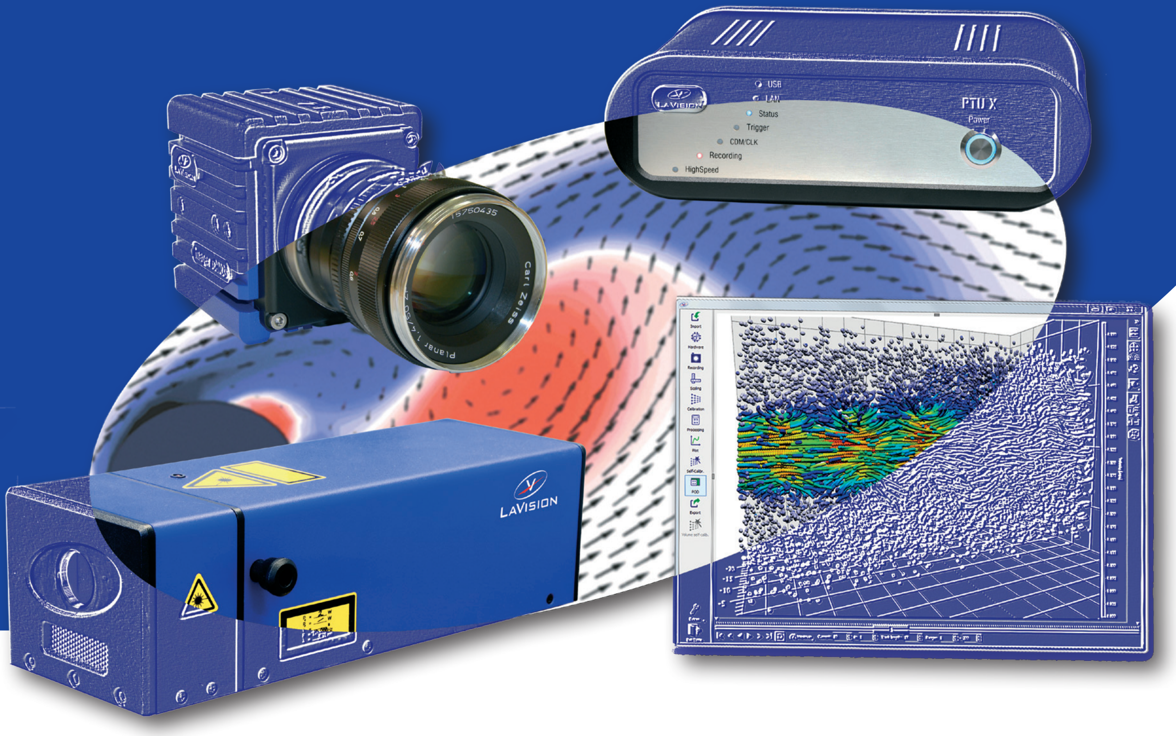

Product Manual

Programmable Timing Unit (PTU X)

Item Number(s): 1108090-1108095

LaVision
FOCUS ON IMAGING

Product Manual for **DaVis 10.2**

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Product specifications and manual contents are subject to change without notification.
Note: the latest version of the manual is available in the download area of our website `www.lavision.com`. Access requires login with a valid user account.

Contents

1 Introduction

1.1 About this manual

This manual describes the physical hardware of the PTU X and its operation as a low-speed triggering device. The operation as a high-speed triggering device, the **LaVision HighSpeed Controller**, is described in detail in a different manual.

1.2 Operating Modes

The PTU X runs in two different modes: low-speed and high-speed.

Comparison to PTU 9 versions prior to **DaVis** 8.2.0:

DaVis 8.1.6 and earlier	**DaVis 8.2.0 and later**
PTU 9	PTU X in low-speed "PTU" mode
HSC	PTU X in high-speed "HSC" mode

Both the former PTU 9 and the HighSpeed Controller (HSC) functionality now run on the same hardware, the PTU X. The difference is made in the hardware setup of **DaVis**, in which you either select a PTU or a HSC.

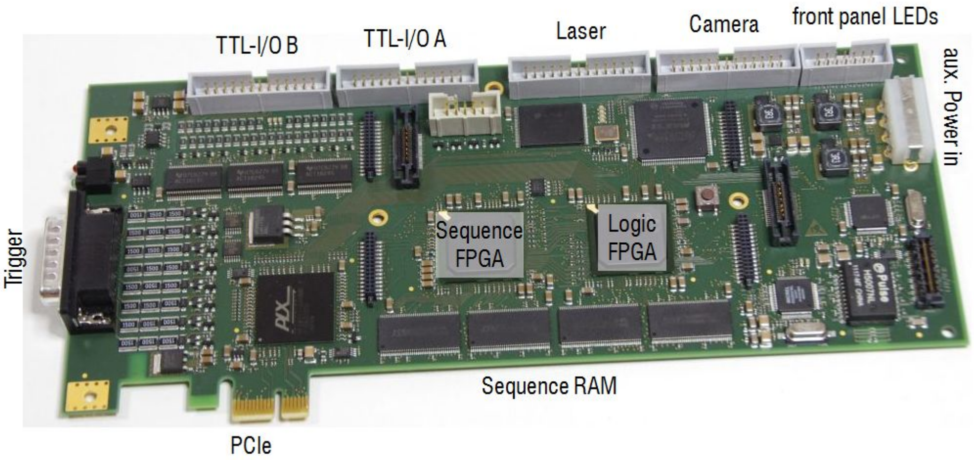
An LED indicator at the front of the PTU X shows in which mode it is running.

Please note: from **DaVis** 10.1 a PTU X HS is required for high-speed systems. The support of the HSC as trigger unit for high-speed systems is discontinued.

1.3 General Description of PTU X

LaVision's software-controlled Synchronization Unit PTU X is an embedded system for generation of complex patterns of pulses (sequences) with highly accurate timing on multiple outputs (up to 16 independent channels) as used for the synchronization of **LaVision**'s Intelligent Imaging Systems. The PTU X is available as a PCI express (PCIe) board or as a standalone USB device. The pulse width and the interval between pulses are programmed automatically by the **DaVis** software according to the application, the hardware connected (laser, camera, etc.) and the user settings in the dialog boxes inside **DaVis**.

The microprocessor-controlled timing sequence can be started by an external trigger or constantly generated by an internal frequency generator (e.g. at a specified laser repetition rate).



The PTU X takes control over the synchronization of all devices connected to it. This is not only to trigger the devices at the right time - which is done with 10 ns resolution - but to accomplish synchronized data readout from all sources. The image files recorded with **DaVis** contain images and scalar values from very different types of sources such as cameras, energy monitors, or A/D converters. It is the main task of the PTU X to guarantee that all data in a multi-frame **DaVis** image arise from the same trigger. This is more than a trivial task because cameras typically have an internal image memory stack of model-dependent size.

2 PTU X Hardware

Part number	Description
1108090	PTU X basic, PCIe internal
1108091	PTU X basic, USB external
1108092	PTU X standard, PCIe internal
1108093	PTU X standard, USB external
1108105	PTU X 19"
1108106	PTU X 19" w/ ADC incl. rotary decoder
1012374	PTU X DIN rail
1108262	Rotary decoder upgrade
1108098	Reference time upgrade 1 to 8
1108100	High-speed upgrade
1005582	Connector cable, extension, 2m, XLR > LEMO 6 pin
1005583	EB plug-in power supply, external Controller, 5 and 12V

2.1 Part Numbers

Part number	Description
1108090	basic PCIe internal
1108091	basic USB external
1108092	standard PCIe internal
1108093	standard USB external

2.2 PTU Versions

Version	Features	Typical applications
PTU X basic	• direct external trigger, static frequency strategy and internal trigger rate generation • accurate camera trigger • supports 2 cameras • supports 1 gated or edge-triggered light source through 1 sequencer line • no ADC • synchronized recording	• 2D/Stereo PIV with DPSS Laser • SprayMaster inspex Q.C. systems • 2D/Stereo FlowMaster PIV systems with DPSS Laser • Camera stand-alone systems (includes camera + IRO solution)

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PTU X standard	• direct external trigger, static frequency strategy and internal trigger rate generation • multi-device recording • 24 sequencer lines • synchronized recording • reference times available	• Tomo PIV • 2D/Stereo PIV • LIF • FlameMaster • SprayMaster • Shock tubes

2.3 PTU X Sequencer I/O Specifications

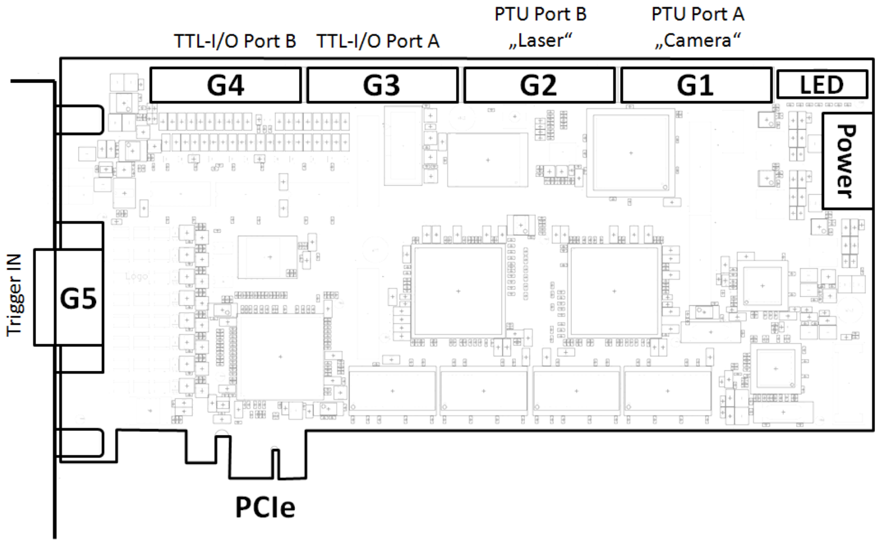
PTU Version	**BASIC**	**STANDARD**
output drivers	TTL 50 Ω	TTL 50 Ω
time resolution	10 ns	10 ns
typical jitter between all outputs	<1 ns	<1 ns
jitter to external signals	±5 ns	±5 ns
trigger source	generator, external TTL input	generator, external TTL input
frequency strategy	direct static	direct static
frequency generator range	0,01 Hz–1 MHz	0,01 Hz–1 MHz
reference times	1	1, 8
user trigger outputs	1	8
supported devices	2 cameras trigger, 1 gated/pulsed light, A/D converter, image intensifier	all
interface	PCIe	PCIe
external PTU	USB	USB
digital inputs	TTL programmable polarity, 2.7 kΩ to GND, optional: 50 Ω	

2.4 PTU X TTL I/O Lines

TTL-I/O lines available on all PTU versions:

Direction	**No. of lines**	**Signal level**	**Load**
outputs	8	TTL 5V	50 Ω
inputs	4	TTL 5V	2,7 kΩ or 50 Ω to GND (software selectable)

2.5 PTU X Board Layout



The PTU X board has a row of 5 connectors on top of the board and a connector at the slot bracket front.

Label	Function	Connector Type
G1	PTU Port A "Camera"	26-pin PCB header
G2	PTU Port B "Laser"	26-pin PCB header
G3	Port A	26-pin PCB header
G4	Port B	26-pin PCB header
LED	LED Front Panel	14-pin PCB header
G5	Trigger Input	male D-Sub-15
Power	5V/12V Power	male 4-pin Molex

> ⚠ **Attention:**
>
> The power input must be connected to the power supply of the PC!

2 LEDs on the slot bracket (fig. 2.1) show the internal state of the PTU X firmware:

Safe configuration (red LED): The PTU X is booted into a safe wakeup configuration. This happens during firmware updates. The purpose of this configuration is to load a new firmware into the PTU X. In this mode the PTU X cannot send normal trigger signals.

Normal operation (green LED): The PTU X firmware has booted to normal operation. The PTU X is ready to run with **DaVis** and can generate trigger signals.

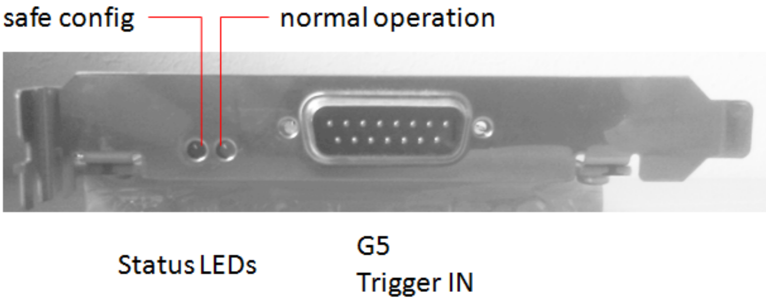


Figure 2.1: Slot bracket of PTU X

2.5.1 Internal Pin Assignment

On board of the PTU X are the headers G1-G4 and the LED header. The pin assignment of these connectors is shown in tables 2.3 for G1-G4, 2.4 for the LED Connector.
The board has an additional power connector which must be connected to a ATX power supply.

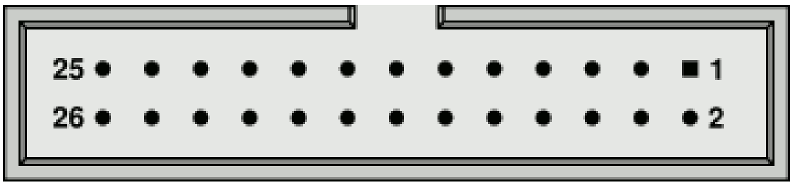


Figure 2.2: Pin assignment of 26-pin PCB header

Pin	G1 PTU PortA	G2 PTU PortB	G3 Pio PortA	G4 Pio PortB
1	Seq. OUT A0	Seq. OUT B0	IN 1 high	IN3 high
2	GND	GND	IN 1 low	IN3 low
3	Seq. OUT A1	Seq. OUT B1	IN 2 high	IN4 high
4	GND	GND	IN 2 low	IN4 low
5	Seq. OUT A2	Seq. OUT B2	Pio OUT A0	Pio OUT B0
6	GND	GND	GND	GND
7	Seq. OUT A3	Seq. OUT B3	Pio OUT A1	Pio OUT B1
8	GND	GND	GND	GND
9	Seq. OUT A4	Seq. OUT B4	Pio OUT A2	Pio OUT B2
10	GND	GND	GND	GND

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Pin	G1 PTU PortA	G2 PTU PortB	G3 Pio PortA	G4 Pio PortB
11	Seq. OUT A5	Seq. OUT B5	Pio OUT A3	Pio OUT B3
12	GND	GND	GND	GND
13	Seq. OUT A6	Seq. OUT B6	Pio OUT A4	Pio OUT B4
14	GND	GND	GND	GND
15	Seq. OUT A7	Seq. OUT B7	Pio OUT A5	Pio OUT B5
16	GND	GND	GND	GND
17	Arming input	DR_IN3	Pio OUT A6	Pio OUT B6
18	GND	GND	GND	GND
19	Seq. Trigger input	DR_IN2	Pio OUT A7	Pio OUT B7
20	GND	GND	GND	GND
21	Seq_GP_out0	SEQ_GP_OUT3	+5V	+5V
22	GND	GND	GND	GND
23	SEQ_GP_OUT1	SEQ_GP_OUT4	TTL-I/O IN3	DAC output1
24	GND	GND	GND	SGND
25	SEQ_GP_Out2	SEQ_GP_OUT5	TTL-I/O IN4	DAC output2
26	GND	GND	GND	SGND

Table 2.3: Pin assignment of PTU X headers G1-G4

Pin	Name
2	Status safe config
4	Status normal
6	USB (not used for internal PTU)
8	Trigger
10	CDM/CLK
12	Recording
14	HighSpeed
others	VCC (+5V)

Table 2.4: Pin assignment of PTU X G8 (LED) header

The pin assignment of the external connector G5 (D-Sub-15) can be seen in table 2.5.

Pin	Name
1	Trigger
2	Arming (not used)
3	Start
4	CDM/CLK
5	*not used*
6	*not used*
7	TTL I/O IN1
8	TTL I/O IN2
9-15	GND

Table 2.5: Pin assignment of PTU X G5 (D-Sub15) port

2.6 Power Supply

The PTU X is delivered in several packagings, offering an ideal solution for different application environment. Different PTU X versions have different way of connecting them to the power supply.

External PTU X

To power the extrernal PTU X on, the power supply unit 2 must be plugged in to the power port 3 present on the back side of the external unit through the extender cable 1 .

Figure 2.3: PTU X external and power supply unit

Internal PTU X

The PTU X internal card has to be connected to the PC power supply via the HDD power connector in order to turn the device on. The HDD power connector should be plugged in the aux. power input port 1 as shown below:

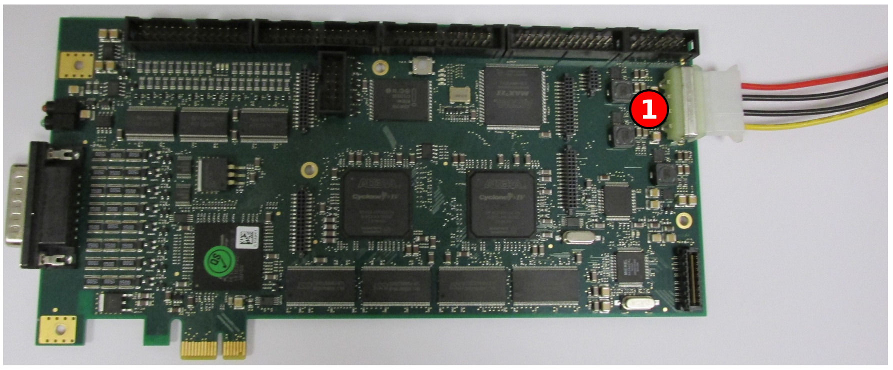


Figure 2.4: PTU X internal connected to the power supply

2.7 PTU Terminals

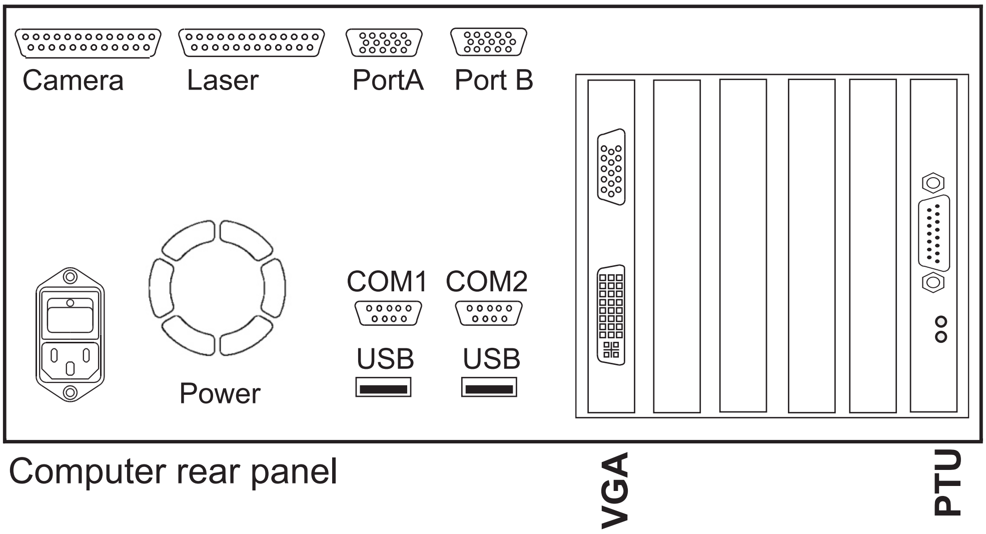
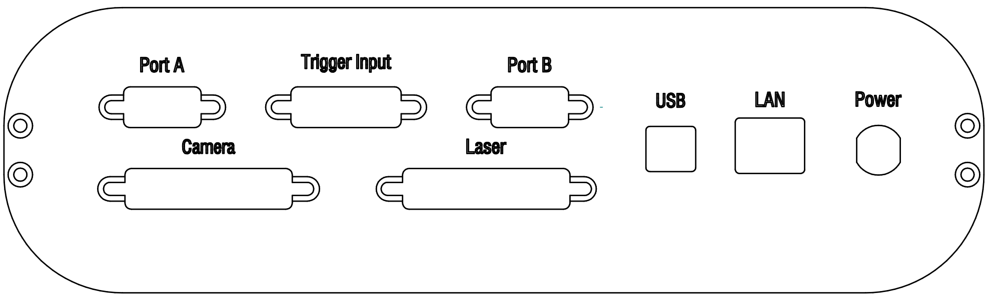
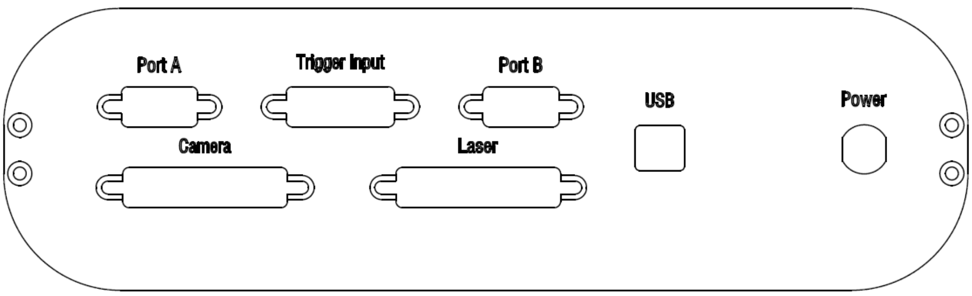


Figure 2.5: Computer rear panel with PTU connectors



(a) first version of external PTU (delivered until endof 2020)



(b) actual version of external PTU

Figure 2.6: Rear panel of external PTU with connectors

Note:

The actual version of the external PTU was first shipped beginning of 2021.

Terminal	Connector Type	only external PTU
PTU Port A "Camera"	female D-Sub 25	
PTU Port B "Laser"	female D-Sub 25	
TTL-I/O Port A "Port A"	male D-Sub 15 condensed	
TTL-I/O Port B "Port B"	male D-Sub 15 condensed	
Trigger Input	male D-Sub 15	
USB	USB 2.0 compliant Type B	yes
LAN [1]	Ethernet RJ-45	yes
Power	Power supply	yes

[1] LAN port cannot be used to connect the PTU with **DaVis**. This only works through the USB port.

2.8 Status LEDs

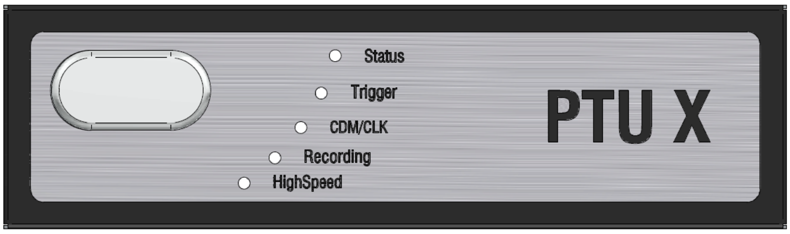


Figure 2.7: Status LEDs on the front panel of the internal PTU X

(a) first version of external PTU (delivered until end of 2020)

(b) actual version of external PTU

Figure 2.8: Status LEDs on the front panel of the external PTU X

Label	Color	Meaning
USB	white	(only external PTU X): Shows a USB connection
LAN	white	(only former external PTU X): Shows a network connection
Status	white	Ready for normal operation
	yellow	Safe configuration has booted
Trigger	white	Trigger signal received
CDM/CLK	white	CDM/CLK signal received
Recording	white	Recording active
HighSpeed	white	PTU supports high-speed timing domains

⚠ **Note:**

LAN is only available in the former version of the external PTU, as shown in Fig. 2.6a and Fig. 2.8a. The LAN port cannot be used to connect the PTU with **DaVis**.

Meaning of the status LEDs:

- **USB (only external PTU):** The external PTU is connected via USB.
- **LAN (only former version of external PTU):** The external PTU is connected via an Ethernet network line.
- **Status:**

  white: Normal operation of the PTU X has been started. The PTU X is ready to run with **DaVis** and can generate trigger signals

  yellow: The "Safe Configuration" has booted. This mode is used during firmware upgrades. The PTU X cannot generate trigger signals while in this mode.

