which the detector gain changes as a result of electron induced chemical allocation together with degassing residual gas molecules from the inside of the channels, the MCP performance is very stable over a large amount of extracted output charge. The MCP gain is also a function of the detectors operation voltage. Therefore gain degradation can always be compensated by increasing the detector voltage.

Detector delivery will still happen with the MCPs operating within the burn-in period, although the detector has been operated for some longer time with highest count rates during the test phase, Therefore gain degradation will be still significant in the first year of operation (or even longer, depending on applied count rates) and becomes obvious by a decline of the detector performance. Therefore it will become necessary to increase the operation voltage from time to time. Voltage increase should always be made in small steps (typically 50 V). There is a recommended maximum operation voltage, to which the detector voltage can be increased to compensate gain degradation over time. This voltage is given in the specification sheet of each detector.

A typical behaviour of the detector voltage increase over time to compensate gain degradation is given schematically in **Figure 16**.

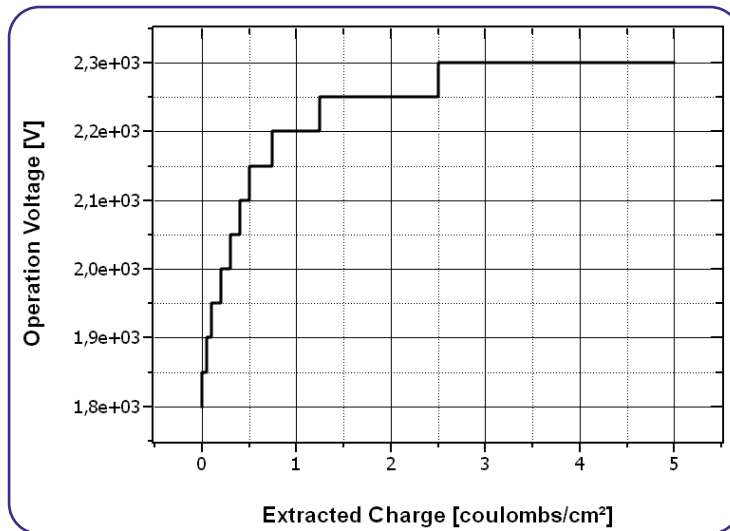


Figure 16: Schematic plot of increasing the operation voltage to compensate gain degradation over time as function of the extracted charge (all values are only exemplary).



It is not unusual that the operation voltage must be increased several times especially in the first year of operation.

Typically, the final operation voltage at the end of the burn-in period will be close to the recommended maximum operation voltage. An increase of the operation voltage above the recommended maximum operation voltage is in principal possible and allowed, as long as there is no significant increase in the dark count rate, bright spots at the detection area and/or appearance of high voltage sparking.



The operation voltage can be increased even above the recommended maximum operation voltage. A safe and reliable operation will still be possible as long as there is no increase in the dark count rate and/or no appearance of high voltage sparking.

It can be sufficient to estimate the correct operation voltage by monitoring the detector results, when increasing the voltage to compensate the gain degradation. The exact operation voltage can always be determined by measuring a so called MCP curve. The MCP curve plots the detected count rate as a function of the operation voltage. Do as follows to measure an MCP curve:

- Start the detector operation with a homogeneous illumination (as good as possible).
- Open the rate meter in the Surface Concept GUI Software to monitor the count rate output of the detector.
- Decrease the operation voltage until the count rate of the detector is reduced to zero.

- Increase the operation voltage in steps of 50V until far above the last operation voltage (please respect the recommended maximum operation voltage) or until the detector shows significant artefacts. Measure the count rate for each voltage step.
- Plot the measured count rate as a function of the operation voltage. This is the MCP curve. It should show a change in the slope of the rising curve, which indicates the beginning of the area of operation.
- The new value for the operation voltage should be a bit above the position of the change in the slope.

Figure 17 shows an example of a MCP curve with the specified operation voltage. The MCP curve for specifying the starting operation voltage for a detector can always be found in the specification sheet.