- **Trigger:** Indicates that a trigger signal has been received. This signal triggers a PTU cycle. In case of low speed systems (e.g. PIV) this is the recording of a PIV image pair. In case of HighSpeed systems this is the start of an entire sequence of images.
- **CDM/CLK:** Indicates the "Crank Division Mark" (CDM) or image clock (CLK) signal has been received. CDM signals are used in combination with crank angle encoders, which deliver a fine resolved clock for a certain phase. CLK signals are used for high-speed systems to trigger each image of a sequence.
- **Recording:** This indicates that **DaVis** is currently recording images.
- **HighSpeed:** When lit, it indicates that the PTU X supports high-speed timing domains and can be used to trigger high-speed cameras.

2.9 PTU Adapters

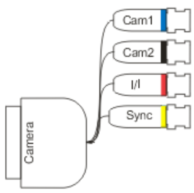
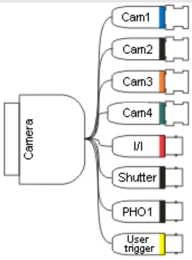
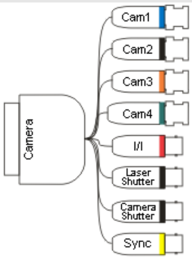
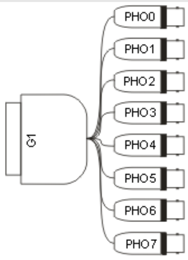
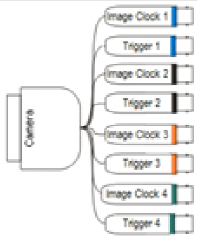
Every **adapter** is connected to a certain **terminal** at the PTU.

- **Terminal:** Connector at the computer rear panel or the rear side of the external PTU. See chapter 2.7.
- **Adapter:** An adapter fits on one selected terminal and provides connection lines for the individual signals. Most adapters have BNC connectors. For a correct assignment, please select the adapter connected to a specific terminal in the hardware setup of **DaVis** (see chapter 4.5.2).
- **Line:** A signal line which delivers a TTL-level pulse. The lines are assigned to specific functions, like trigger for a camera or a laser. Labels on the cables show you how to connect your system.

Generic adapters: We deliver a set of generic adapters. They have non-specific lines, labeled as "Physical Out" (PHO).

2.9.1 Camera Adapters

Adapters mainly connected to cameras and their accessories are listed here.

Art. Nr.	1000298	1003830	1003344	1003517	1007820
PTU/HSC	PTU/HSC	PTU/HSC	PTU/HSC	PTU/HSC	PTU/HSC
Terminal	G1	G1	G1	G1, G2	G1
Pin 1	Cam 1	Cam 1	Cam 1	PHO0	Image Clock 1
Pin 2	Cam 2	Cam 2	Cam 2	PHO1	Image Clock 2
Pin 3	Image Intensifier	Cam 3	Cam 3	PHO2	Image Clock 3
Pin 4	User Trigger	Cam 4	Cam 4	PHO3	Image Clock 4
Pin 5		Image Intensifier	Image Intensifier	PHO4	Trigger 1
Pin 6			Laser Shutter	PHO5	Trigger 2
Pin 7		Camera Shutter	Camera Shutter	PHO6	Trigger 3
Pin 8		User Trigger	User Trigger	PHO7	Trigger 4
Image					

2.9.2 PTU Trigger Adapter

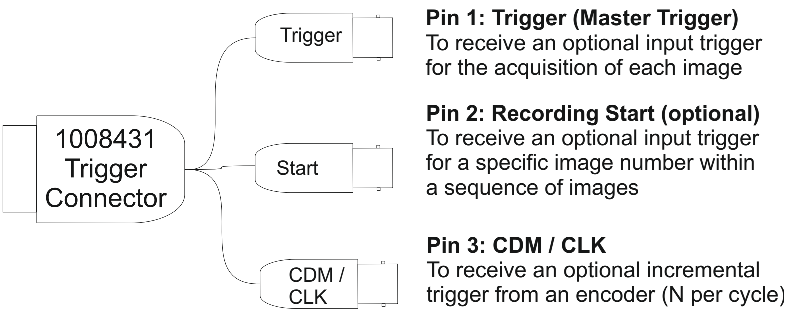


Figure 2.9: PTU trigger adapter

To connect input trigger signals to the PTU you can use the PTU connector 1008431 (Fig. 2.9) for the PTU DSub15 port. The **Trigger** line can be used to trigger the acquisition of each image. In general we recommend to use 50 Ω termination in order to clean the TTL signal from overshooting peaks (see chap. 4.3.1 for details how to select input impedance). The recommended pulse width for the external trigger signal is $\geq 1\,\mu$s, the detection limit is a pulse width of 20 ns.

For the readout of a rotary encoder, send the **Master** trigger (1 per revolution) to the **Start** input, and the **Incremental** trigger to the **CDM/CLK** input (connector 1008431).

2.10 Signal Quality and Missing Triggers

PTU X and HSC have a fast responding input trigger electronics for the "Start", "Trigger" and "CDM" signals. These signals are sensitive to short spikes at the leading or trailing edge of a trigger signal. Typically, signal spikes are the result of reflections at the end of the signal cables, cable junctions and connectors.

This type of interferences will be seen as a sequence of very quick multiple triggers by the PTU/HSC logic. In this case, the internal frequency measurement may get unstable and drastically changing values or missing detection of triggers. In consequence, parts of the DaVis logic may not follow these unstable conditions and may work in an unpredictable way. Spikes on the CDM signal can lead to a misinterpretation of the actual phase of a rotary decoder, including wrong number of CDM pulses per revolution.

Typical symptoms are:

- timeout during acquisition, especially when using the CDM signal from a rotary decoder
- missing reaction on triggers signals
- wrong or changing values for input frequency / rpm readings
- wrong values for rpm and CDM/cycle when using the rotary encoder and phase angle based trigger modes
- missing indication of an existing trigger clock

2.10.1 Possible causes of missing trigger

A missing trigger can have different causes. The symptom is always that the system is not triggered. Typical reasons and measures against it are listed here.

- **Broken trigger lines:** BNC cables are relatively sensitive to mechanical stress. Please check first if the trigger really appears at the end of the trigger line. An oscilloscope normally has a very high impedance, which may give the false impression that the trigger is coming through. Better use a BNC-T-branch and measure the trigger while it is connected to the PTU. Note that also the returning ground line may be broken.
- **Broken BNC connectors:** Even BNC-T-branches can fail. When using them for testing, please make sure to do so under conditions under which they are known to work.
- **Trigger source in software is not set properly:** Make sure that the software settings correspond to the hardware connected.
- **Trigger source has not enough power to drive 50 Ω:** This quite frequent problem is caused by an internal impedance (resistance) of the trigger source. When using an oscilloscope, it looks fine, but when applied to load (such as the PTU), the voltage breaks down.
- **Trigger source has not enough power to drive the PTU's HighZ:** The term ”HighZ” often refers to a ”very high” impedance. For the PTU X, this is 2.7 kΩ, which is part of the input protection circuit. The trigger source must be powerful enough to drive this line.
- **Internal 50 Ω termination is switched on, but the source cannot drive it:** It is possible to set the inputs of the PTU internally to 50 Ω. See chapter 4.3.1 Input Setup on how to change this. Using 50 Ω termination is preferable, but the entire BNC network including the trigger source must be capable of driving the higher current. If this is not the case, switch the PTU back to ”HighZ”.
- **Multiple transient spikes on trigger lines:** The following chapters explain how to deal with this.

2.10.2 Analysis of Signal Quality

Characteristics of a "good" trigger signal are: high and low voltage level, slope ("steepness") of the leading and trailing edge, absence of spikes and extra modulations. These characteristics need to be monitored with the entire system cabling. Most critical are spikes at the leading and trailing edge, because they could differ very much from the behavior of the main pulse and are typically on a much shorter time scale, e.g. 100 ns.

Measurements can be done with a common oscilloscope with at least 50MHz bandwidth. Use a 50 Ohm T-junction as close to the PTU/HSC as possible with a short cable to the Oscilloscope. Connect the oscilloscope to the same AC line as the PTU/HSC.

Oscilloscope Settings:

Time Base: 100-200 ns/div, delay = 0

Trigger: DC-coupling, rising edge, no HF-rejection,
Trigger mode = "normal" (not "auto")

Signal input: 1-2 V/div, DC coupling, High-Z (high impedance)

Display: no averaging; if existent: peak-detection and "persistence" (=each trace stays on the screen for a few seconds as with analog phosphor oscilloscopes)

Measure the signal shape on the leading edge. If there is only 1 rising edge or if there are oscillations / spikes, vary the trigger level slowly from 0 V to 5 V and monitor the display.

Repeat the same with the trailing edge: switch the oscilloscope trigger to "falling edge" and again vary the trigger level slowly from 5 V down to 0 V.

This is done in order to ensure that the monitored trigger edge is free of any extra peaks / spikes.

Checklist:

Characteristics	**Acceptance criterion**	**Measured by**
Signal level low	0.0 - 0.8 V	Oscilloscope at a speed that shows the entire trigger pulse
Signal level high	2.0 - 5.0 V	Oscilloscope at a speed that shows the entire trigger pulse
Leading edge	no extra spike	Oscilloscope at 100 ns/div, trigger rising edge
Trailing edge	no extra spike	Oscilloscope at 100 ns/div, trigger falling edge

The example in fig. 2.10 shows a leading peak pulse of about 200 ns length and 3 V amplitude before the main trigger pulse. This will generate 2 trigger edges to the PTU in rapid succession. Using a low-pass filter could effectively suppress this extra pulse.

Also typical: the main trigger pulse does not have a very sharp edge but slowly increases over about 1 μs . This is not critical in means of triggering, as the PTU converts this internally to a clearly defined trigger pulse. But due to the small slope, the exact moment of triggering might vary, which would lead to a jitter. It is better to generate a sharp-edged trigger pulse.

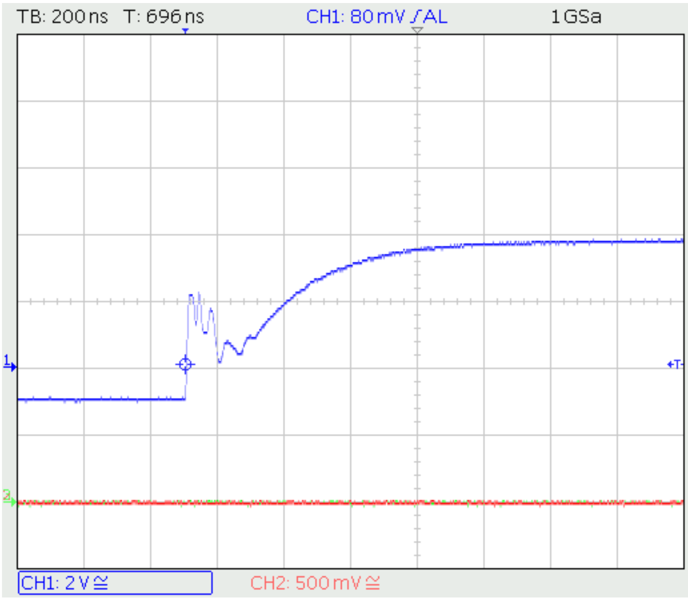


Figure 2.10: Oscilloscope Image from a peak at the leading edge (time base = 200ns/div)

2.10.3 Measures to improve signal quality and to reduce interfering spikes

The following measures can reduce the likelihood of unwanted interfering signals on trigger lines:

- using 50 Ω terminal resistors
- reducing the bandwidth with a low-pass filter
- routing extra earth and signal lines properly

These options are discussed in the following sections.

Using 50 Ω BNC cable with terminal resistor

If the trigger source allows to do so, using 50 Ω impedance is recommended. Either the source has sufficiently low impedance or it can be switched to it: many devices have a "High-Z" / "50 Ω" switch.

"High-Z" means a high impedance, typically in the range up to 1 MΩ. This setting is not suitable to be used with 50 Ω cabling. Nevertheless, some devices still drive enough current even in High-Z mode, so this is worth giving a try. In this case please check that the high-level voltage is sufficient (at least 2 V).

"50 Ω" means that the signal source can drive a 50 Ω load. This setting is ideal for a noise-reduced cabling. Together with 50 Ω impedance cabling (RG58 type BNC cables), reflections at cable ends can be effectively reduced. In this case, all devices must be arranged in a line with 50 Ω impedance terminal resistors at both ends.

Using the internal 50Ω termination of the PTU X

The PTU X has built-in 50Ω terminal resistors, which can be switched on in the hardware setup. Please refer to the chapter 4.3.1 ”Input Setup” on how to switch them on.

⚠ **Note:**

Make sure that either the internal 50 Ω termination or an external 50 Ω resistor is used, but not both. Never use both 50 Ω terminals together at the same input.

In the following diagrams it makes no difference whether an external 50Ω resistor is used or the internal 50Ω termination of the PTU is switched on.

Single line direct connection

Use a RG58 type BNC cable with 50 Ω impedance to connect the source with the PTU/HSC. Put a 50 Ω BNC resistor as close as possible to the PTU/HSC. Make sure that the output of the trigger generator is set to 50 Ω impedance.

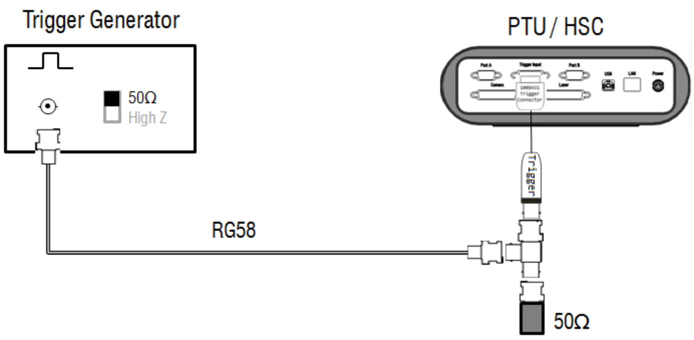


Figure 2.11: Connection between a single device and the PTU/HSC

Signal network

In case the trigger signal needs to be split off to additional devices, proper linear cabling (as in fig. 2.12) in a single signal path is essential, while the end of this network gets a 50 Ω terminal. Avoid a star-type layout (fig. 2.13), as this generates reflections.

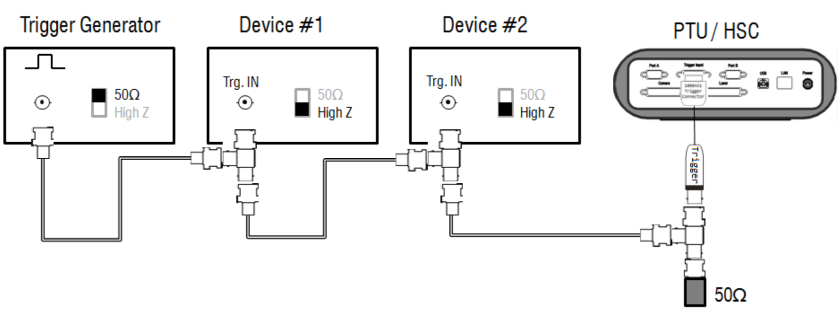


Figure 2.12: Correct layout of a 50 Ω network with more than 1 device

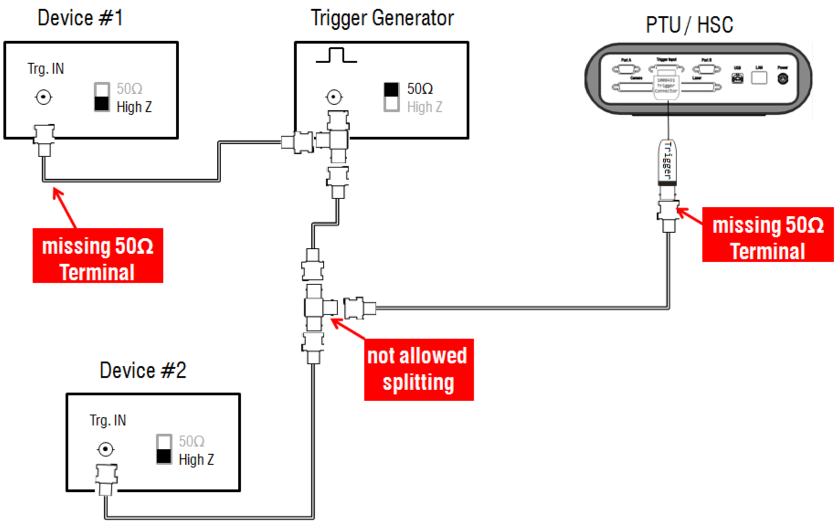


Figure 2.13: Wrong layout of a 50Ω network with splitting and missing end terminators

Reducing the bandwidth with low-pass filters

A very effective method of suppressing signal spikes is to reduce the bandwidth of the signal with a low-pass filter (fig. 2.14). **LaVision** provides a BNC-insert-type low-pass filter, which should be connected close to the PTU. This filter works fine with low-impedance sources.

Be aware that using this filter may shift the detected trigger time by about 1 μs.

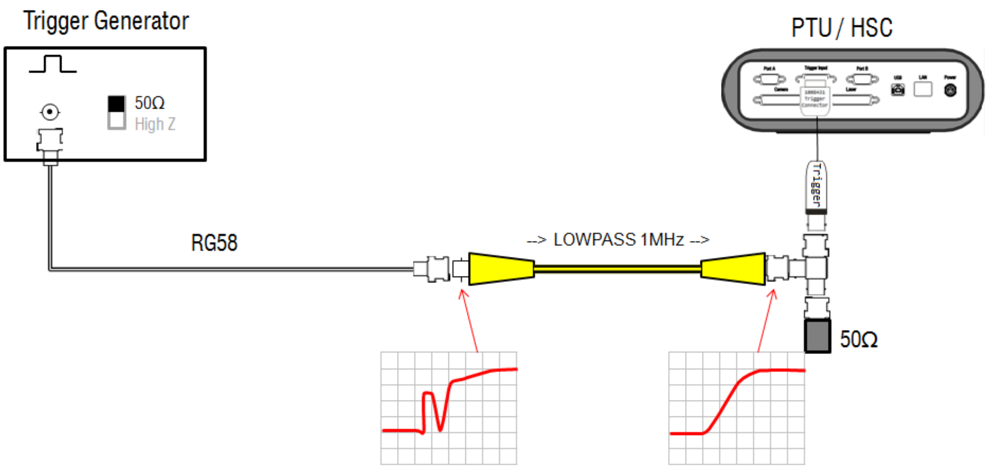


Figure 2.14: Using a low pass filter to suppress signal peaks in the trigger line. Oscilloscope samples at 200 ns/div

For lower impedance sources, the low-pass filter can also be used without 50Ω terminators. In case of a rotary encoder, use the low-pass filters on both trigger and CDM as shown in fig. 2.15.

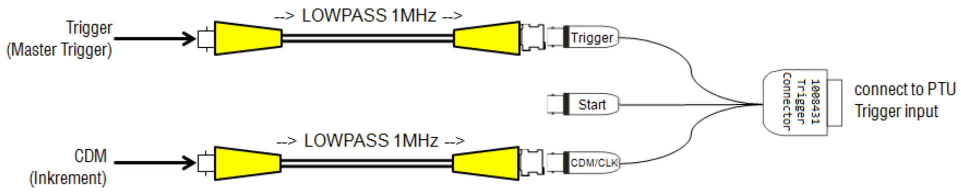


Figure 2.15: Using the low-pass filters for (engine) rotary encoders

Specifications for the low-pass filters are:

- 1^{st} order low-pass at 1MHz
- -1.5dB attenuation at 50Ω load
- max. input voltage 10V

The electric circuit diagram of the filter is shown in Fig. 2.16

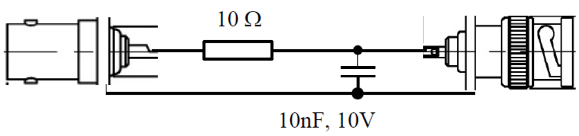


Figure 2.16: Electric circuit diagram of low-pass filters

Avoiding ground loops

Ground loops are a frequent source of signal interference when the experimental area is spread over a larger room. Many devices are connected to each other and when electromagnetic radiation sources are present, such as ignition system or generators, this acts as a large antenna and receives interfering signals. The origin behind this effect is that the involved devices have several connections over different routes:

- AC power lines may come from different sockets. Internally they are connected, but the cable often routes around the room, with the electromagnetic noise sources in between.
- Signal lines go across several devices. Mainly their shielding builds up another network of connections through the experimental section

- The physical bodies of devices such as controllers and cameras are connected to each other through a frame structure. These connections have low, but not perfectly zero impedance.
- Extra earth / GND lines: once separate ground line is used to earth terminal points – which is a good idea in general, but their layout may create another loop.

These loops work as antenna for any type of interference. In addition a wrong layout may lead to high earth leakage currents on sensitive signal lines, such as USB connections to a PC.

Good practice is:

- Keep all cables from a device parallel as much as possible. Reduce the area covered by the cables (see fig. 2.17). Avoid large areas surrounded by cables going to the same device (see fig. 2.18).
- Apply extra earth lines, but route them as a star to a single point (see Fig. 2.19). Avoid branches and loops with earth lines (as in fig. 2.20). Use high-cross-section cables and low-impedance connectors. These ground lines help to reduce floating signal levels on low voltage TTL signals. The target is to bring all devices connected to the measurement system to the same ground level.
- Use plugs located close to each other. This is often difficult to maintain, but try keeping sensitive devices together and provide good extra earth lines.

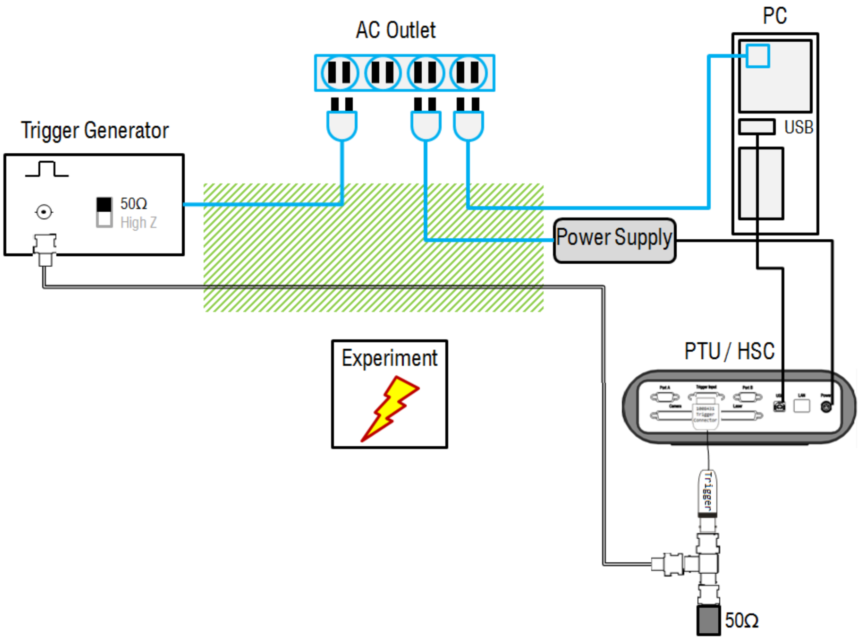


Figure 2.17: Optimized routing with parallel lines and small EM-sensitive area (green)

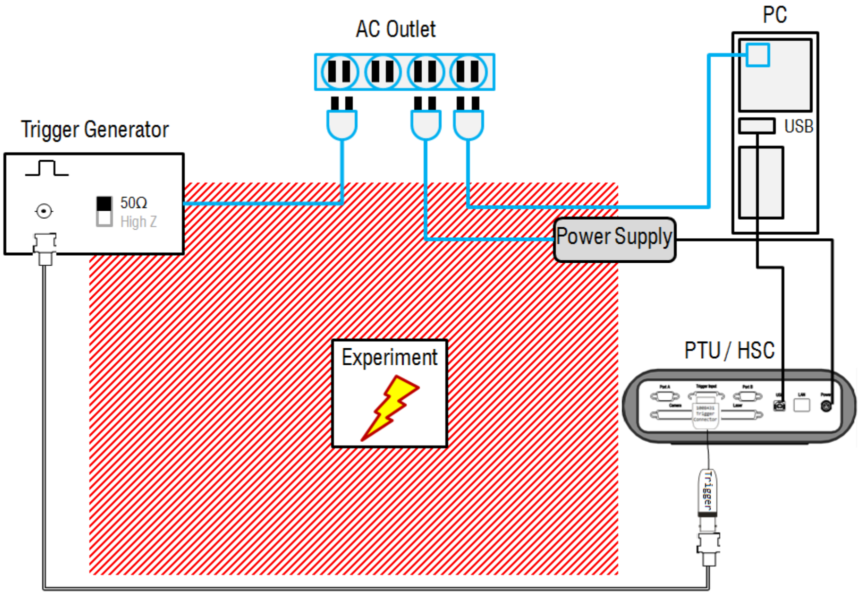


Figure 2.18: Bad routing with large EM-sensitive area (red)

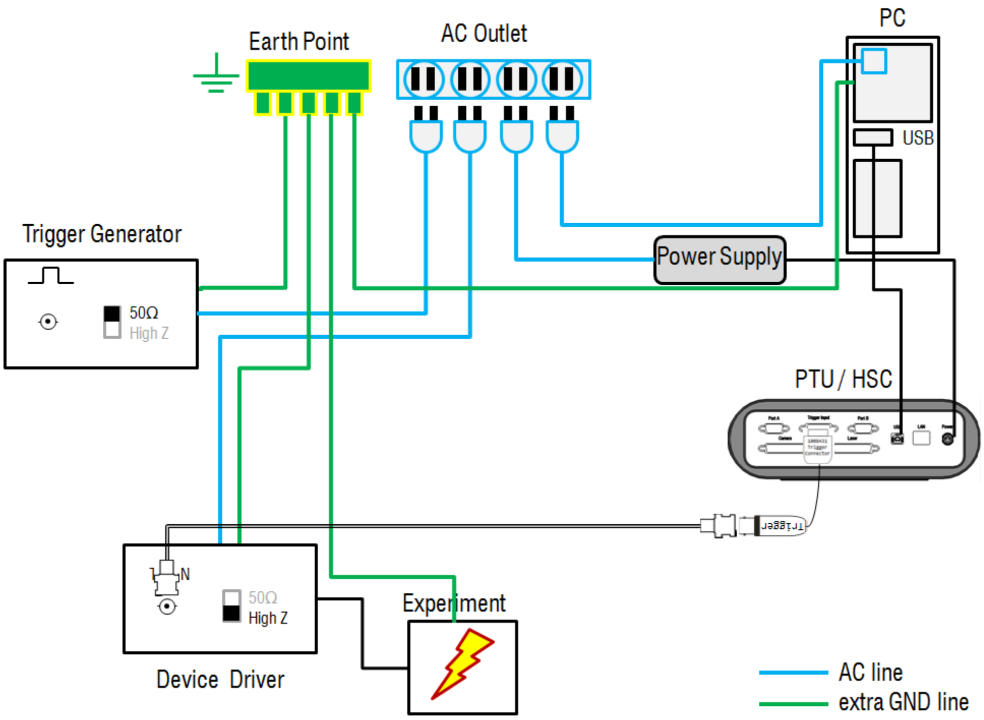


Figure 2.19: Optimized Routing with a star-type earth line layout small areas covered by lines

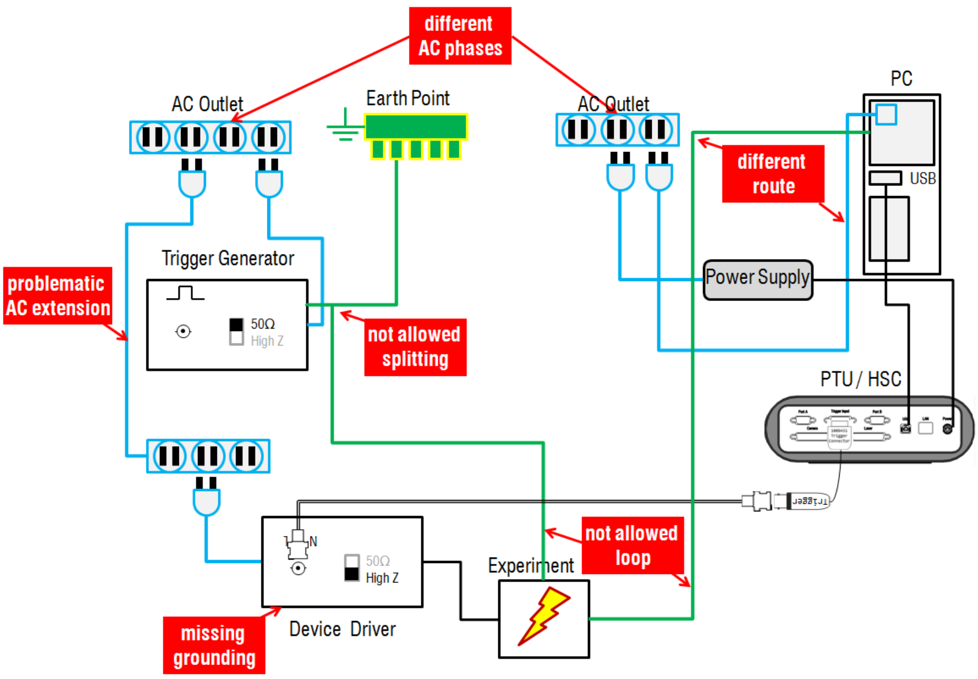


Figure 2.20: Wrong routing with branches in the grounding system, AC extensions, and large areas between lines

2.10.4 Technical Information about Input Electronics

The input electronics of the PTU/HSC has the following specifications:

- input impedance 2.7 kΩ, software switchable to 50 Ω
- maximum input voltage 12 V
- Schmitt-Trigger, High > 2 V, Low < 0.6 V, at least 0.3 V hysteresis
- reverse polarity protection
- ESD protection

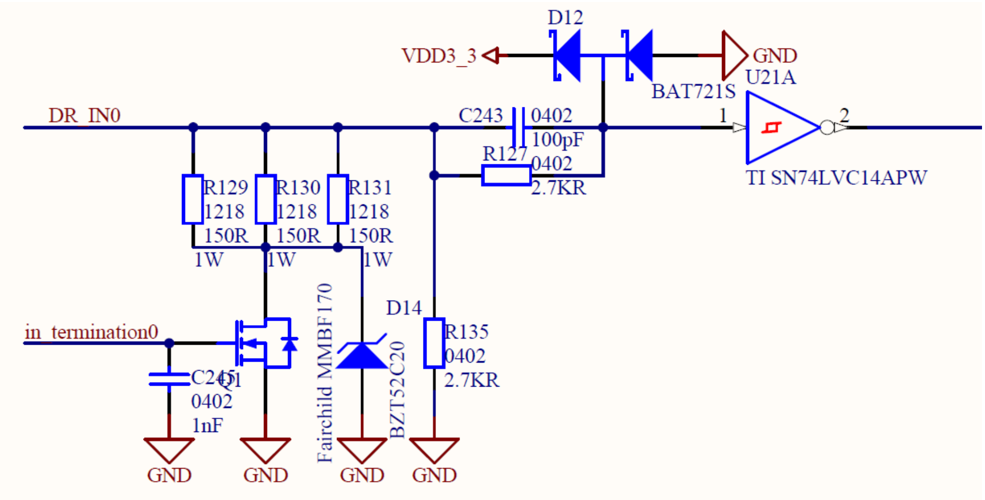


Figure 2.21: Input circuit diagram

3 Driver Installation

This chapter describes how to install or update the driver for the PTU X (PCIe and USB version) for a Windows 10 (Professional or higher) operating system (64 bit version).

Usually no manual driver installation is required if DaVis has been installed on the computer. The **DaVis** installer installs the PTU driver in the system and Windows automatically uses it whenever a PTU is detected.

Note: For the PTU driver to install properly, the Secure Boot feature has to be switched off in the BIOS settings. Please refer to the manual of the computer mainboard for details.

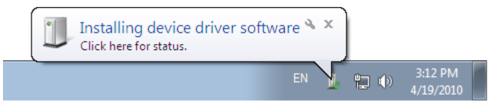
3.1 PCIe version

3.1.1 Driver location

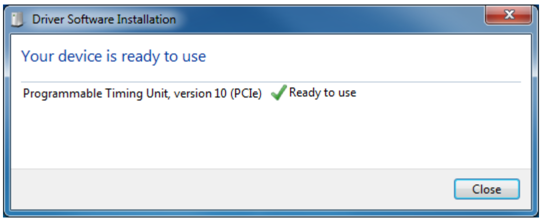
If you have a **DaVis** version installed on your PC the driver can be found in the '`~DaVis/driver/LaVision Generic`' directory. Otherwise the driver for the PTU X can be found on your **DaVis** installation CD in the '`/drivers/LaVision Generic`' folder.

3.1.2 Installing for the first time

If Windows 10 is started for the first time after the PTU X has been installed in (PCIe) or connected via (USB) to the PC Windows will recognize the new hardware component and search for a suitable driver in the local system and through Windows Update.

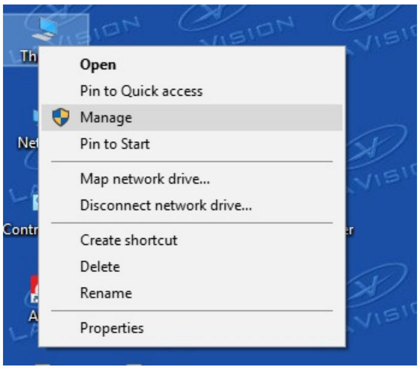


If you have installed the latest **DaVis** software, the automatic search should automatically find and install the driver for the PTU X. Otherwise you have to follow the next section (3.1.3).

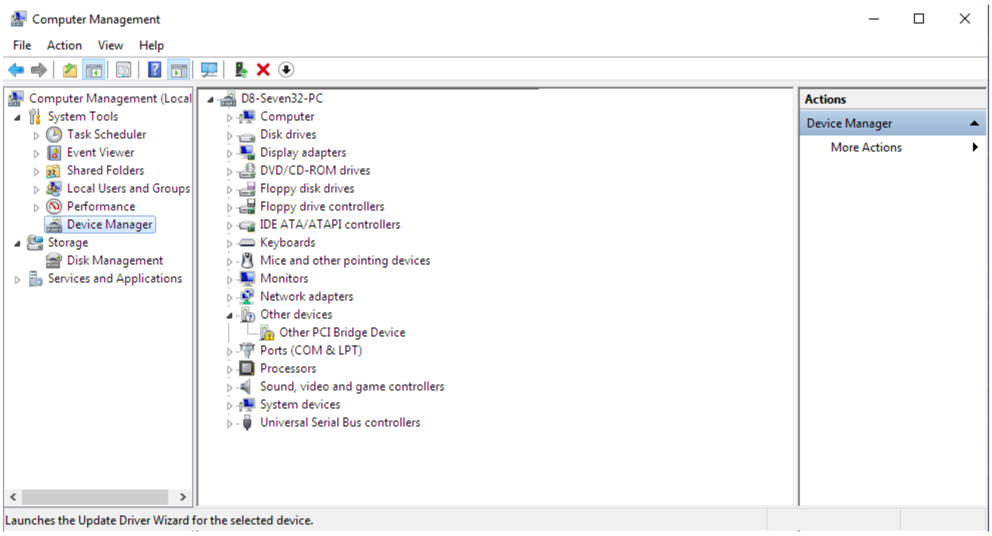


3.1.3 Installing the PTU X (PCIe) driver manually

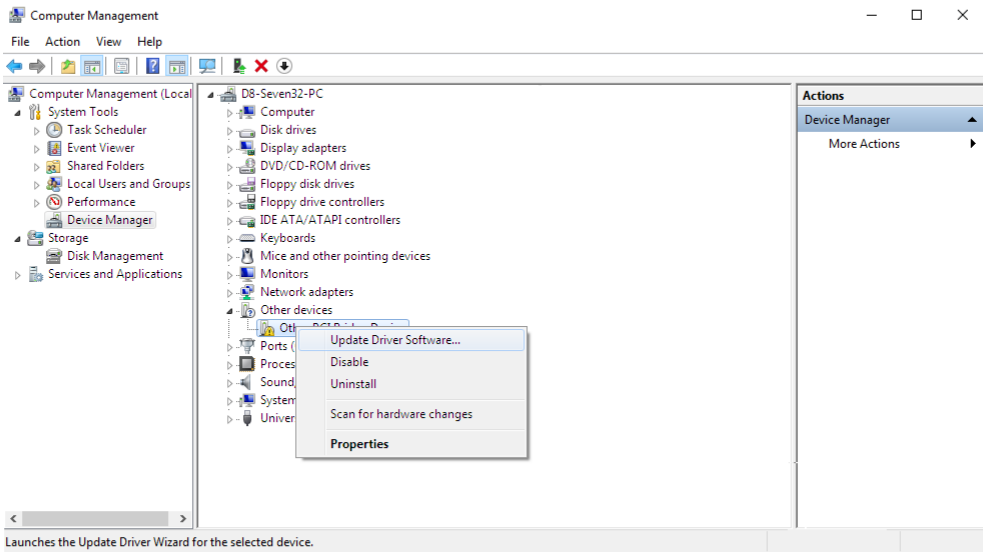
Open the **Computer Management Console** in Windows 10 via **Start** button, right mouse click on the **Computer** entry and selecting the **Manage** option. Select the **Device Manager** under the **System Tools** entry.



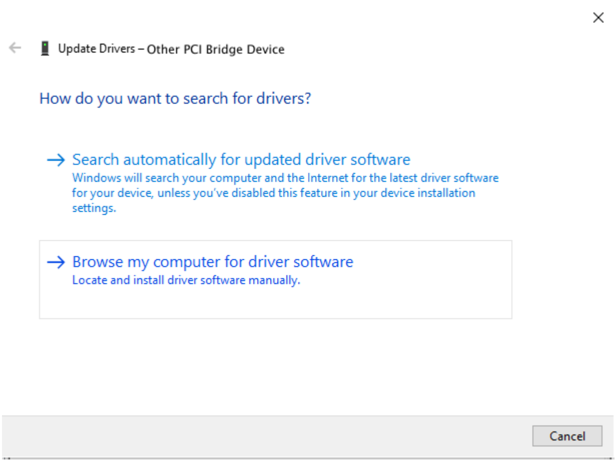
Under **Other Devices** you will find an **Other PCI Bridge Device** entry.



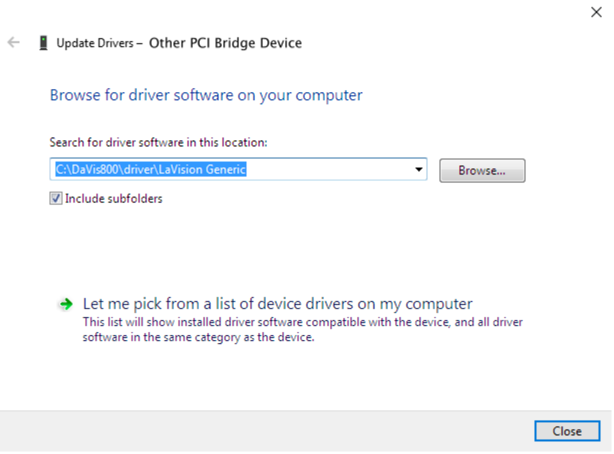
Use right mouse click on the **Other Devices** → **Other PCI Bridge Device** entry and select the **Update Driver Software...** option.



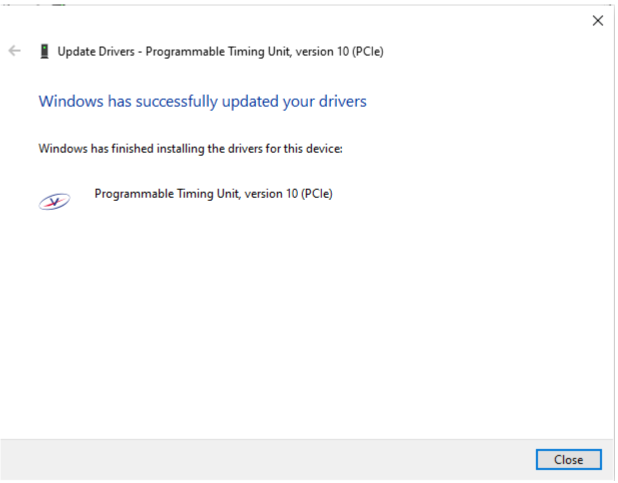
On the **How do you want to search for driver software** question select the **Browse my computer for driver software** option.



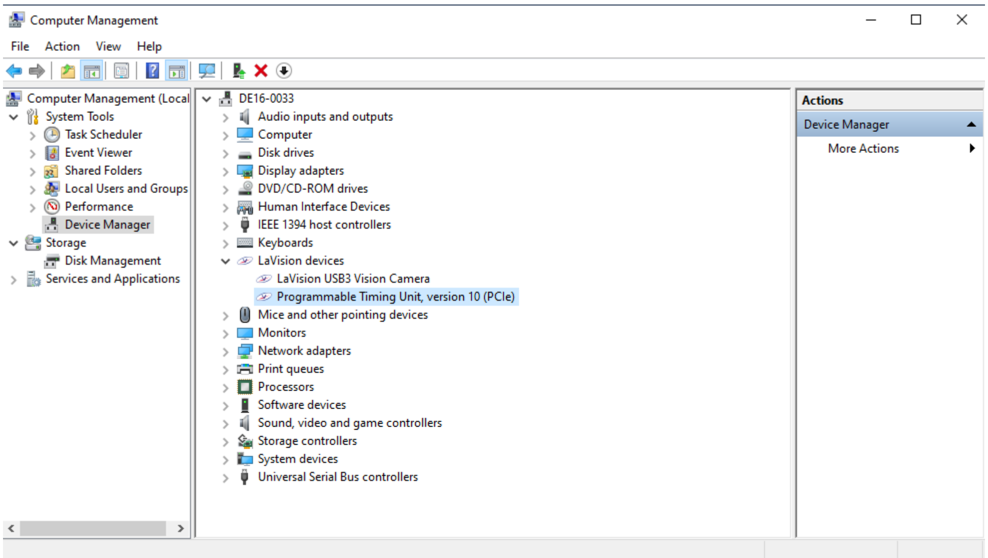
On the **Browse my computer for driver software** dialog click the **Browse** button, refer to the ∼**davis/driver/LaVision Generic** directory and click the **Next** button.



After the driver has been installed you will see the **Windows has successfully updated driver software** notification. Click the **Close** button.



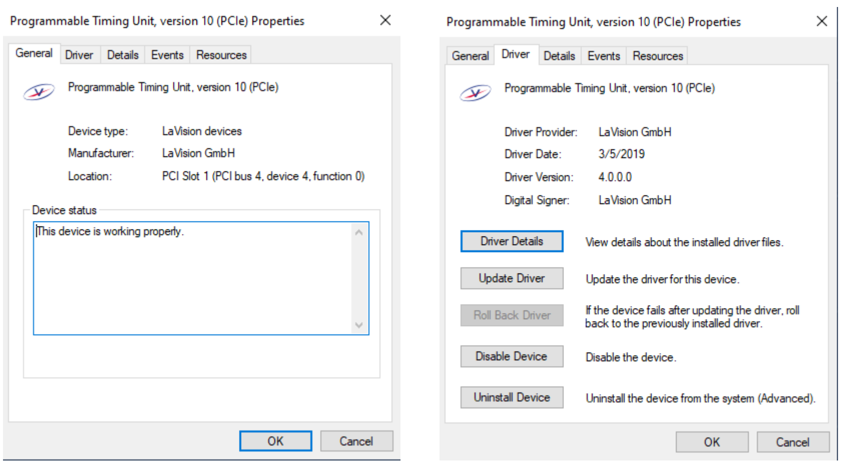
After restart of the PC you will find a **Programmable Timing Unit, version 10 (PCIe)** entry under **LaVision devices** in the Windows **Device Manager**.



3.1.4 Verify the driver installation

To make sure that the driver has been installed properly and to get an information on the exact driver version that has been installed please check the driver information in the Windows **Device Manager**.

Use right mouse button on the **Programmable Timing Unit, version 10 (PCIe)** entry and select the **Properties** option.

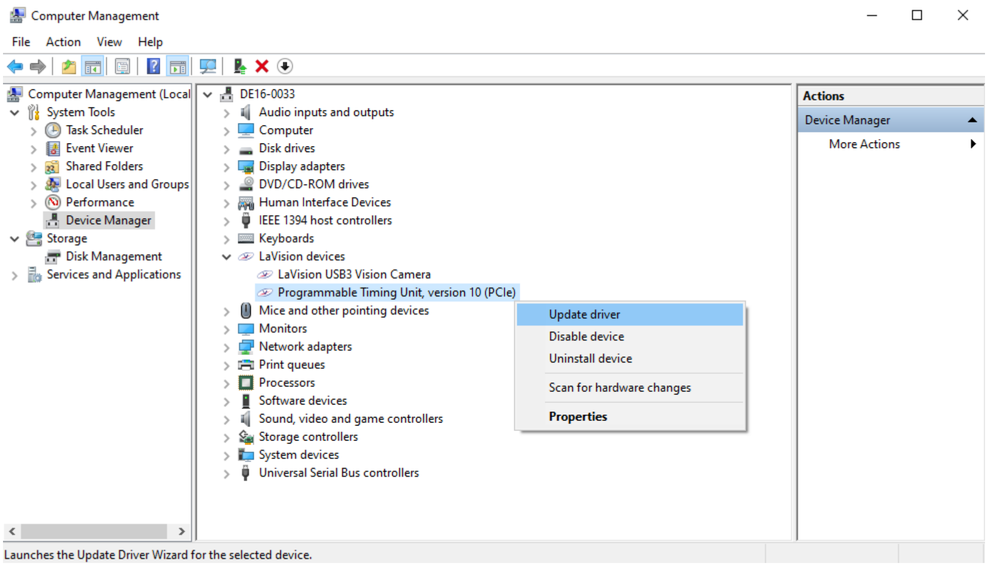


On the **driver** card you should find the version no. **4.0.0.0** or higher.

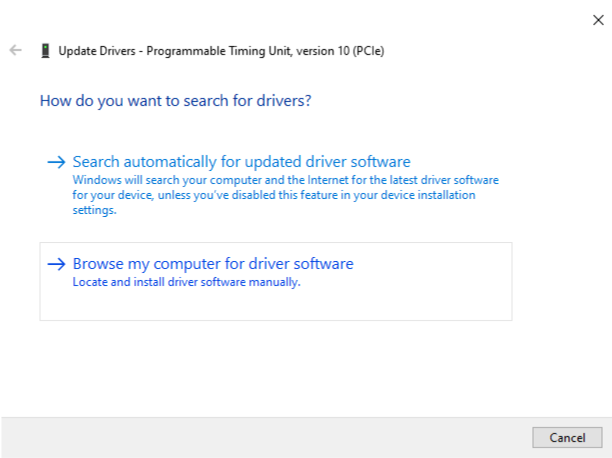
3.1.5 Updating the driver

In order to update the driver make sure that the new driver files are available locally. In this case we assume that the new files are available in the ∼**davis/driver/LaVision Generic** directory.