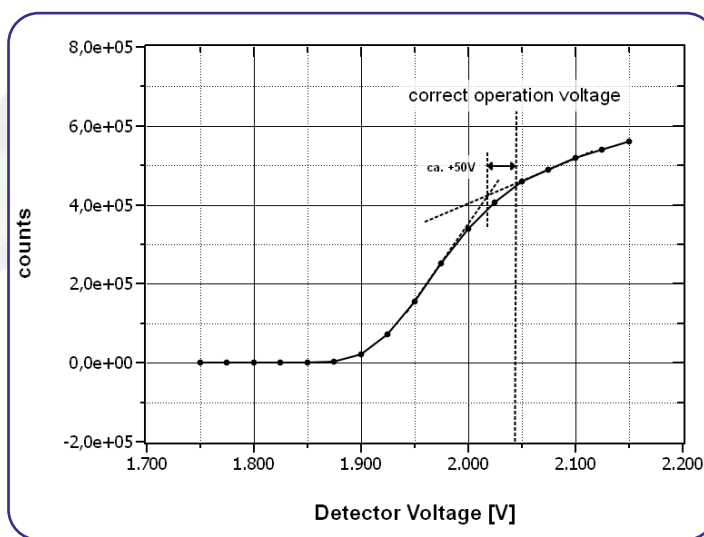


Figure 17: Example of MCP curve (for illustration only).

The life time of MCPs can be very large, due to the high stability of the operation performance over a large amount of extracted output charges after the burn-in period. The main reason for an often much shorter operation time of the MCPs is an inhomogeneous irradiation of the MCPs. This is connected to a locally (strong) different gain degradation, which results in an inhomogeneous detector response. Locally different gains can still be compensated by increasing the operation voltage, but very often the increasing voltage step must be much larger to reach again a homogeneous detector response.

Gain degradation also depends strongly on the environment in which the MCPs are being operated. Care should be taken to prevent exposure to high concentrations of hydrocarbons and halogens. Also prevent MCP operation at higher temperatures (> 50°C, e.g. respect an appropriate cooling phase after bake out).



Note Strong inhomogeneous irradiation of the MCPs lead to strong locally different gain degradation and to an inhomogeneous detector response, which is the main reason for a shortened operation time of the MCPs.

8.6 MCP Degas Procedure

The effect of MCP outgassing can be reduced by running a degas procedure. To do so the detector must be operated at a count rate of about a factor of three higher (if possible - maximum count rates must be respected of course) than the count rate which is planned for the specific application (e.g. count rates of about 3 million counts per sec when a count rate of 1 counts per sec is planned for the application).



It is really important that the detector is irradiated homogeneously over the complete active area. Otherwise the MCPs will degenerate at various positions differently, which will lead to an inhomogeneous flat field of the detector.

Operate the detector continuously until the pressure increase has reduced significantly to an acceptable pressure range (this will take quite a while, especially with new MCPs). Then switch to the final application. The pressure increase for the smaller count rate should now be much smaller. The detector will be delivered already pre-conditioned. Unfortunately the degas procedure must be started anew (to a certain extend) after each venting of the detector.

8.7 Replacement



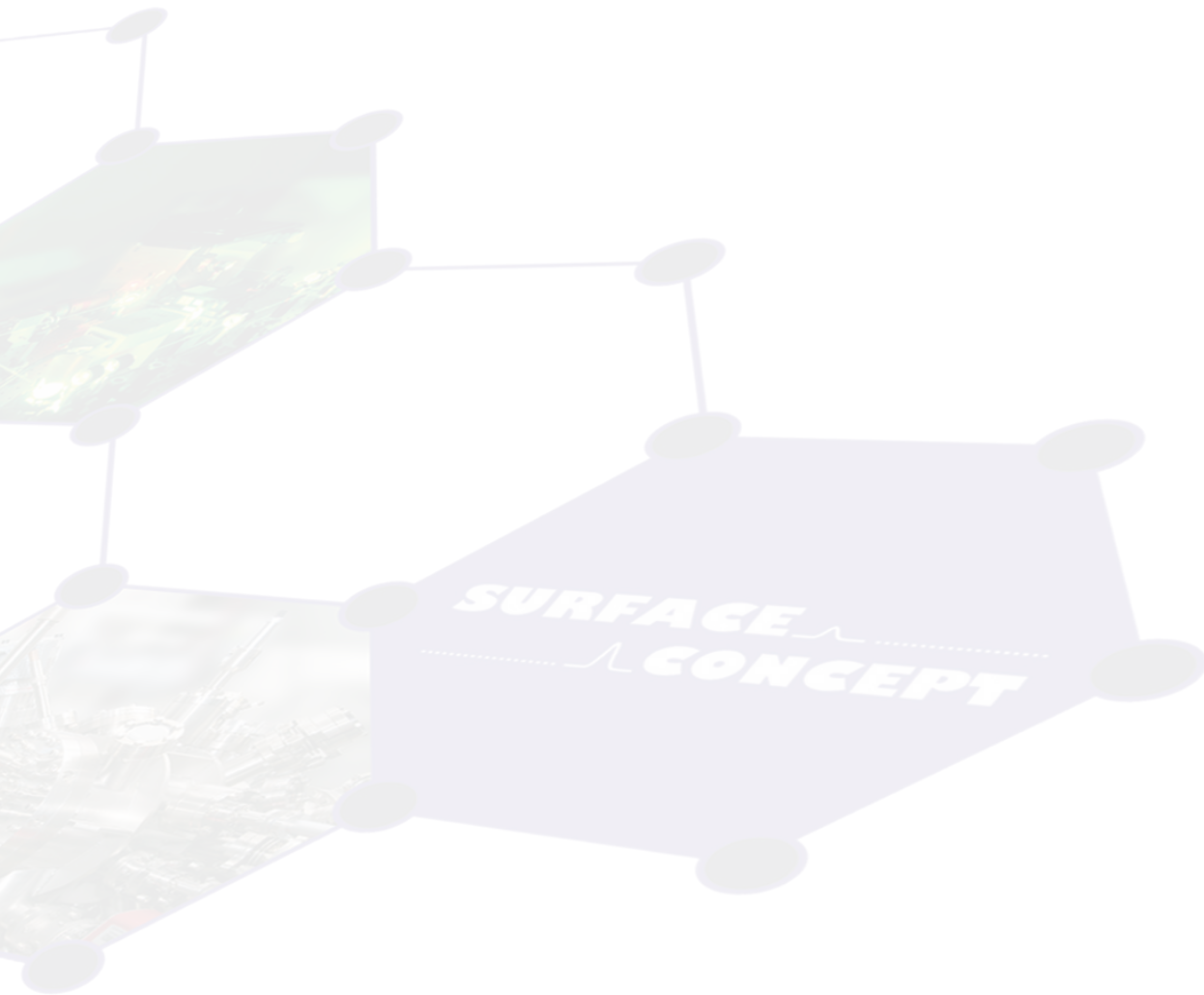
Contact your provider before performing a replacement.