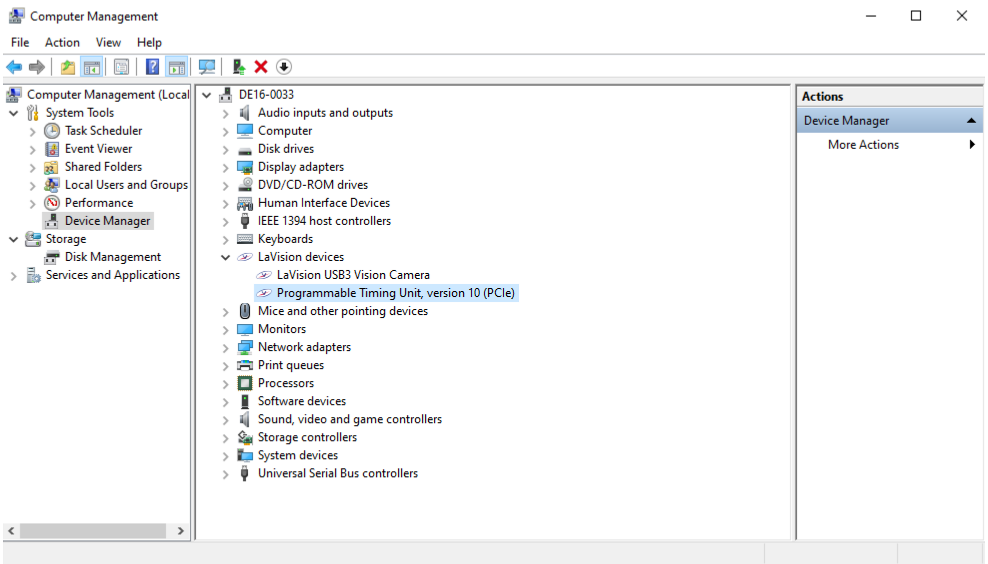
Open the Windows **Device Manager**, select the **Programmable Timing Unit, version 10 (PCIe)** entry under **LaVision devices** and use right mouse click to select the **Update Driver Software...** option.



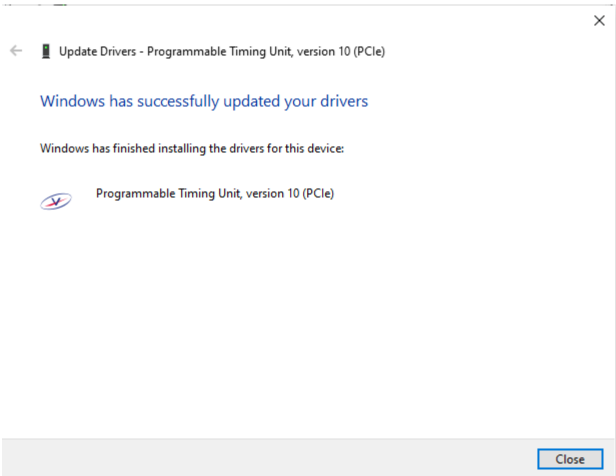
On the **How do you want to search the driver software** question select the **Browse my computer for driver software** option.



On the **Browse for driver software on my computer** notification click the **Browse** button and refer to the directory that contains the new files, e.g. to the ∼**davis/driver/LaVision Generic** directory. If this is done click the **Next** button.

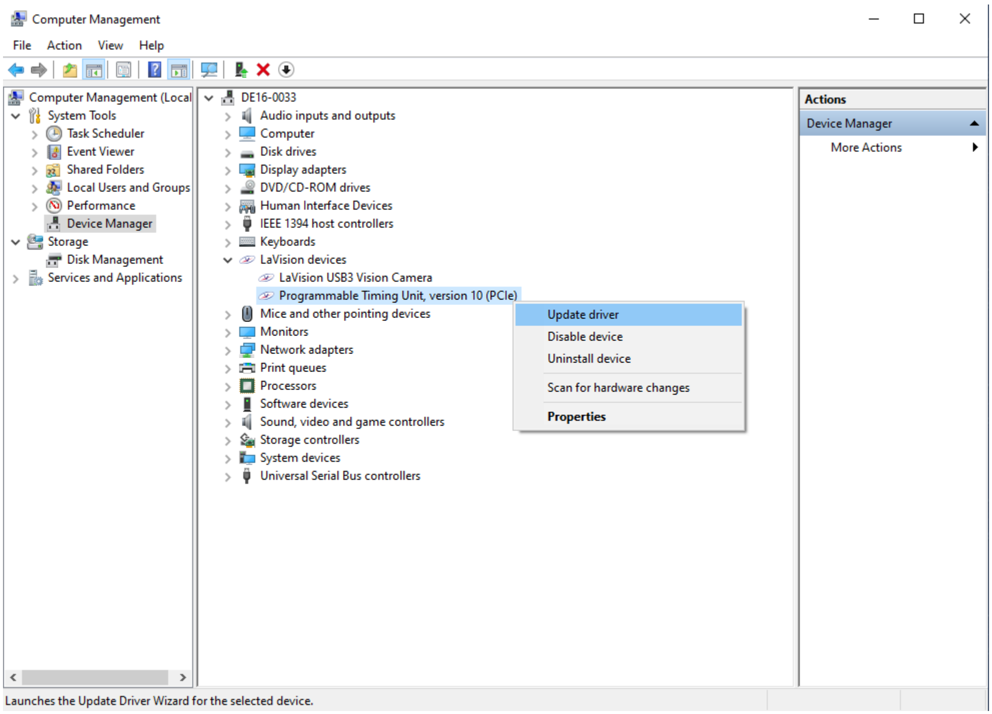


After the driver has been updated you will see the **Windows has successfully updated driver software** notification. Click the **Close** button.



3.1.6 Uninstall the driver

In order to uninstall the PTU driver open the Windows **Device Manager**, select the **Programmable Timing Unit, version 10 (PCIe)** entry under **LaVision devices** and use right mouse click to select the **Uninstall** option.


Computer Management
File Action View Help
Computer Management (Local
System Tools
Task Scheduler
Event Viewer
Shared Folders
Local Users and Groups
Performance
Device Manager
Storage
Disk Management
Services and Applications
DE16-0033
Audio inputs and outputs
Computer
Disk drives
Display adapters
DVD/CD-ROM drives
Human Interface Devices
IEEE 1394 host controllers
Keyboards
LaVision devices
LaVision USB3 Vision Camera
Programmable Timing Unit, version 10 (PCIe)
Mice and other pointing devices
Monitors
Network adapters
Print queues
Processors
Software devices
Sound, video and game controllers
Storage controllers
System devices
Universal Serial Bus controllers
Update driver
Disable device
Uninstall device
Scan for hardware changes
Properties
Actions
Device Manager
More Actions
Launches the Update Driver Wizard for the selected device.

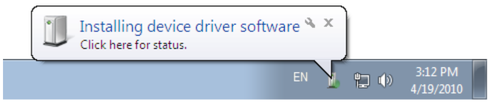
3.2 USB version

3.2.1 Driver location

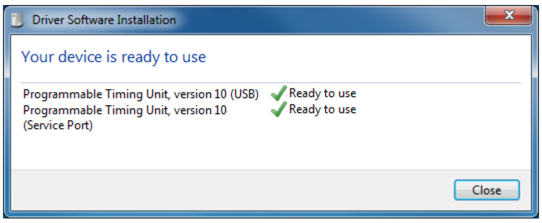
If you have a **DaVis** version installed on your PC the driver can be found in the '∼DaVis/driver/LaVision Generic' directory. Otherwise the driver for the external PTU X can be found on your **DaVis** installation CD in the '/drivers/LaVision Generic' folder.

3.2.2 Installing for the first time

If Windows 10 is started the first time after the external PTU X has been installed physically in the PC Windows will recognize the new hardware component and search for a suitable driver in the local system and through Windows Update.

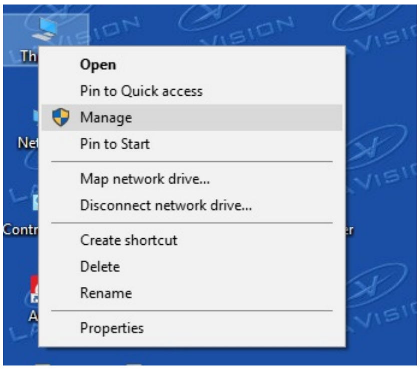


If you have installed the latest **DaVis** software, the automatic search should automatically find and install the driver for the PTU X. Otherwise you have to follow the next section (3.2.3).

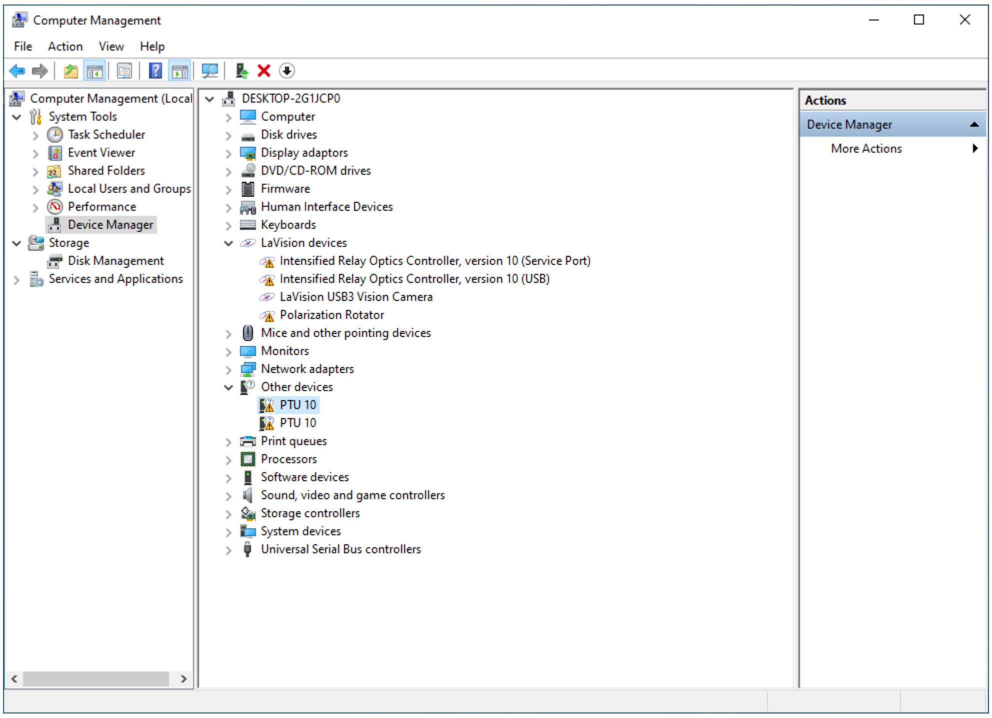


3.2.3 Installing the PTU X (USB) driver manually

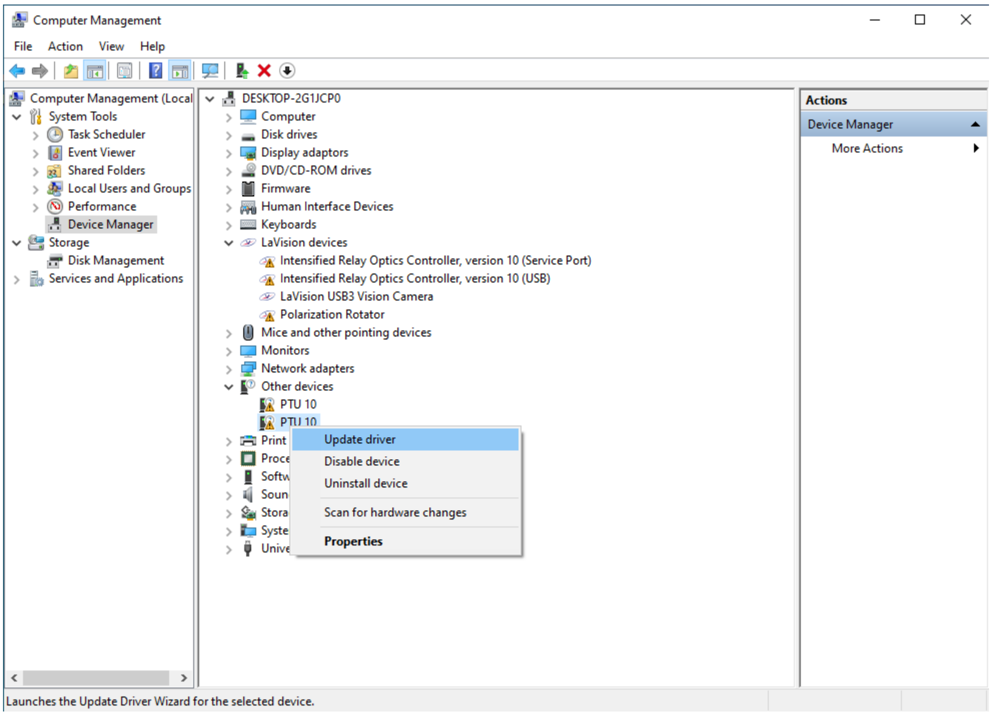
Open the **Computer Management Console** in Windows 10 via **Start** button, right mouse click on the **Computer** entry and selecting the **Manage** option. Select the **Device Manager** under the **System Tools** entry.



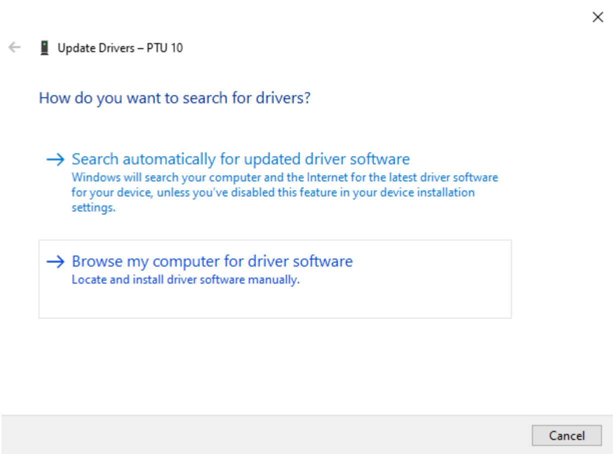
Under **Other Devices** you will find two **PTU 10** entries.



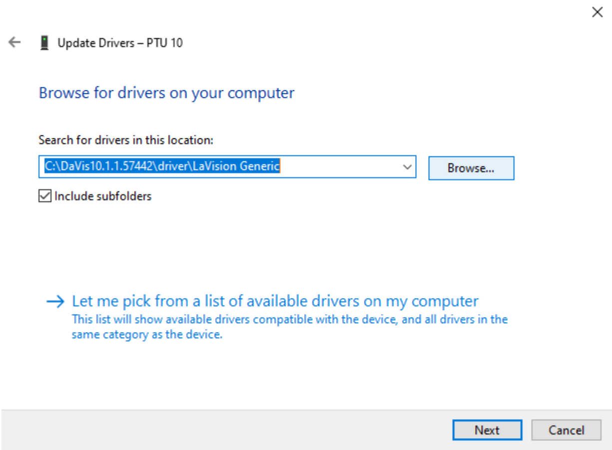
Use right mouse click on one of the **Other Devices** → **PTU 10** entries and select the **Update Driver Software...** option. It doesn't matter which one you install first.



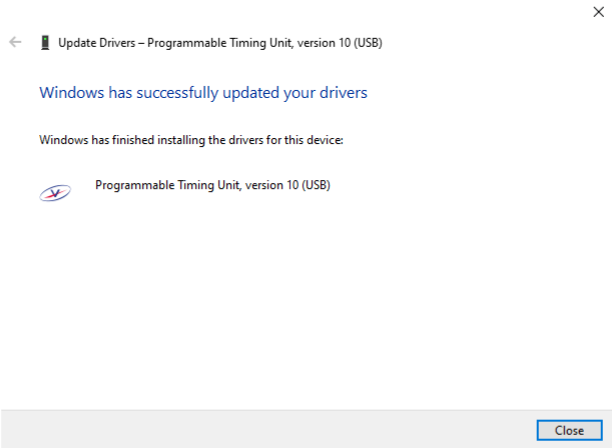
On the **How do you want to search for driver software** question select the **Browse my computer for driver software** option.



On the **Browse my computer for driver software** dialog click the **Browse** button, refer to the ∼**davis/driver/LaVision Generic** directory and click the **Next** button.



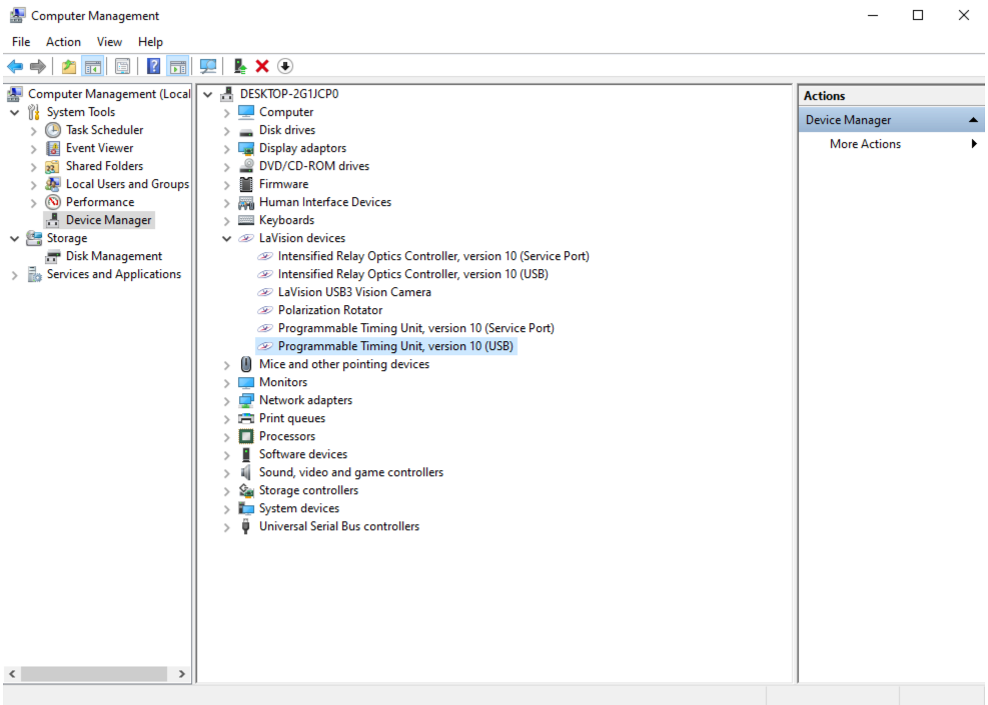
After the driver has been installed you will see the **Windows has successfully updated driver software** notification. Click the **Close** button.



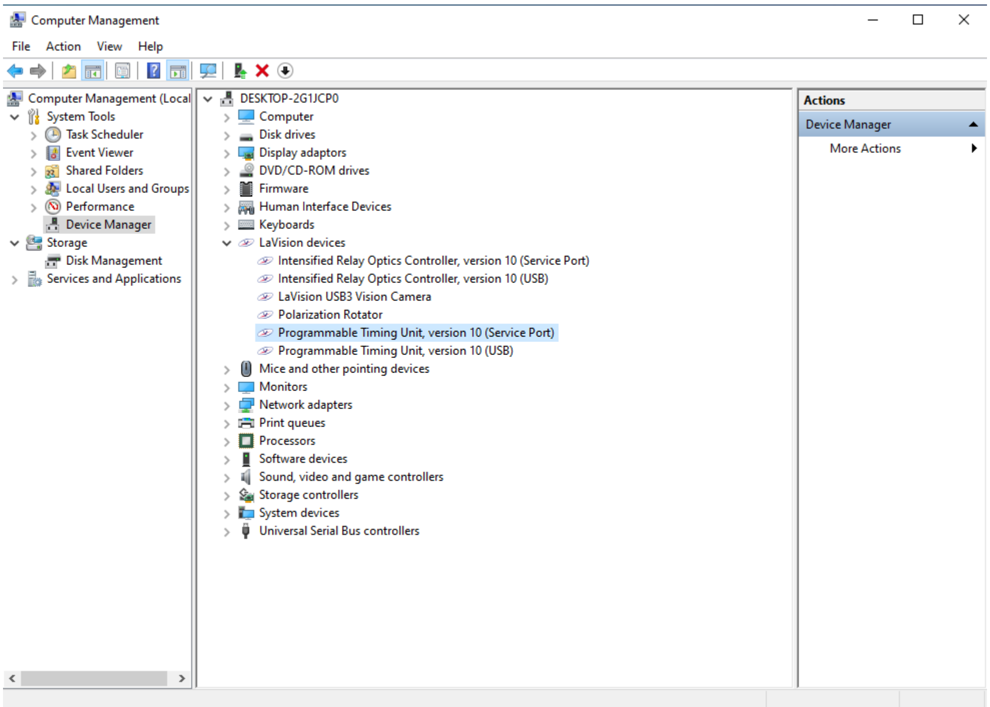
After restart of the PC you will find:

- **Programmable Timing Unit, version 10 (USB)** or
- **Programmable Timing Unit, version 10 (Service Port)**

entry under **LaVision devices** in the Windows **Device Manager**.



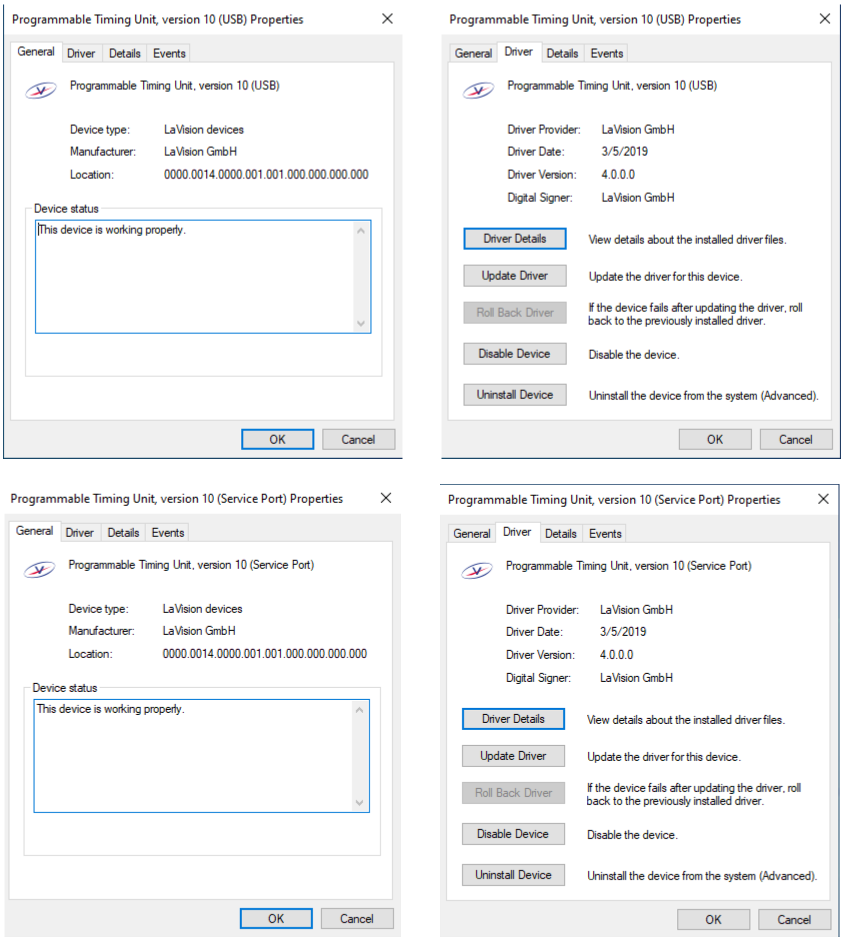
Repeat the steps for the second **Other devices** → **PTU 10** entry. As result you will see two entries for the PTU X driver in the device Manager.



3.2.4 Verify the driver installation

To make sure that the driver has been installed properly and to get an information on the exact driver version that has been installed please check the driver information in the Windows **Device Manager**.

Use right mouse button on the **Programmable Timing Unit, version 10 (USB)** and **[...](Service Port)** entry and select the **Properties** option.

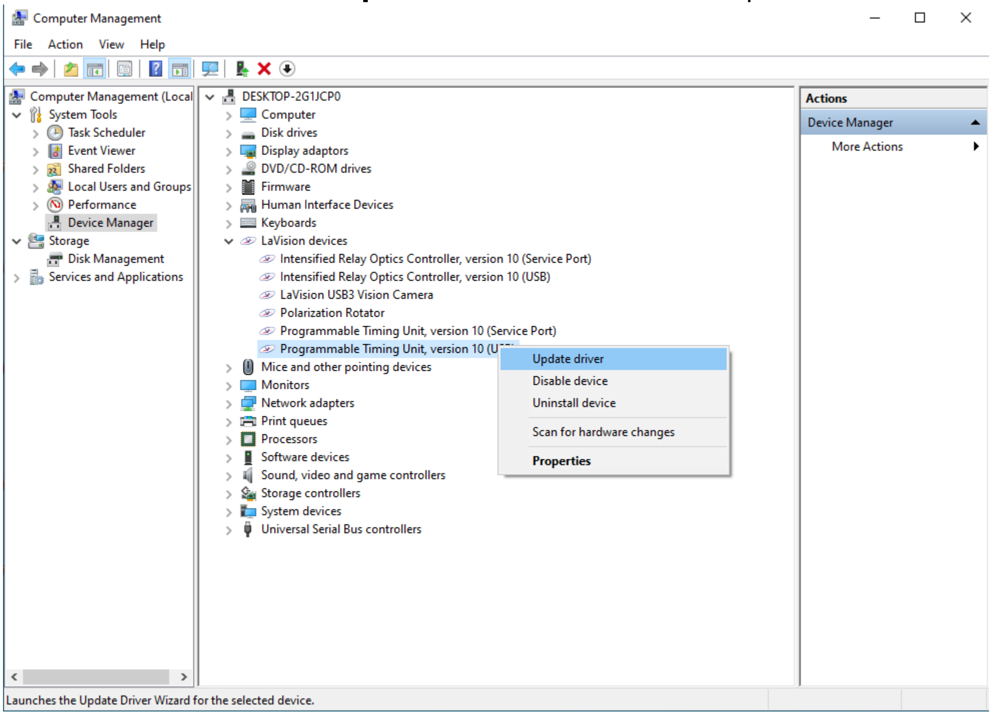


On the **driver** card you should find the version no. **4.0.0.0** or higher.

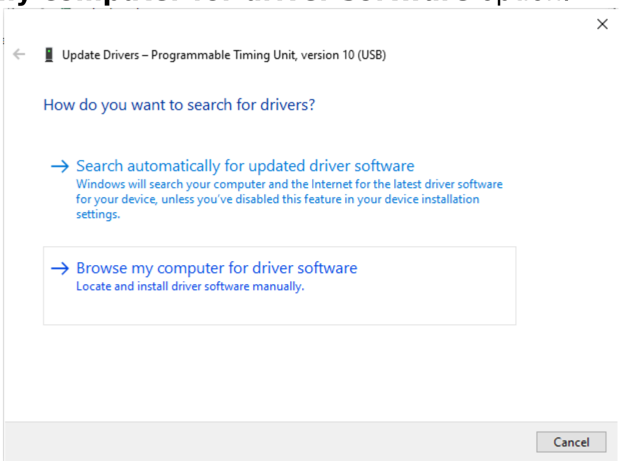
3.2.5 Updating the driver

In order to update the driver make sure that the new driver files are available locally. In this case we assume that the new files are available in the ∼**davis/driver/LaVision Generic** directory.

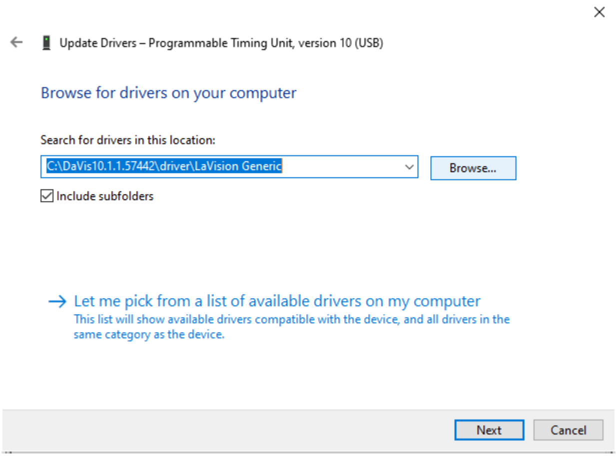
Open the Windows **Device Manager**, select the **Programmable Timing Unit, version 10 (USB)** entry under **LaVision devices** and use right mouse click to select the **Update Driver Software...** option.



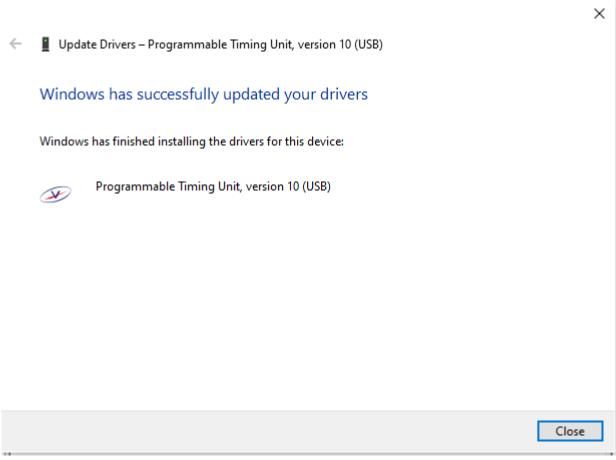
On the **How do you want to search the driver software** question select the **Browse my computer for driver software** option.



On the **Browse for driver software on my computer** notification click the **Browse** button and refer to the directory that contains the new files, e.g. to the ∼**davis/driver/LaVision Generic** directory. If this is done click the **Next** button.



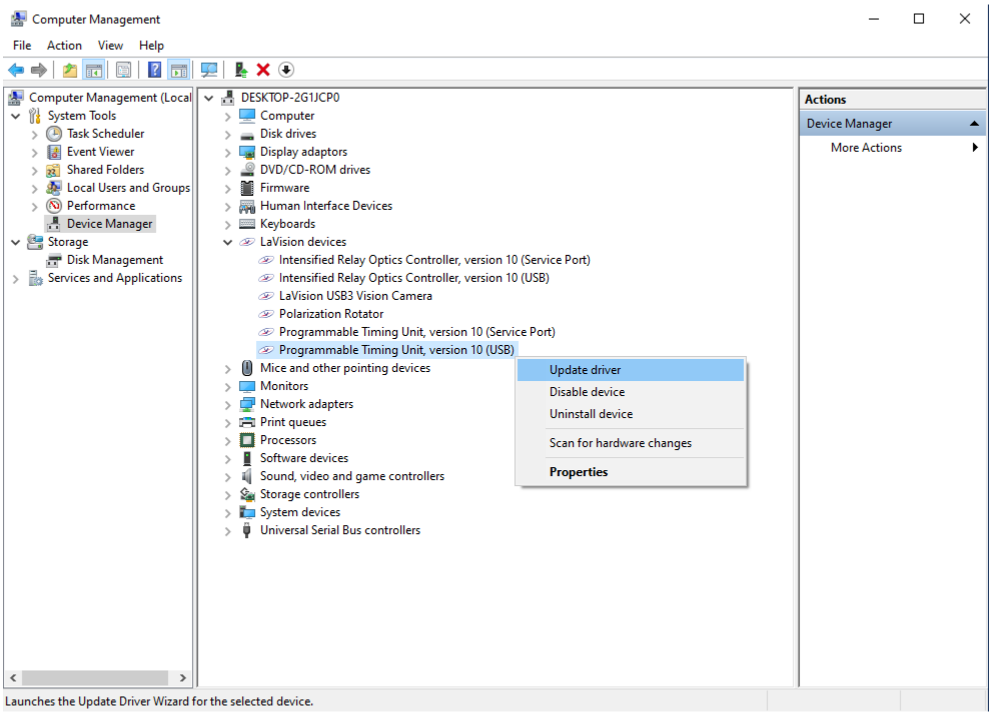
After the driver has been updated you will see the **Windows has successfully updated driver software** notification. Click the **Close** button.



Repeat the steps for the second **Other devices** → **PTU 10** entry.

3.2.6 Uninstall the driver

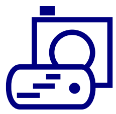
In order to uninstall the PTU driver open the Windows **Device Manager**, select the **Programmable Timing Unit, version 10 (USB)** entry under **LaVision devices** and use right mouse click to select the **Uninstall** option.



Repeat this for the second **Other devices** → **PTU 10** entry.

4 DaVis Hardware Setup

The settings in the **Hardware Setup** dialog are entered by **LaVision** application specialists during production or installation of your system. These values should not be changed by the end user. Changing parameters may cause a malfunction of the system. To be able to control the camera on remote by **DaVis**, it needs to be added as device to the **DaVis Hardware Setup** dialog. Additionally, the camera needs to be provided with trigger signals that are synchronized to other devices, e.g. an external trigger from the experiment or a trigger signal to a light source for illumination. Therefore, a camera in a **LaVision** system is delivered with a Programmable Timing Unit (PTU).



Open the Hardware Setup dialog to add a PTU, add devices and change configurations.

4.1 Programmable Timing Unit

If the PTU is already installed in the hardware setup, you find a Programmable Timing Unit in the hardware configuration.

If this item is not present in the diagram, please follow the instructions given.

First drag-and-drop a timing unit from the left-hand side device list into the right-hand side *Configuration Window* (see Fig. 4.1).

Select the if you want to configure your system for low-speed or high-speed measurements. This will add the according default connectors to the PTU.

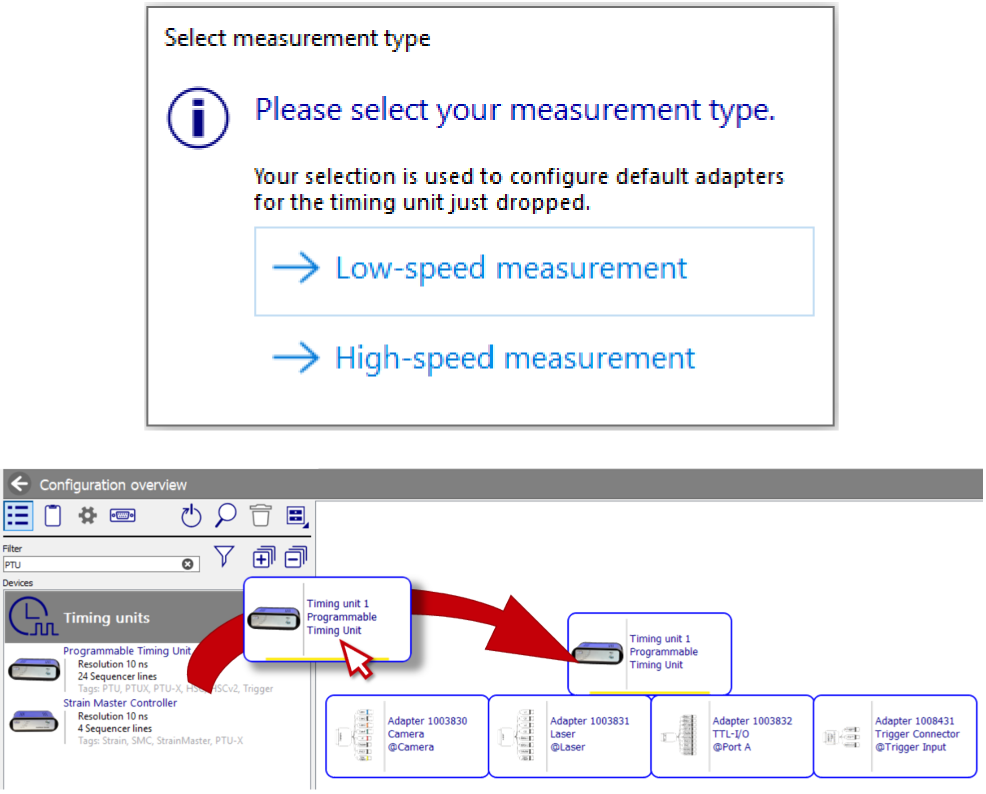


Figure 4.1: Drag-and-drop the PTU X from the device list into the Configuration Window.

4.1.1 Change PTU Settings

In order to change the PTU settings, click on the **Edit device settings** button, which appears when hovering over the PTU icon (Fig. 4.2).

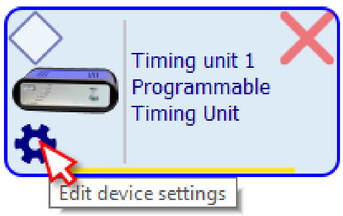


Figure 4.2: Edit the PTU X device settings.

4.2 Timing Settings

Open the **device settings** dialog and click on the *Timing* tab (Fig. 4.3).

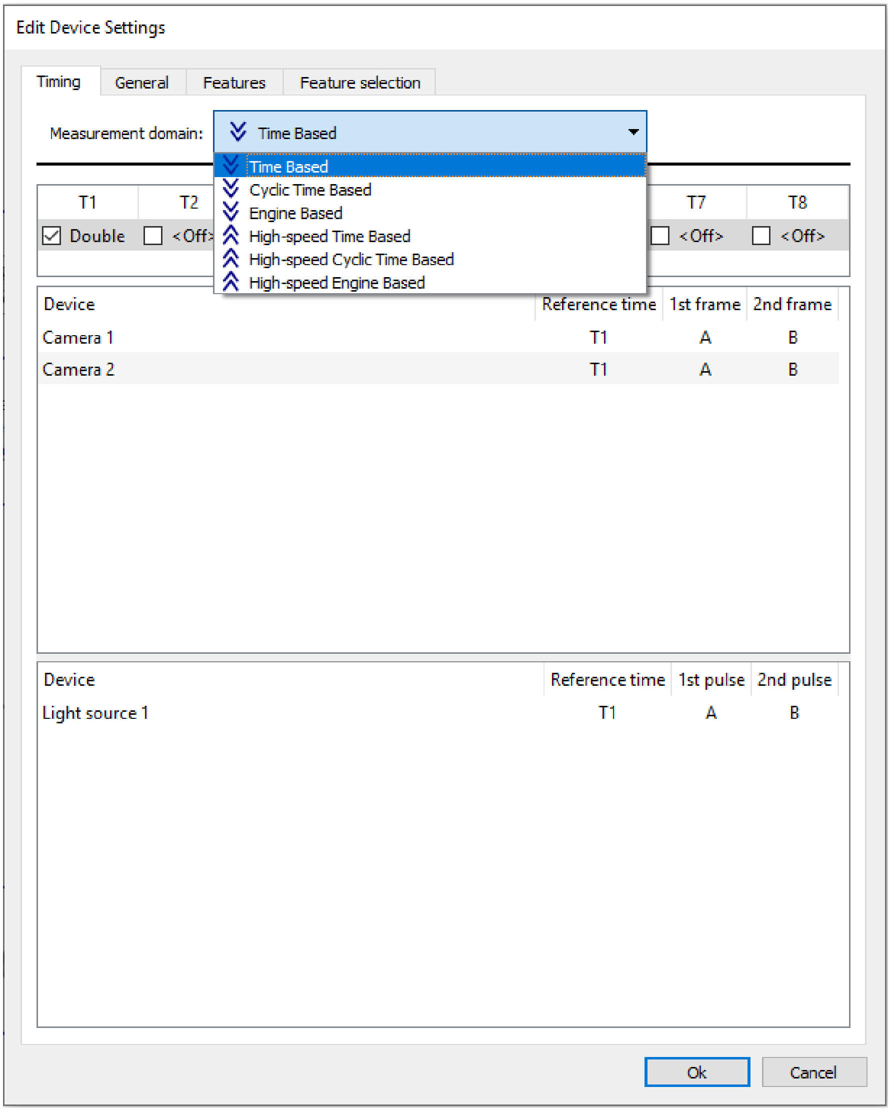


Figure 4.3: Change timing settings for the PTU X.

In the *Timing* tab of the **Device Settings** dialog, the behavior of the PTU and the Reference times can be set up.

1. Select the Timing tab.

2. Select the Measurement domain. This is a general setting of the timing behavior. This setting has its main effect on the Timing controls shown in the **Recording** dialog. The list of possible measurement domains depends on the feature flags the PTU has installed.

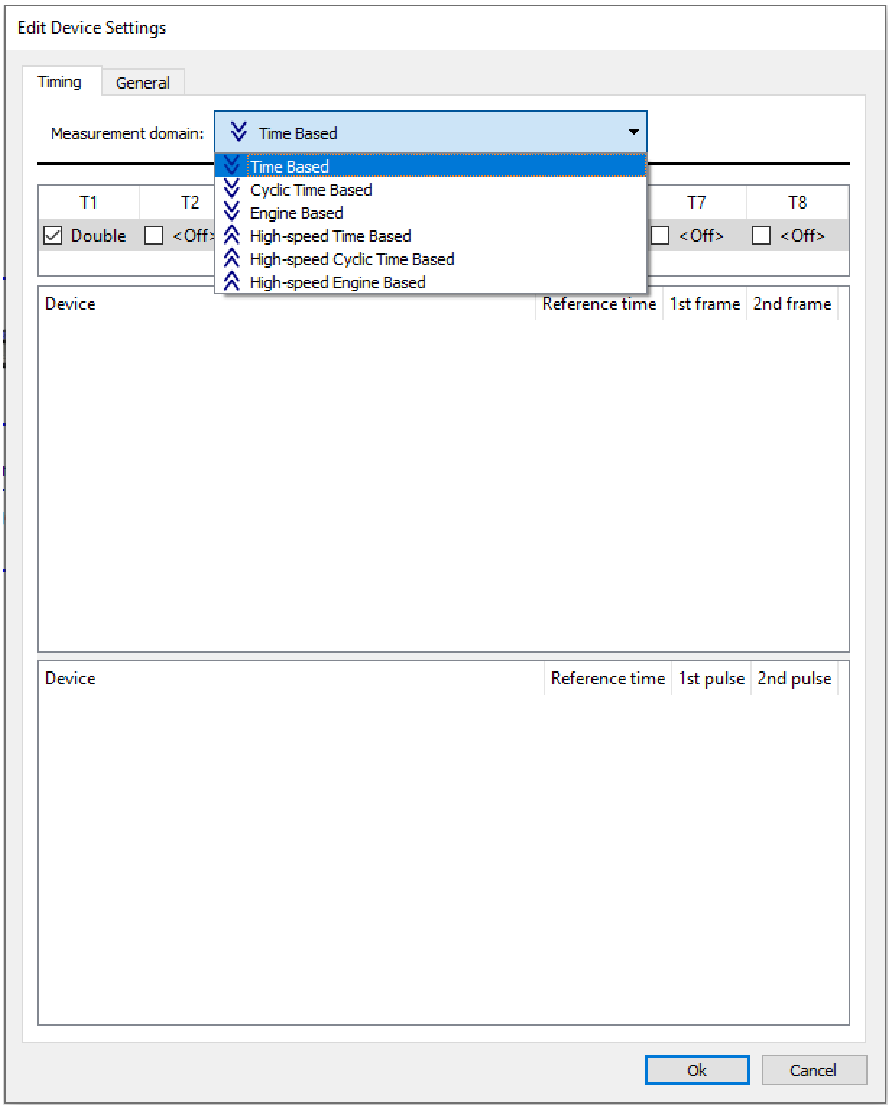


Figure 4.4: Change timing settings for the PTU X.

4.2.1 Measurement Domain

The Measurement domain is the fundamental setting of the PTU timing behavior. This setting also changes controls in the **Recording** dialog.

Time based: This is the default timing where the PTU runs on an internal clock. All timings will be given in "microseconds" and frequencies in "Hertz".

Cyclic Time based: This is an alternative timing scheme for periodic events, like rotary devices (gas turbines) or oscillating objects. It is assumed that the trigger has a "period" or a "frequency". Timings can be given in "phase angle", where 360° refers to a full oscillation or revolution.

Engine based: This is a special version of "phase angle based" for engines with rotary encoder. Timings will be crank angle based. A 4-stroke cycle has 720° crank angle (CA). Different crank division marks (CDM) can be used and the top dead center of the combustion stroke is defined as 0°CA. In addition to frequency, the engine speed is also given in revolutions per minute (RPM).

High-speed Time based: This is the default timing for high-speed recordings. This measurement domain is available if the PTU X has the high-speed functionality enabled. where the PTU runs on an internal clock. All timings will be given in "microseconds" and frequencies in "Hertz".

High-speed Cyclic Time based: This measurement domain is designed for phase-locked recording start where the trigger occurs in a periodic or random pattern. With Programmable Parameter Recording (PPR) different sub-ranges in a cycle can be selected and parameters like the PIV dt, Intensifier gate and others can be dynamically changed through the cycle.

High-speed Engine based: This measurement domain is designed for engine based measurements. The devices are synchronised to rotary engines throught the PTU X. With Programmable Parameter Recording (PPR) different sub-ranges in a cycle can be selected and parameters like the PIV dt, Intensifier gate and others can be dynamically changed through the cycle.

4.2.2 Reference Time

Multiple Reference times

The PTU X supports this independent timing behavior with the Reference time feature. Multiple reference times allow to combine different techniques for your measurement task. This could mean that you have to measure at several independent times or phase angles at the same event. E.g. you want to measure a flow-field in an early stage of an automotive fuel injection with Stereo-PIV and a little bit later with LIF the resulting flame in the same engine cycle. Both events are independent from each other, so your PIV is somewhere just after the system trigger and the LIF must come later, but both are from the same main trigger.

Double events

The Double event checkbox defines if a certain reference time supports double pulse behavior with a "dt". Only if the event is declared to be a double event, it is possible to select the double frame mode of a camera and to map other devices to this reference time. The reference time will then split up to T1A and T1B for the first and second pulse, respectively.

Note: A standard PTU only supports 1 reference time. Please contact your sales representative to purchase more reference times if needed. For more details regarding Reference times, please refer to chapter 5.4.

Device mapping to reference times

Using the device mapping, you can assign a reference time to each device that receives a trigger signal. In the trivial case, you use only one reference time and all devices are started with respect to this reference time. In case this one reference time is specified as a double event, the reference time is split into T1A and T1B. The exposure of first and second frame of the double-frame camera is started to T1A and T1B, respectively. The pulse A and B of a double-pulsed Nd:YAG laser can also be triggered with respect to T1A and T1B (see Fig. 4.5).

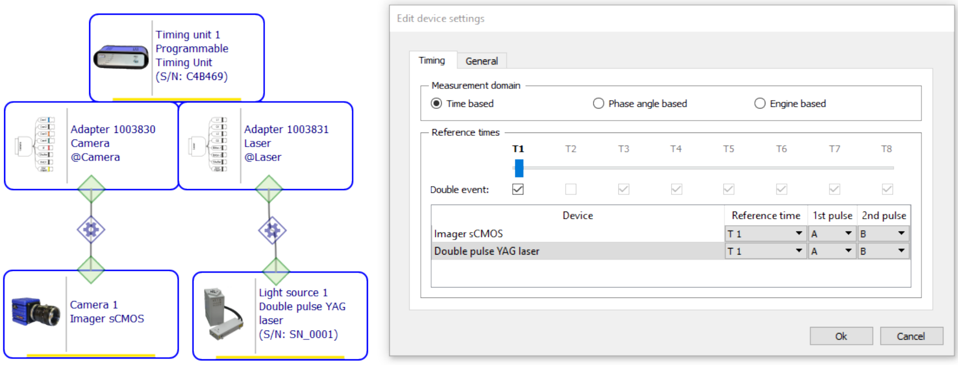


Figure 4.5: Example with double frame camera and double pulse laser.

Alternatively, you could also use a double-frame camera and two single-pulsed lasers. In this case, the exposure of the two frames are started at

T1A and T1B while the first laser is triggered at T1A and the second laser is triggered at T1B (see Fig. 4.6).