Please contact your provider before performing any MCP replacement. We will provide you with a detailed step by step description.

Please take care to note the orientation of the MCPs. The channels in the MCPs include a certain angle against the surface normal to the plate and the MCPs must be mounted in a chevron or z-stack configuration (depending on number of MCPs in the detector). All parts of the detector, especially the MCPs should be handled with great care. The MCP surfaces are very sensitive and should never be touched or scratched.

9 Troubleshooting

Consult the Hints_and_TroubleShootingDLDs Manual (part of the detector delivery) in case of any problems prior to contacting your provider.



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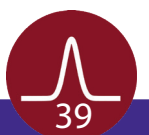
10 Technical Data

Delayline Detector General

Base Flange:	GATAN
Active area of the DLD4040:	Ø 40mm round
Operation voltage at detector:	see specification sheet
Voltage at MCP front:	see specification sheet
Voltage difference between MCP back and anode:	typ. 400 V
Potential of Detector Cover:	not available
Grid voltage:	not available
Signal Feedthrough:	1x 4-fold SMB Feedthrough on CF40 Flange
HV Feedthrough:	3x SHV5 Feedthrough
Additional Feedthroughs:	1x D-Sub Feedthrough for motor control
Bake out temperature (max.):	not made for bake out
Vacuum pressure range for operation:	< 1E-6 mbar

Amplifier CFD - Unit ACU 3.4.2

No. of Amplifier-CFD Channels:	4
Bandwidth of DLD amplifiers:	1.6 GHz
CFD working frequency:	200 MHz
CFD jitter (max.):	20ps
CFD walk (typ.):	< 50ps (while ambient temperature varies less then 5 K)



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EC Declaration of Conformity

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Product

Delayline Detector

The above named products comply with the following European directive:

89/336/EEC

Electromagnetic Compatibility Directive, amended by 91/263/ EEC and 92/31/ EEC and 93/68/EEC

73/23/EEC

Low Voltage Equipment Directive, amended by 93/68/EEC

The compliance of the above named product to which this declaration relates is in conformity with the following standards or other normative documents where relevant:

EN 61000-6-2:2005+AC:2005

Electromagnetic compatibility (EMC):
Generic standards - Immunity for industrial environments

EN 61000-6-4:2007+A1:2011

Electromagnetic compatibility (EMC):
Generic standards - Emission standard for industrial environments

EN 61010-1: 2010

Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory Use

For and on behalf of **Surface Concept GmbH**

Mainz,.....01.04.2013.....
(Date)

Legal Signature.....
(Dr. Andreas Oelsner)

This declaration does not represent a commitment to features or capabilities of the instrument. The safety notes and regulations given in the product related documentation must be observed at all times.