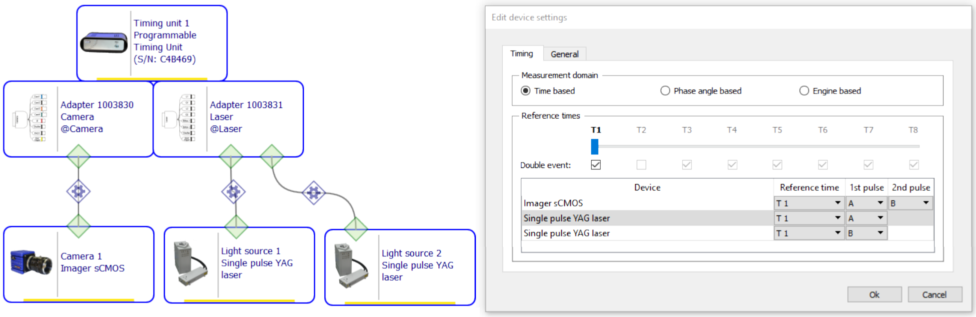


Figure 4.6: Example with double frame camera and two single pulse lasers.

In another example, you could use two single-frame cameras and two single-pulsed lasers at two independent reference times. You could trigger the first camera and the first laser with respect to T1 while the second camera and the second laser are triggered with respect to T2 (see Fig. 4.7).

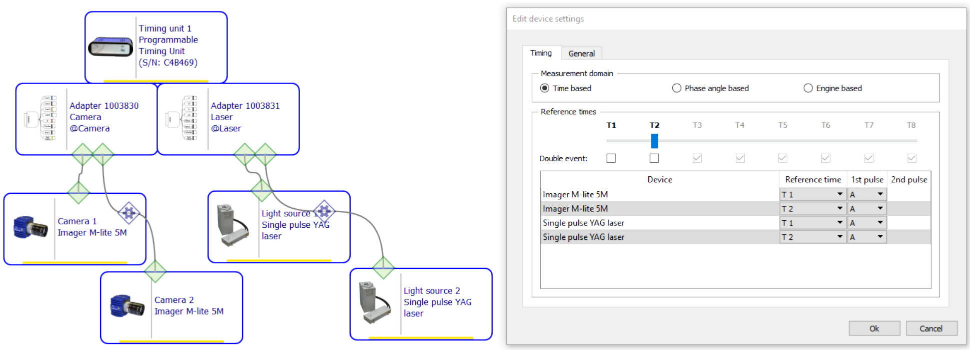


Figure 4.7: Example with two single frame cameras and two single pulse lasers.

4.3 General Settings

4.3.1 Input Selection

The Input Setup can be used to specify whether an input channel connected to the Trigger port of the PTU is triggered at the rising edge or the falling edge of a TTL pulse. In addition, the termination can be switched from high impedance ("HighZ", 2,7 k Ω) to 50 Ω.

There are three input lines affected by these settings.

Trigger: This input is referred to as the main system trigger and defines a cycle for a periodic trigger. For low-speed systems it triggers an individual image acquisition.

Start: This input line can start a recording.

CDM/CLK: This input clock is used for crank division mark (CDM) or phase angle encoders, typically from rotating machines. It provides the clock or subdivision within a cycle.

For high-speed systems an external image clock signal can be input on this line.

The polarity settings are:

rising edge: The trigger is detected when changing from low to high (default).

falling edge: The trigger is detected when changing from high to low. The default polarity is "rising edge".

The termination describes the electrical load (impedance) on these TTL-lines.

High-Z: The impedance is "high" (2,7k Ω), i.e. the input has almost no load to the TTL line (default). This setting does not require a high-current trigger source but it is sensitive to glitches or interfering signals.

50 Ω: The impedance is 50 Ω, which is commonly used to terminate a connection through BNC cables. This setting requires higher driving current from the trigger source, but is less sensitive to electrical interference or glitches.

Note: The trigger source must be capable of driving 50 Ω in order to reach the trigger threshold.

The benefit of using 50 Ω termination is to reduce interfering electromagnetic influence on the trigger lines and to get a more precise timing. Please refer to the chapter 2.10 "Signal Quality and Missing Triggers" on details about how to properly design and setup trigger lines and their termination. An electric circuit diagram of the input electronics is shown in chapter 2.10.4 "Technical Information about Input Electronics".

4.3.2 Rotary Decoder Setup (optional)

An integrated rotary decoder for trigger generation at user defined rotation angle (formerly known as "N-degree") on rotary machines (engines, turbines, etc.) decodes cycle trigger and crank division mark (CDM) signals (e.g. 1°) to generate a trigger at a user defined phase angle. This option is available only for the PTU X rotary encoder version. Please contact **LaVision** sales, if you intend to upgrade your existing PTU.

In many periodic experiments such as IC-engines or turbines, an encoder is often used to read the phase position of the machinery and to generate a periodic signal as a time reference for making measurements. The output from the encoder will typically provide a master trigger output or Master Gate, which is generated once every 360 or 720 degrees and an incremental Crank Division Mark (CDM) trigger output which is generated many times for every revolution of the encoder.

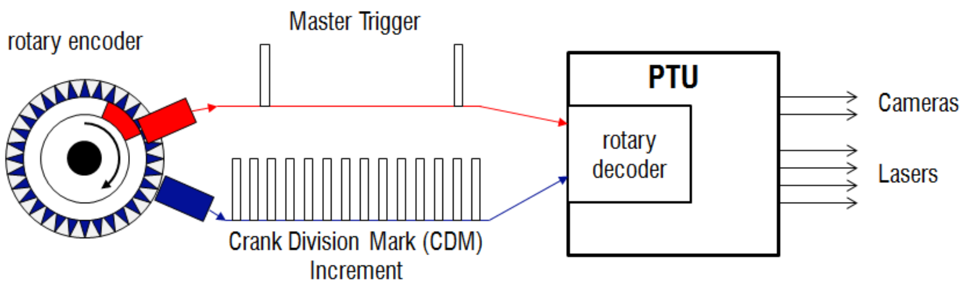


Figure 4.8: Read-out of a rotary encoder.

Additional hardware is available to read the encoder signal(s) and to combine these with the known initial delay to fire the lasers Q-switch and acquire images at a precise and user specified phase angle or delay. This functionality is implemented in the rotary decoder built into the PTU's hardware. The rotary decoder accepts a Trigger and CDM signal as input from the encoder. The PTU in turn triggers the laser(s) and camera(s) for an acquisition at a precise phase position accounting for the initial delay described above.

In order to deliver the Master Trigger and CDM Increment (Crank Division Mark) signals to the PTU, plug the PTU Trigger adapter to the D-Sub-15C terminal on the slot bracket of the PTU X board. It is recommended to activate BNC T-connectors and 50 Ω terminators on the Trigger and CDM port (see chapter 4.3.1). Connect the master trigger (1 per revolution) to the Trigger port and the incremental trigger (1 per division, e.g. 1°) to the CDM port.

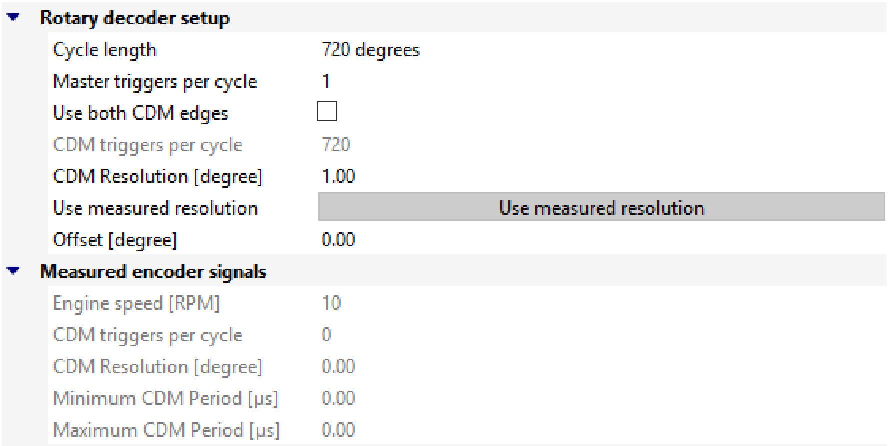


Figure 4.9

For CDM signals with 50% duty cycle optionally both edges can be used to increase the resolution by a factor of 2. For 4-stroke engines **DaVis** assumes a cycle to be from -360° to +360° crank angle with the TDC in the center at 0°. An offset can be specified to correct the trigger input to TDC at 0° crank angle.

Adjust the following parameter according to the values given by the encoder used:

Cycle Length: Indicates whether a single cycle is 360° (normal rotation) or 720° (4-stroke engines).

Master triggers per cycle: Select the number of Master Trigger signals per full cycle. The main purpose is for 4-stroke IC-engines, where the Master Trigger pickup either sits on the crank shaft (2 triggers per cycle) or the cam shaft (1 trigger per cycle). In case of 2 triggers per cycle, a switch in the **Recording** dialog allows toggling between the two possible triggers.

Use both CDM edges: If this is checked, the PTU detects the rising and falling edges of the CDM signal and increases the resolution. Else, only one of the edges is used, depending on the polarity of the CDM input. Please note: It is only meaningful to use this feature if the CDM signal has 50% duty cycle.

CMD triggers per cycle: Calculated number of CDM signals per cycle. This value cannot be set, it is calculated from other settings. Note: For a 4-stroke engine this is the number of CMD triggers for 720°.

CDM Resolution: Resolution of increment trigger (in degrees).

Use measured Resolution: This button copies the measured values from the **Measured encoder signals** section to the input fields above. The only things to be specified manually are Cycle length and Offset.

Offset: May be used to provide an offset to correct any misalignment of the encoder relative to 0°-position. Default is 0°.

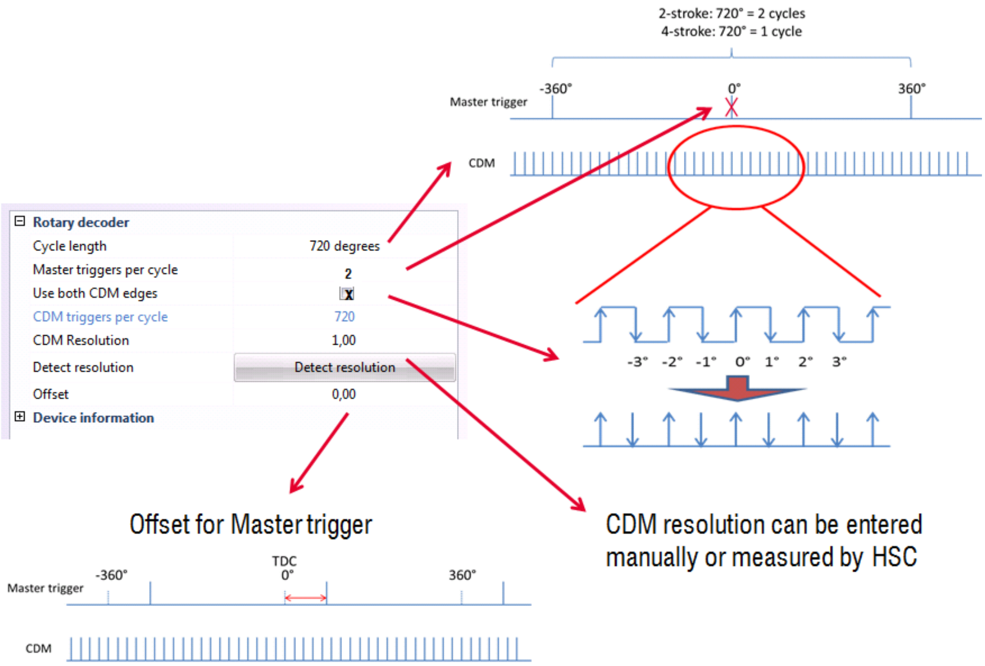


Figure 4.10: Offset

Once a rotary encoder is connected to the PTU, it automatically measures the properties of these encoder signals and display them live in the section **Measured values**:

Engine speed [RPM]: Displays the measured engine speed based on the master triggers. If **Master triggers per cycle** is not set correctly, the measured value is a factor 2 different compared to the applied speed.

CDM triggers per cycle: Displays the measured number of CDM triggers per cycle based on the selected settings in **Rotary decoder setup.**
E.g. Setup: cycle length=720°, 2 master/cycle
Input: 2 master/cycle, 1 CDM every 0.1° → measured CDM triggers

per cycle = 7200
Input: 1 master/cycle, 1 CDM every 0.1° → measured CDM triggers per cycle = 14400

CDM resolution [degree]: Displays the calculated CDM resolution based on the measured values

Minimum/Maximum CDM period [μs]: Displays the measured minimum and maximum CDM period in a cycle. These measured values can be compared to oscilloscope traces to find sources of synchronization issues. The two values should be close together. Their difference should only reflect the speed variations within an engine cycle. Very different values may result from bad trigger signal quality.

4.4 PTU Features

The PTU X can contain additional features.

Features can be purchased separately. Please contact your sales representative if you intend to upgrade your PTU.

Available features are:

Reference times: This feature can only be used for low-speed systems. It Allows to use more than one reference time. This is used when two measurement tasks need to be bound to different times within the same cycle. Please refer to "Reference times" for more details on this feature.

Rotary decoder: Supports to read rotary encoder signals with a built-in hardware rotary decoder. This allows precise measurement timing.

Dynamic frequency strategy: This advanced feature allows to measure an accelerating or decelerating trigger with a fixed frequency laser (but cannot be combined with multiple reference times).

High-speed: Allows to run the PTU in high-speed mode for high-speed cameras.

Programmable Parameter Recording: This feature is available for high-speed systems. It enables the selection of multiple sub-ranges for the image acquisition and the possibility to dynamically change parameters during a cyclic recording. Parameters that can be changed are:

cycle sub-ranges, PIV dt, image intensifier gate, light source state (on/standby).

Hypersampling: This feature is available for high-speed systems with rotary decoder feature. It enables measurements of transient phenomena with strong variations of the engine speed like acceleration and allows to utilize devices with fixed or limited frequency range to fluctuating engine speeds. It requires a digital sampler as additional hardware.

Cold start add on for Hypersampling: This feature extends the functionality of Hypersampling. The recording can be started while the engine is not running in order to capture the start. Additional a selectable number of initial full cycles can be recorded before switching to PPR recording.

A list of installed features is available after initializing the PTU.

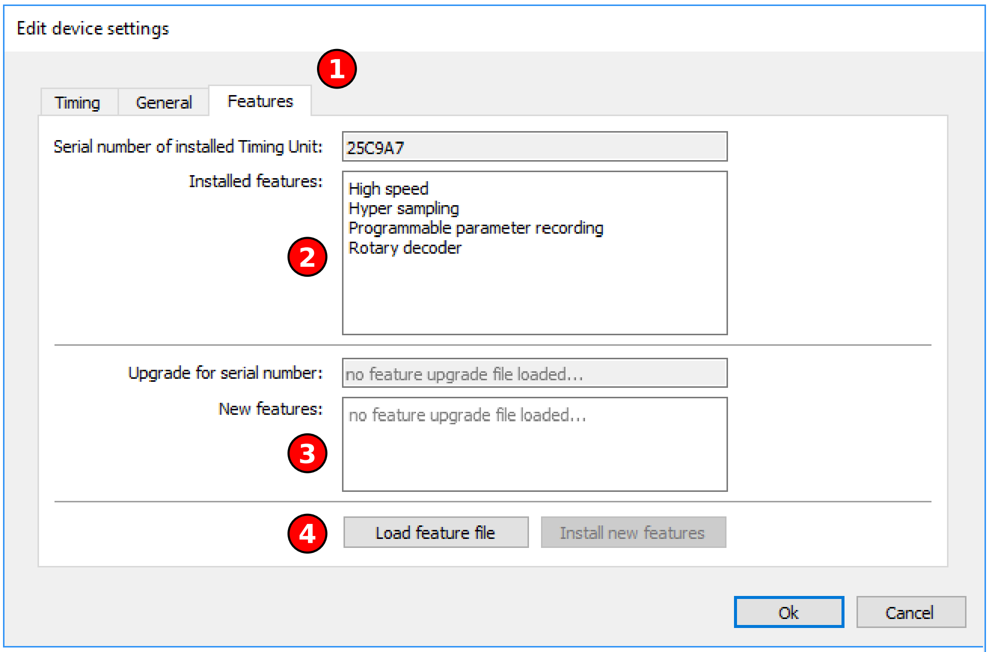


Figure 4.11

Once purchased, **LaVision** will send to you a feature file, which allows to upgrade the PTU X.

1 Open the Feature tab in the PTU Device settings. This tab is only visible after the PTU is initialized.

2 The installed features are listed in the table. This is the functionality currently available with your PTU.

3 New features which are shipped with the feature file are listed here.

4 Load a feature file shipped by **LaVision**. **DaVis** checks, if the features are compatible with your PTU. If you decide to install the new features now, please click on "Install new features". Restart **DaVis** after the feature upgrade.

4.5 Wiring Setup

4.5.1 Adapters

When adding a PTU to the hardware setup, a set of default adapters is connected to the PTU as well. Adapters provide the connection between the PTU and the trigger lines to the devices. There are default adapters for certain systems but in general there are different adapters available that can be used. Therefore, you need to make sure that the correct adapter and trigger line is selected in your setup. For more details on adapters, please refer to chapter 2.9.

In order to remove an adapter from the PTU in the hardware configuration, click on the red X in the adapters icon.

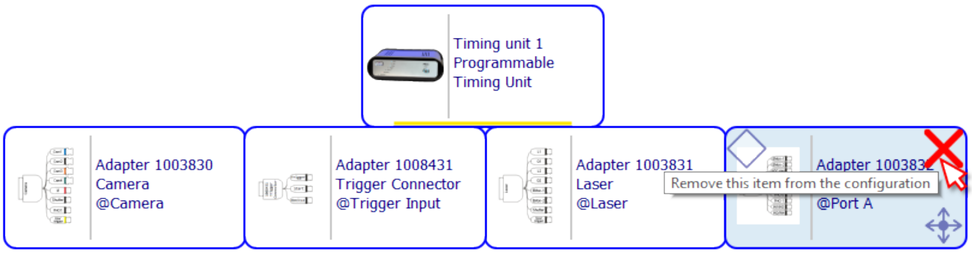


Figure 4.12: Remove an adapter from the configuration.

To add an adapter, select it from the list 1 and drag-and-drop it 2 to the PTU icon 3 . The adapter will automatically connect to the PTU 4 .

Also the trigger input to the PTU needs to be configured with an adapter. Optional external trigger signals from the experimental setup can be received on up to four input lines. By default, the #100843 PTU adapter is used on the rear panel of the PTU board directly. The different BNC cables can be used as follows:

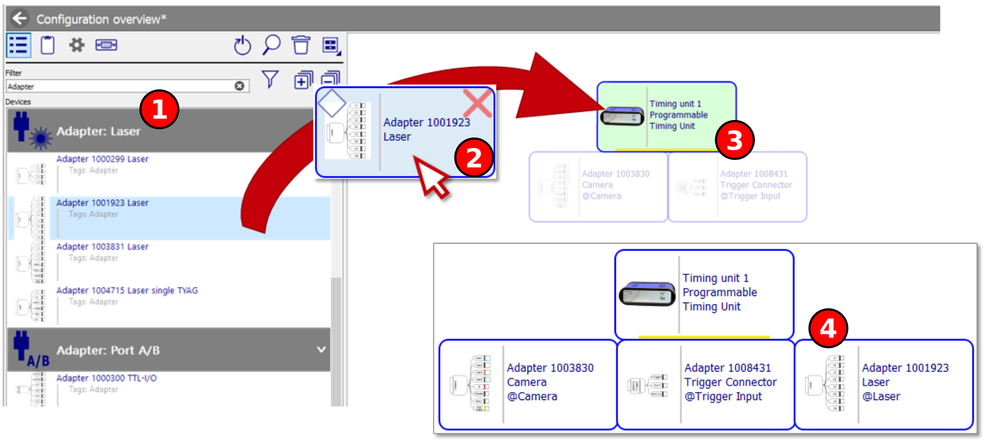


Figure 4.13: Add an adapter by drag-and-drop it onto the PTU icon.

Trigger: Can receive a trigger signal for the phase-logged recording of each single image or a master trigger (one per cycle) during the read-out of an encoder.

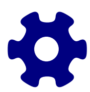
Start: Can receive a trigger signal in order to trigger a specific image within a sequence of images.

CDM/CLK: Can receive the incremental trigger signals (Crank Division Mark) from a rotary encoder.

4.5.2 Line Configuration

DaVis automatically connects the PTU outputs to signal lines according to the adapters used on the PTU. In the hardware setup overview, the layout of these connections is visible.

Note: Only trigger lines to the PTU are shown in the diagram. Communication lines, like USB or RS-232 connections are not shown.



For more details on each trigger line and to change an assigned connection, click on the cable icon or the **Show configuration details** button in the toolbar.

The **Configuration details** dialog will show up. When opening the Configuration Details window by clicking on the cogwheel on a specific connection, the shown cable is pre-selected. It is possible to change between the devices with the arrow buttons 1 .

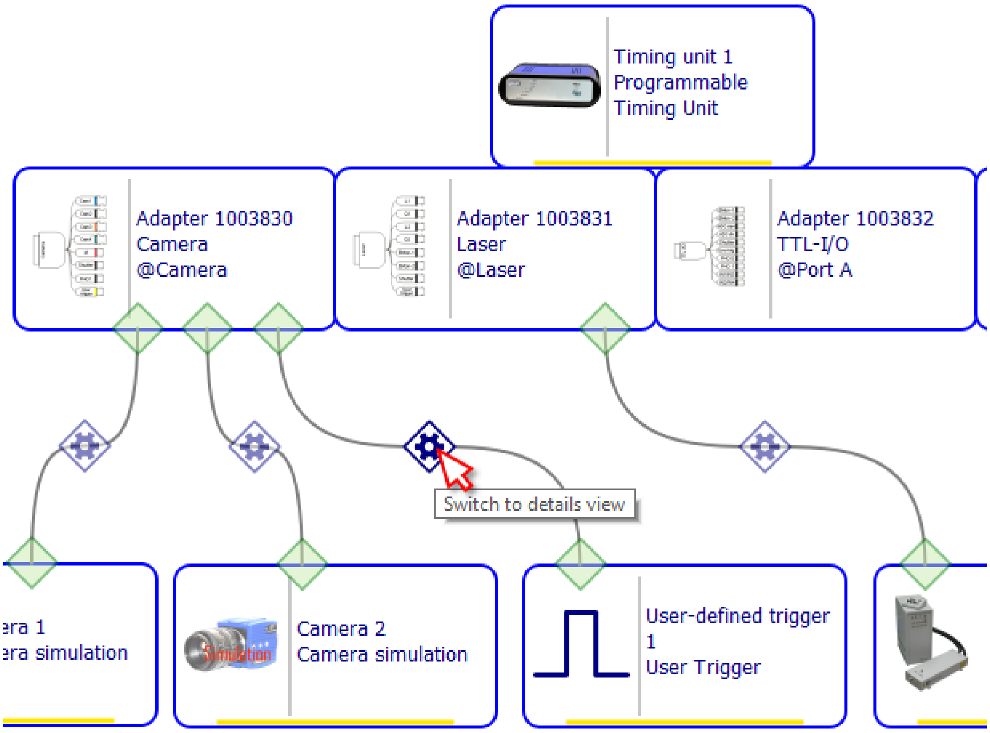


Figure 4.14: Click on a wire to open the Configuration details dialog.

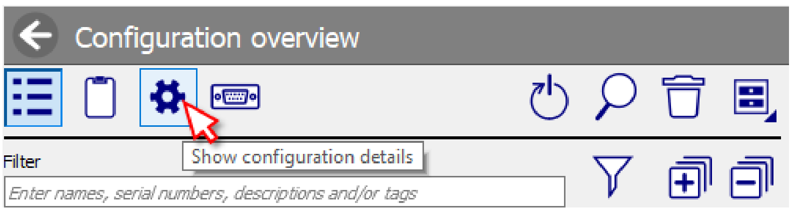


Figure 4.15: Open the Configuration detail dialog.

Click on the end of a connection and drag it over another port. **DaVis** indicates if this new connection is possible or not by showing something similar to either Fig. 4.17 (impossible) or Fig. 4.18 (possible). Ports which other devices are connected to are grayed-out.

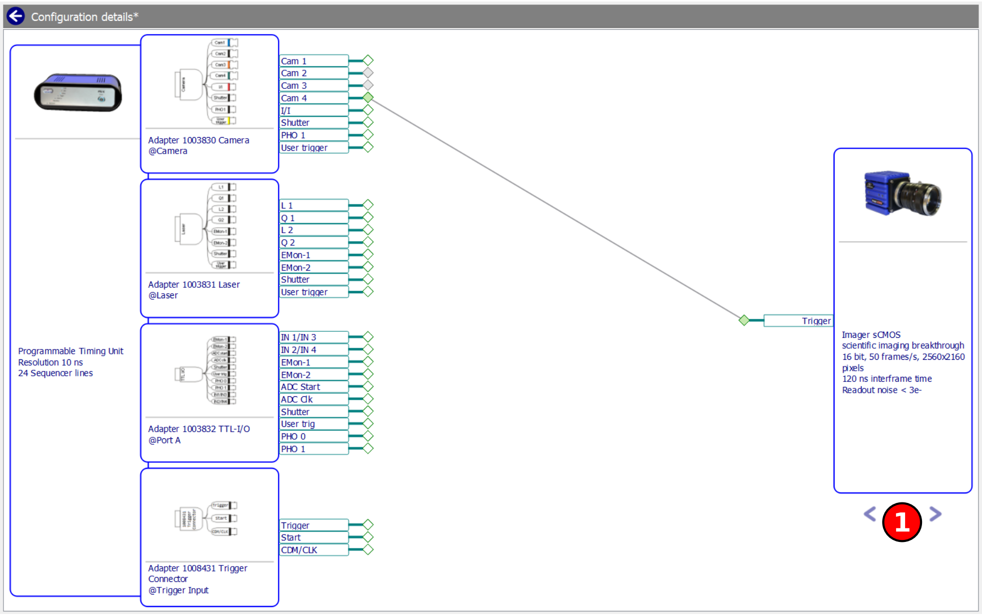


Figure 4.16: Configuration Details.

Figure 4.17: Impossible Connection.

Figure 4.18: Possible Connection.

5 Recording

In the **Recording** dialog, the Programmable Timing Unit (PTU) will be programmed via different options and parameters. Depending on these options, the PTU will provide different devices (e.g. camera or light source) with the required trigger signals. It automatically takes into account the device specific intrinsic delays since they are known and considered in **DaVis**. The PTU can also be used to receive external trigger signals from the experiment to phase-lock the recording to an external event.

The **Recording** dialog can be opened using the **Recording** button in the Project Manager.

The main settings for the PTU in the recording dialog are **Devices** and **Timing**. The detailed behavior depends on the Hardware settings of the PTU, such as Measurement domain, use of Phase encoders, laser alignment and number of reference times.

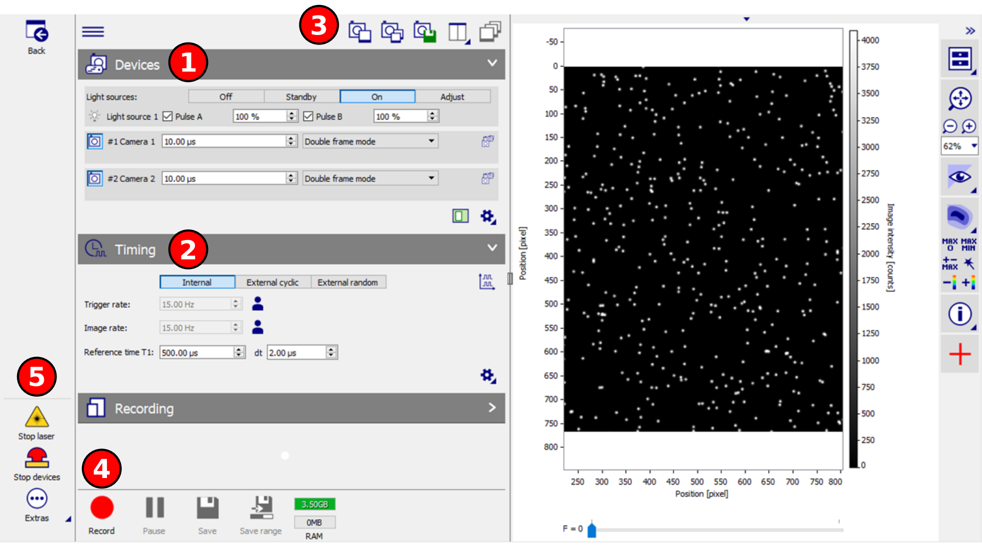


Figure 5.1: Recording Dialog overview.

1 Devices: In the Devices section, the light source (laser), cameras and other devices are controlled.

2 Timing: In the Timing section, the trigger behavior of the PTU is configured.

3 Live view: The live view buttons in the top row switch the camera to live operation.

4 Recording: The Recording section and the recording buttons acquire an image sequence and store them to disk.

5 Stop buttons: Laser and running devices will stop immediately, when pressing these buttons.

5.1 Devices Section

Expand the Devices section to get access to device settings, such as the light source and cameras.

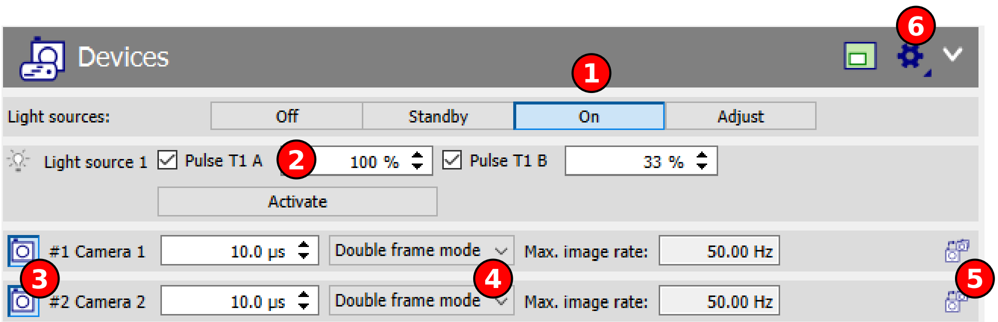


Figure 5.2: Devices section in the **Recording** dialog.

1 **The Light source states**
The light source has 4 different states

Off: No trigger is sent to the light source

Standby: No light emission will appear, but the light source is warming up. This state needs to be supported by the light source. In case of a Nd:YAG laser, flashlamp triggers are sent to the laser. When using a laser shutter, the laser will be fired, but the shutter keeps closed.

On: The laser will be fired, when the camera is active, i.e. during live image or recording. This is the default operation mode.

Adjust: The laser fires all the time, independently from the camera activity. This mode is useful to adjust the laser beam.

2 **Light source activation and power**
Each individual light source in the system or each cavity of a double pulse laser can be activated independently. Also the power can be set if the light source supports this feature. For flash lamp pumped Nd:YAG lasers the laser power is controlled by shifting the time between flashlamp and Q-switch triggers. In the laser settings, two values are defined "Q-Switch delay at minimum power" and "Q-Switch delay at maximum power". The percentage settings of the laser power linearly interpolates between these two values.
Note: The power settings are not linear with the output laser power!

3 **Camera control**
Each camera can be switched on separately with the button in front of the camera name. The exposure time can be entered, according to the capabilities of the camera connected. Some cameras do not allow to enter an exposure time in double frame mode. In this case, the value is set automatically.

4 **Single/Double frame operation mode of the camera**
This setting switches the camera between single and double frame operation. The camera needs to support this feature, and the corresponding Reference time in the Hardware setup needs to be set to "double event".
The time between the two exposures, the "dt", is set in the Timing section.

5 **Copy settings to all**
Clicking this button copies the setting of the camera to all other cameras.

6 **Details**
Clicking this button opens the Details dialog to set device behavior and timing details.

5.2 Timing Section for low-speed measurement domains

Expand the Timing section to get access to the trigger and timing settings.

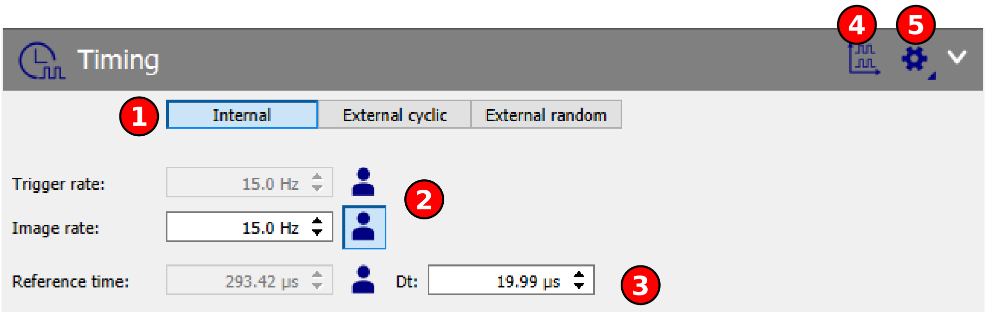


Figure 5.3: Timing section in the Recording dialog.

1 **Trigger source**
The trigger source setting determines the origin of the PTU trigger and its general behavior.

Internal: The PTU internal clock generates the trigger. This trigger has a precise constant frequency. This is the default trigger source for free running of the system.

External cyclic: A TTL trigger signal needs to be sent to the PTU. It is assumed that this signal is periodic and has a frequency which stays constant during a measurement.

External random: A TTL trigger signal needs to be sent to the PTU. The trigger has no frequency and could even be a single trigger.

2 **Trigger rate settings**
The settings for the trigger rate depend on the trigger source settings above. Details are described in the following sections.

3 **Reference time**
The delay of the reference time is set with respect to the trigger. In case a reference time has **double events** (like for PIV), the time between these events, the "dt", can be set here.
The number of reference times and if they are double events is set in the details of the PTU hardware settings.
Depending on the **Measurement domain** of the PTU, the Reference time can also be set in phase angle degrees instead of time.

4 Timing diagram
Clicking on this button opens the timing diagram. The timing diagram shows the electric TTL signals and the active times of the devices.
Note: The timing diagram reflects the actual state of all recording settings. E.g.: Laser pulses will only be shown, if the laser is activated ("On" mode).

5 Device Offset
Clicking on the Details button allows to fine tune the Device offset and advanced settings, such as the Dynamic frequency strategy..

5.2.1 Time based measurement domain

The trigger source setting determines the origin of the PTU trigger and its general timing behavior. Three different types can be set: Internal, External cyclic and External random.

Internal trigger

The trigger source **"Internal"** is used if the recording does not need to be synchronized to an external trigger signal from the experimental setup. Usually, this is the case for steady phenomena that should be observed.

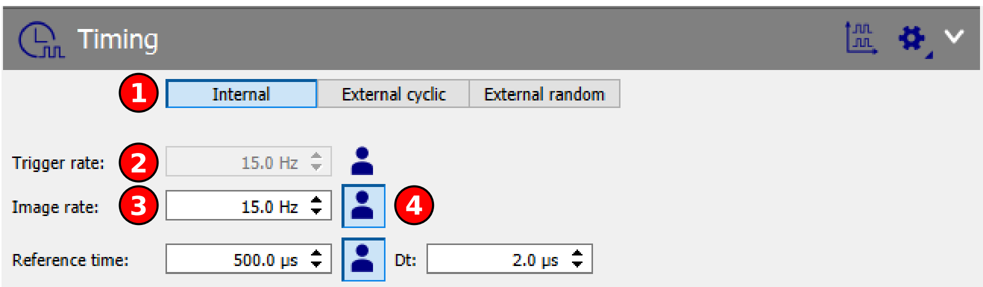


Figure 5.4: Internal trigger.

1. Select **Internal** for trigger generation by the PTU's internal clock.
2. The **Trigger rate** can be determined automatically from the maximum trigger frequency of all active devices.
3. The **Image rate** is the speed the camera is running at. This is the same as or an integer fraction of the trigger rate.

4 Allows user entry: deactivated = automatically calculated rate, activated = allow user input. In case of the image rate, the best matching integer fraction of the trigger rate will be chosen.

The timing is determined by the values that are selected for **Trigger rate** and **Image rate**. The trigger rate is the rate that is generated by the PTU and sent to the different devices. The image rate is the rate that the system is using to take images. The system is able to send trigger signals at a higher rate than it is taking images with, but the trigger rate needs to be a multiple of the image rate. If the value for the image rate is lower than the trigger rate, this will be indicated by a yellow background in the image rate textbox. Different rates can be useful if you need to trigger a device (e.g. a solid state laser or the experiment) at a higher rate than the rate that should be used for image acquisition.

Example 1:

Assuming a maximum camera frequency of 50 Hz in double frame mode (Imager sCMOS) and an allowable laser frequency range of 0-15 Hz, the trigger rate and the image rate are set to 15 Hz by default as the limiting device for the image recording is the laser. Note: The limitation does not happen, when the laser is switched off. Only active devices are taken into account.

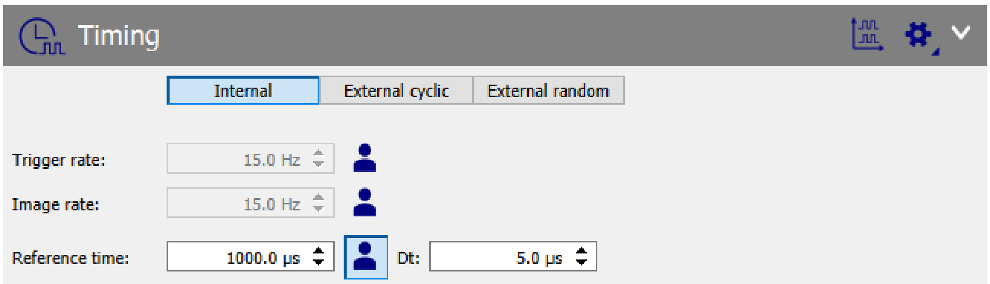


Figure 5.5: Example of automatic calculation of common rate for camera and laser.

Example 2:

Assuming a maximum camera frequency of 25 Hz in double frame mode (Image sCMOS) and an allowable laser frequency range of 0-15 Hz and a specified Image rate of 1 Hz, the flashlamp of the laser and the camera as well are triggered at 1 Hz.

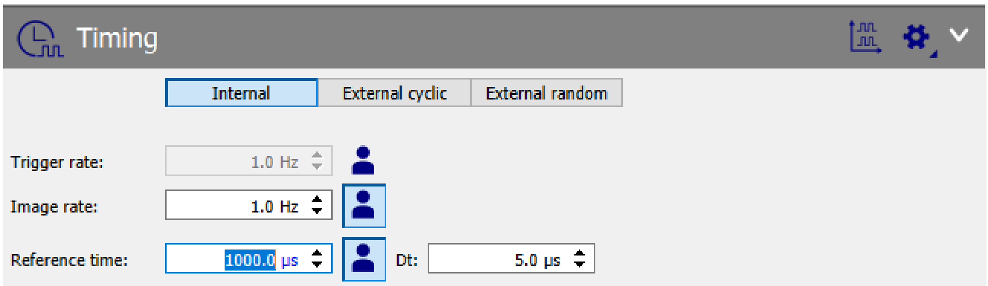


Figure 5.6: Example of manually set image rate.

External cyclic trigger

The trigger source **"External cyclic"** can be selected for phase locked acquisition of images with respect to a periodic external trigger signal. In this case, the system can calculate a trigger strategy for image acquisition and usually goes for the lowest common multiple of external trigger and allowable trigger rates of the devices used.

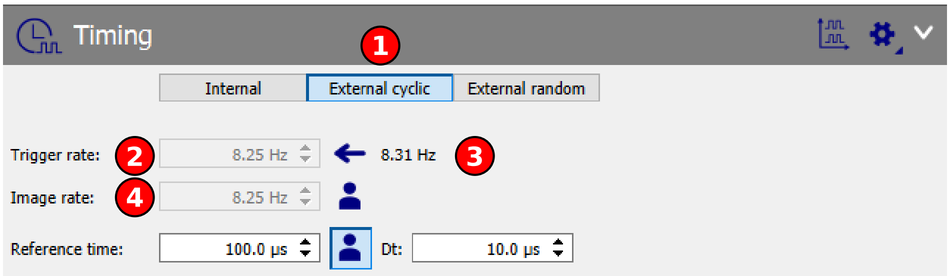


Figure 5.7: External cyclic trigger

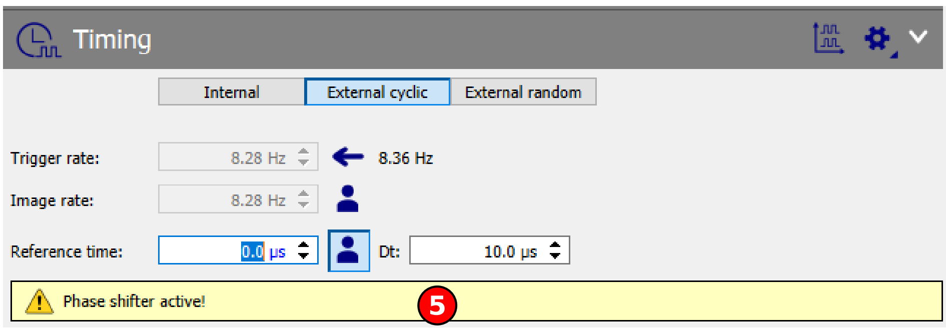


Figure 5.8: External cyclic trigger with activated phase shifter

1. Select **External cyclic** for periodic triggers sent to the PTU.
2. The **Trigger rate** is measured automatically.
3. You can update the setting of the trigger rate to the current value by clicking the arrow button. The trigger rate is updated automatically on live view or recording start.
4. The **Image rate** is the speed the camera is running at. This is the same as or an integer fraction of the trigger rate. You can let **DaVis** calculate this automatically (user entry button deactivated) or enter a desired value manually (user entry button activated).
5. **Phase shifter active**: This warning informs that **DaVis** has decided to activate the phase shifter in the PTU to establish the desired reference time which is closer to the external trigger than the initial delay of the system.

The external trigger signal needs to be a TTL signal with positive logic (0 V to 5 V) and a gate $\geq 1\,\mu$s. The trigger signal has to be connected to the 'Trigger' BNC of the Trigger adapter that has to be plugged to the DSub15C socket of the PTU slot bracket directly. Find details on the required connector in the Wiring setup section of this manual.

The trigger rate is the rate that is sent to the PTU. The PTU tries to send it to all other devices, but their maximum frequency applies limitations to that. The image rate is the rate that the system is using to take images. The system is able to receive signals at a higher rate than it is taking images with, but then the image rate will be reduced to an integer fraction of the trigger rate. If the value for the image rate is lower than the trigger rate, this will be indicated by a yellow background in the image rate textbox.

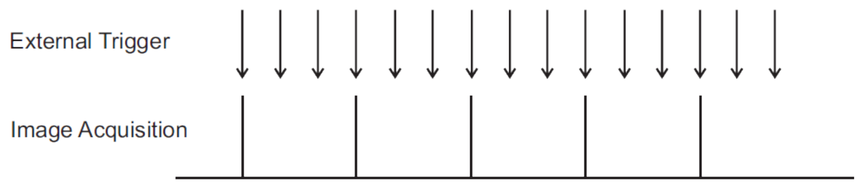


Figure 5.9: Example of different Trigger and Image rate.

The **Phase shifter** is a PTU built-in hardware device, which allows to shift the trigger to a time earlier than it actually arrives. This is necessary if a measurement should take place very early after the trigger or even slightly before the trigger. The system normally needs a setup-time for the devices, e.g. the flashlamp of the laser must be fired before the Q-switch. If it is desired to measure right at the trigger, the PTU must send the flashlamp signal *before* the trigger arrives. In order to do this, the PTU measures the frequency at the beginning of the recording. Then, it can shift the incoming trigger in phase to generate a new trigger signal, which appears before the next trigger. This phase shifted trigger is now used to trigger the PTU sequence. The disadvantage of this feature is that the precision of the measurement time now depends on the precision of the frequency of the external trigger. If this fluctuates, the moment of measurement will also fluctuate.

Once the "Phase shifter" is disabled, the timing is precise again but it is not possible to use short or negative reference time.

More details are explained in the section about "Negative Reference Times and Use of Phase Shifter".

External random trigger

The trigger source **"External random"** can be selected for a random triggered acquisition of each single image. The trigger signal that is not periodic and can be a single trigger. In this case, the system has no chance to calculate a trigger strategy for image acquisition.

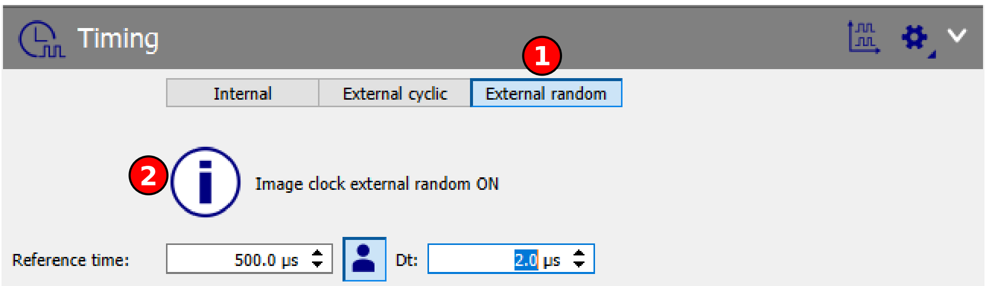


Figure 5.10: External random trigger.

1. Select **External random** for single or random triggers sent to the PTU.
2. There is no further calculation of a timing strategy. The image clock follows the random trigger, if possible.

This mode requires a PTU-controlled light source that can be triggered at a range that has no lower limit, i.e. an allowable frequency range between 0 Hz and a maximum frequency.

If the external trigger signals come with a delay that is shorter than the required time for the acquisition of one recording, it can happen that some external trigger signals will not start a recording.

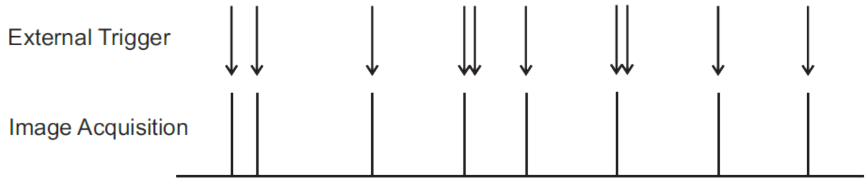


Figure 5.11: Random external trigger and corresponding image acquisition.

Device Offset

The Device Offset allows adjusting the timing if one or more of the used devices have internal delays that are different from the default values. For each of the used devices, you may select a positive or negative offset in order to make sure that they are synchronized properly to the other devices. Usually, the system should arrange the timing in a manner that all values can be set to zero in this dialog.

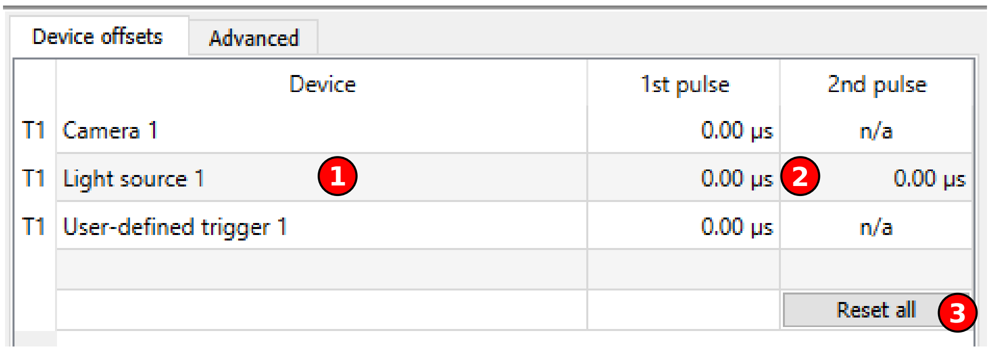


Figure 5.12: Device offset.

1. All devices which receive a signal from the PTU are listed here.
2. You can shift the calculated timing by the values for the 1st pulse and 2nd pulse, referring to the both pulses of a double event with a "dt". Negative numbers make the signal appear earlier, positive numbers later.
3. Reset all values to zero.

Example 1:

The **Device offset** can be used for fine-tuning of the synchronization of a double-frame camera and a double-pulsed laser system. The effect of the device offset correction is depicted in Fig. 5.13. Typically, the intrinsic delays of the laser systems are constant but differ from one model to another. If the laser needs a certain time between receiving the external trigger for the Q-Switch and emission of laser light, it may happen that both laser shots illuminate the second frame of the recording. To do so, open the **Timing** card and select a *dt* of 5 μs. Then, open the **Device Offset** card and set the values for **T1A** and **T1B** for the **Light Source 1** to zero. Switch on Pulse A and switch off Pulse B in the **Laser Control** dialog. Select the 'On' mode in the **Laser Control** dialog and take a double frame image. Make sure that the first frame is illuminated.

In the case that Pulse A is illuminating the second frame, enter a negative value for the **T1A** on the **Timing** card (e.g. -0.1 μs) and take an image again. Check if the Pulse A is recorded in the first frame now and reduce this value until Pulse A appears in the first frame.

If Pulse A is neither in the first frame nor in the second frame, enter a positive value for the **T1A** of **PTU Light Source 1** on the **Timing** card (e.g. 5 μs) and reduce this value until Pulse A appears in the first frame.

After you have adjusted the value for **T1A** in a manner that Pulse A illuminates the first frame, enter the same value for **T1B** for **Light Source 1** on the **Timing** card.

As a cross check, switch off Pulse A and switch on Pulse B, take a double frame image again and make sure that Pulse B is in the second frame.

Reduce the 'dt' (e.g. to 1 μs) on the **Timing** card to the smaller values and repeat this procedure.

Dynamic frequency strategy

In the **Advanced** tab, the **Dynamic frequency strategy** may be activated. This option is available, if the PTU is equipped with the 'Dynamic frequency strategy' feature. It allows to measure at varying external frequencies (like an accelerating or decelerating engine) in combination with a fixed frequency laser. When activated, the PTU ensures that the exter-

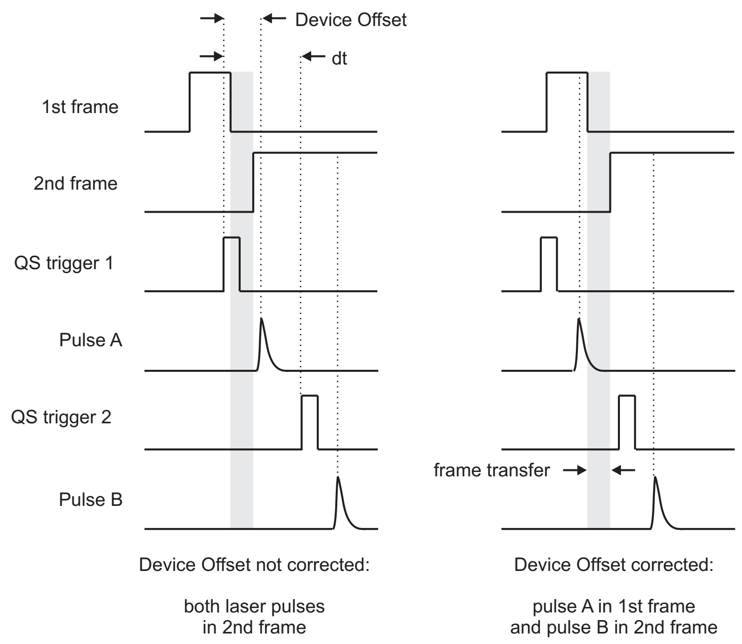


Figure 5.13: Effect of the Device Offset correction.

nal trigger is only accepted, if it falls into the allowed frequency window. Otherwise, a record idle sequence is triggered.

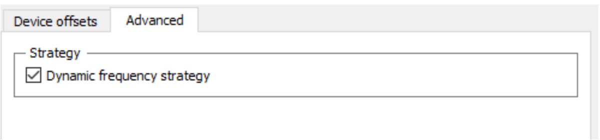
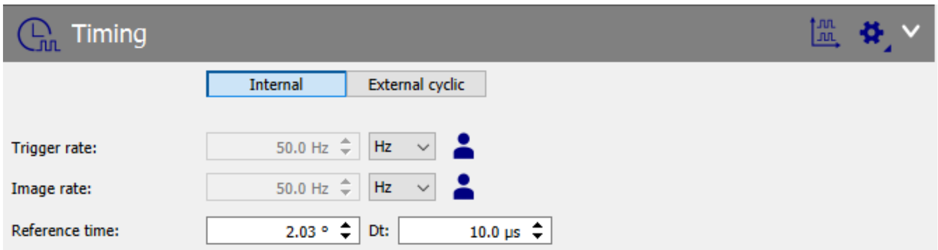


Figure 5.14: Dynamic frequency strategy.

Example 1:

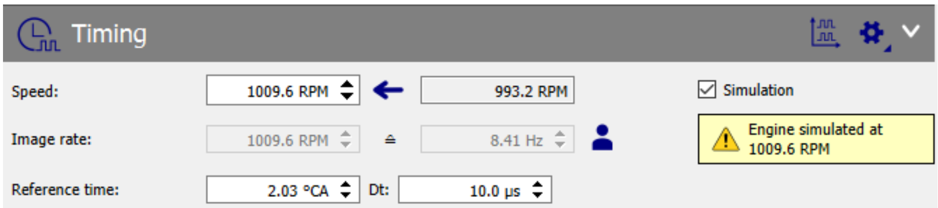
An automotive engine is running at continuously changing speed (engine test cycle), but the laser system has a fixed-frequency laser (i.e. the laser can only be triggered within a narrow range), as some large Nd:YAG lasers are. The PTU X permanently optimizes the laser system trigger during a running measurement in order to match the varying engine speed to the fixed laser frequency for maximum recording rate.

5.2.2 Cyclic time based measurement domain



The cyclic time based measurement is designed for periodic event recordings. This domain is similar to the time based measurement domain described in Section 5.2.1. Here, only the trigger source setting types **Internal** and **External cyclic** are available. The **Trigger** and **image rate** unit can be switched between *Hz* and *RPM*.

5.2.3 Engine based measurement domain

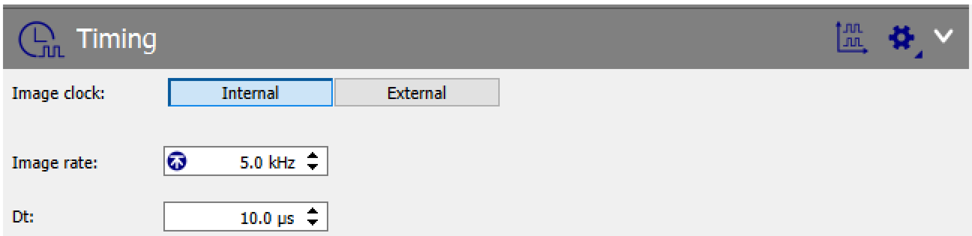


The low speed engine based measurement domain dialog enables measurements on rotary engines. The speed can be entered manually, if a simulation is utilized. Otherwise, the speed can be set based on the value from the actual speed that is continuously measured by the PTU. The image rate is either based on the speed, or can be set manually. The reference time can be given as a phase angle. The quality of the measurement depends on the delay between reference time and hardwre device with the longest setup time. A higher delay time is equivalent to a morre imprecise measurement. More information on reference time and phase angles can be obtained from Section 5.4.2.

5.3 Timing section for high-speed

The appearance of the timing section depends on the selected measurement domain.

5.3.1 Time based measurement domain

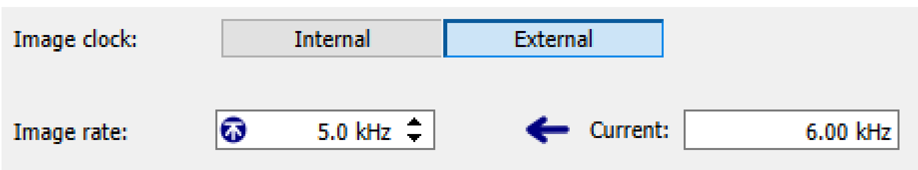


Internal Image clock:

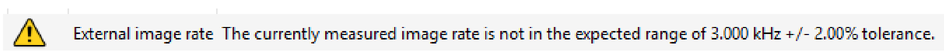
The image rate is generated by the PTU (Internal). The rate can be entered in the Image Rate box. The image rate can be set to the maximum possible using the button. The maximum possible rate is determined by the properties of all devices in the system.

External Image clock:

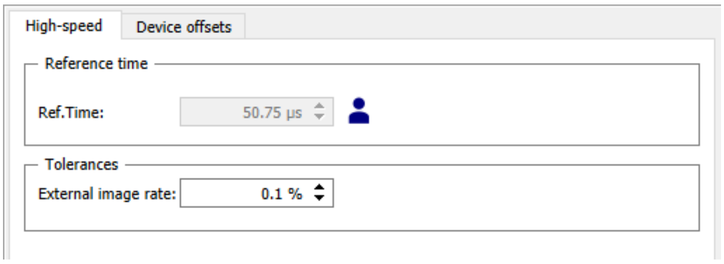
The image rate is genereated by an external device. The external clock signal (5V TTL) has to be connected to the CDM/CLK line of the PTU Trigger connector 1008431. The expected rate can be entered manually if the external signal is not present (e.g. before the experiment is started). The measured frequency is displayed and can be transferred to the Image Rate box by clicking the ← arrow.



If the external frequency differs from the entered frequency more than the specified tolerance, a warning is displayed:

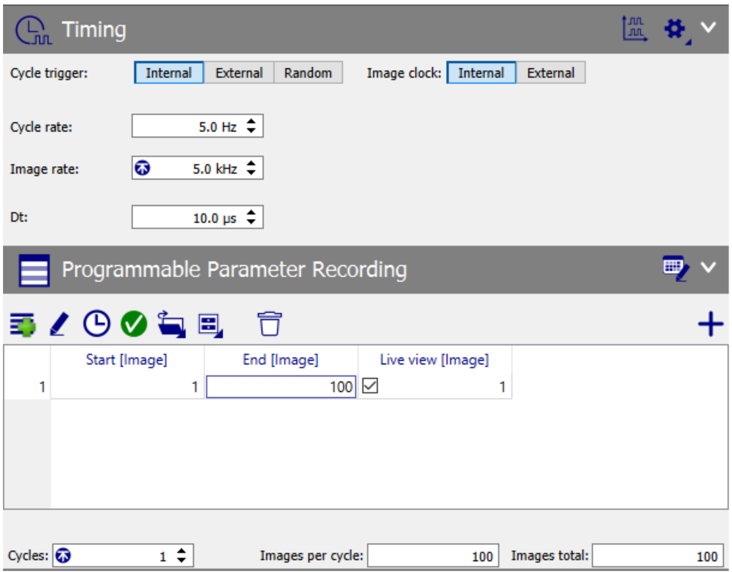


The tolerance for the external image rate can be set in the timing details:



Dt: If a double pulse laser is present in the system the PIV dt can be set here.

5.3.2 Cyclic Time Based measurement domain



The cyclic time based measurement domain is designed for recordings of events that are repeated in a periodic or random pattern. The images are usually stored in the RAM of the cameras during the recording and transferred to the hard disk afterwards.

DaVis checks the consistancy of the selected or measured rates and recording duration and position within the cycle period. Warnings or errors are issued if e.g. the selected and measured rates do not match, if the number of selected images does not fit into the cycle period, if the total number of selected images is too high or if external rates are selected but not applied to the PTU.

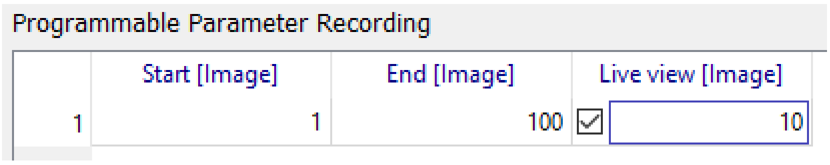
The images can be acquired at any position within the cycle. The recording start of the image sets is always phase-locked relative to the cycle trigger.

The number of cycles that should be recorded can be selected.

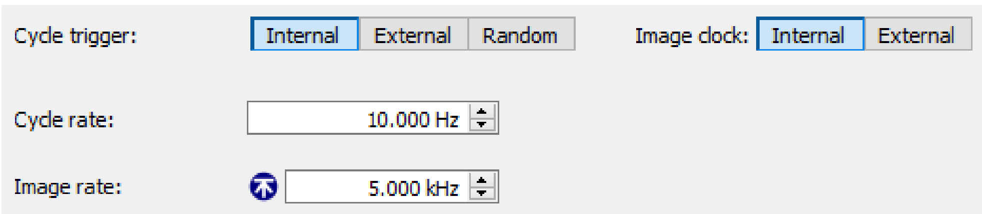
It can be set to the maximum possible – based on the current PPR settings – using the button.

With Programmable Parameter Recording (PPR) multiple subranges in a cycle can be selected. Additionally parameters like the PIV dt or the image intensifier gate and delay can be dynamically changed through the cycle. Light sources can be set to on or standby.

In live view the images are acquired phase-locked in the cycle. The position of the displayed image can be selected in the Programmable Parameter Recording section in the Live view coloumn:

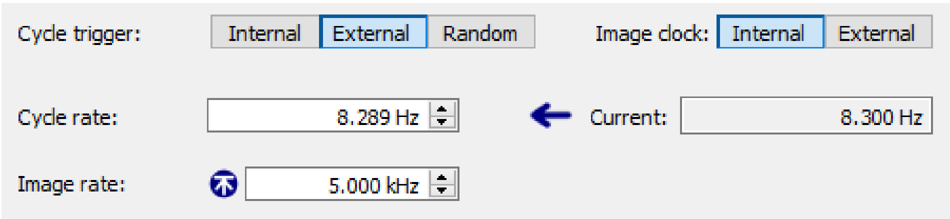


Internal Cycle Trigger / internal image clock:



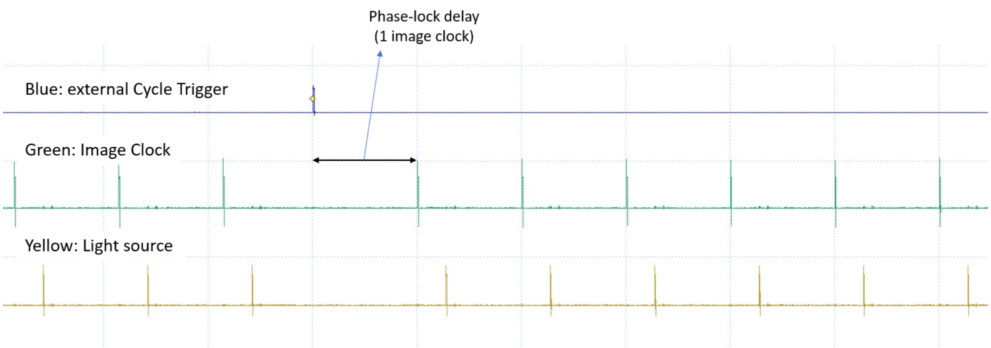
The cycle rate and image rate are generated by the PTU (internal). The cycle and image rate can be entered in the cycle/Image Rate box. The image rate can be set to the maximum possible using the button. The maximum possible rate is determined by the properties of all devices in the system.

External Cycle Trigger / internal image clock:



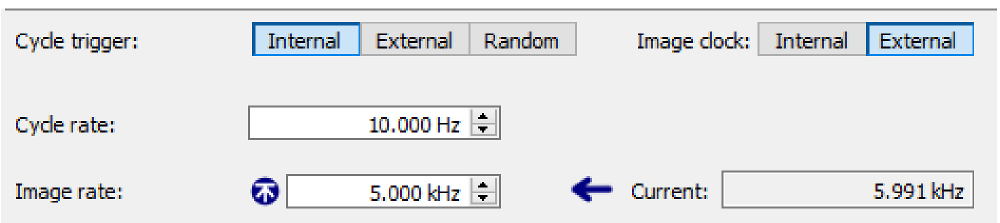
The cycle rate has to be applied to the PTU through the Trigger input line. The PTU measures the external rate. The external rate can either be typed in the Cycle rate box or transferred from the measured value using the ← button. A warning is issued if the measured and selected rates differ more than the specified tolerance (see section Timing details 5.3).

The image rate is phase locked to the external cycle trigger so that the image recording can start with a fixed delay of minimal one image clock.



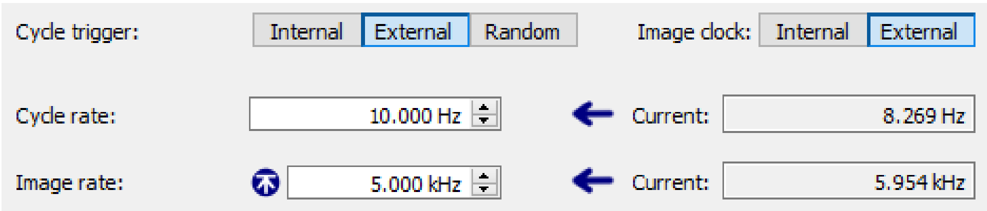
The image rate is generated by the PTU (internal). The image rate can be entered in the Image Rate box. It can be set to the maximum possible using the button. The maximum possible rate is determined by the properties of all devices in the system.

Internal Cycle Trigger / external image clock:



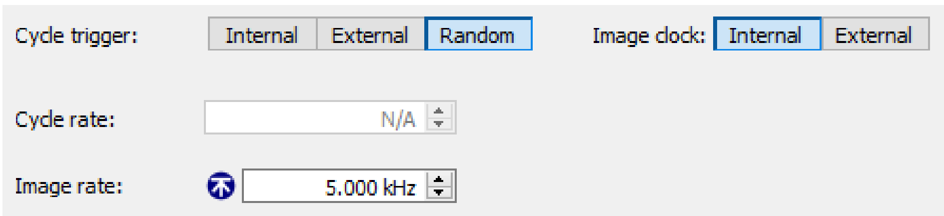
The cycle rate is generated by the PTU (internal), the image clock has to be applied to the PTU through the **CLK/CDM** input line. The PTU measures the external image rate. The image rate can either be entered in the Image rate box or the measured value can be transferred using the ← button.

External Cycle Trigger / external image clock:



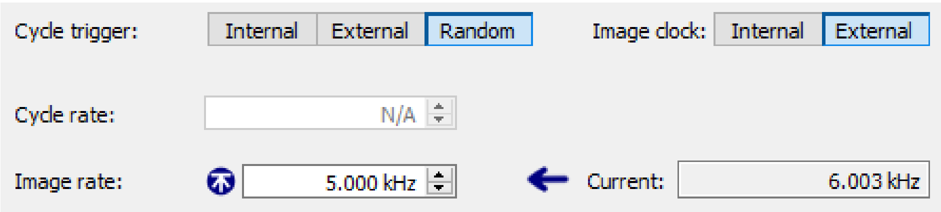
The cycle and image rate have to be applied to the PTU. The PTU measures the applied external rates. The rates can either be entered in the according boxes or the measured values can be transferred using the ← boxes. Warnings are issued if the measured rates selected rates differ more than the specified tolerances (see section Timing details).

Random Cycle Trigger / internal image clock:



The random trigger has to be applied to the PTU through the Trigger input line. On a **Trigger** the selected number of images are recorded. The start of the recording is phase-locked relative to the external trigger.

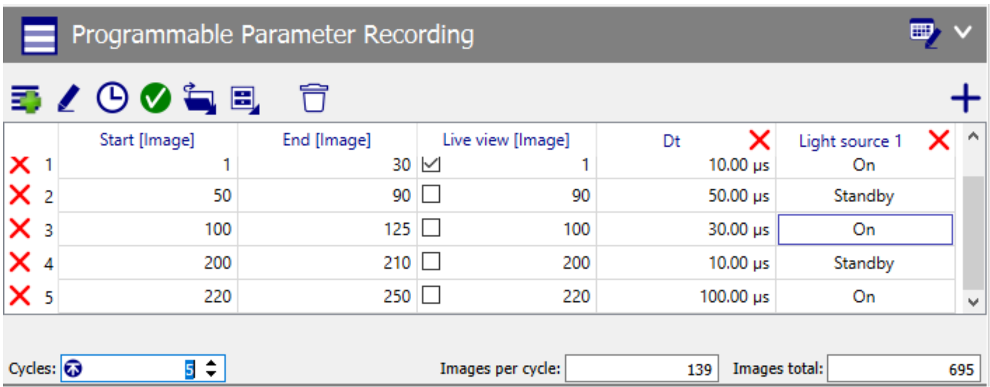
Random Cycle Trigger / external image clock:



The random trigger has to be applied to the PTU through the Trigger input line, the image clock has to be applied to the PTU through the **CLK/CDM** input line. The PTU measures the external image rate. The image rate can either be entered in the Image rate box or the measured value can be transferred using the ← button.

On a trigger the selected number of images are recorded. The start of the recording is phase-locked relative to the external trigger.

5.3.3 Programmable Parameter Recording (PPR)



Programmable Parameter Recording (PPR) is an upgrade for the PTU X High-Speed. It allows to record subset of images at different positions within the cycle and the programming of optimum recording parameters at different phases of the cycle. A table with up to 200 lines can be used.

The image which is displayed on Take / grab can be selected in the live view [image] column.

The value can be changed during the live display.

New lines for the PPR recording can be aded using the  button.

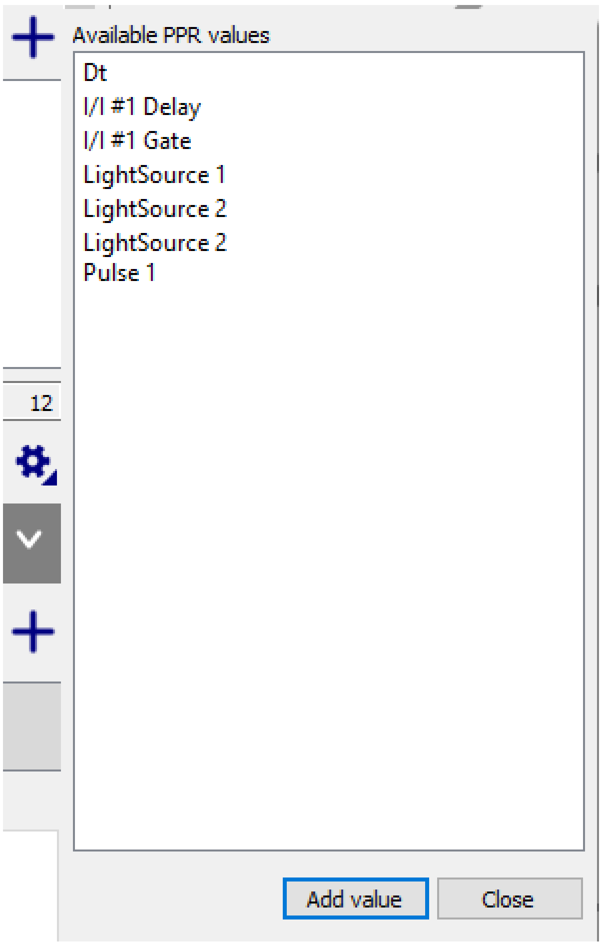
Lines van be deleted using the button on the left end of the PPR table.

PPR values can be edited by clicking on the button or double click in the table.

The button switches the input values between scaled (=time or °CA) and unscaled values (=images).

The button adjusts the input values to valid grid.

The button opens the list of available PPR parameters that can be added to be PPR table. The content of this list depends on the devices in the system.



Available PPR parameters:

Dt: the PIV Dt between the two laser pulses can be changed during the cylce to achieve optimal particle displacement for different flow velocities.

Light source #: The light source can be set to On or Standby for different subranges oft he cycle.

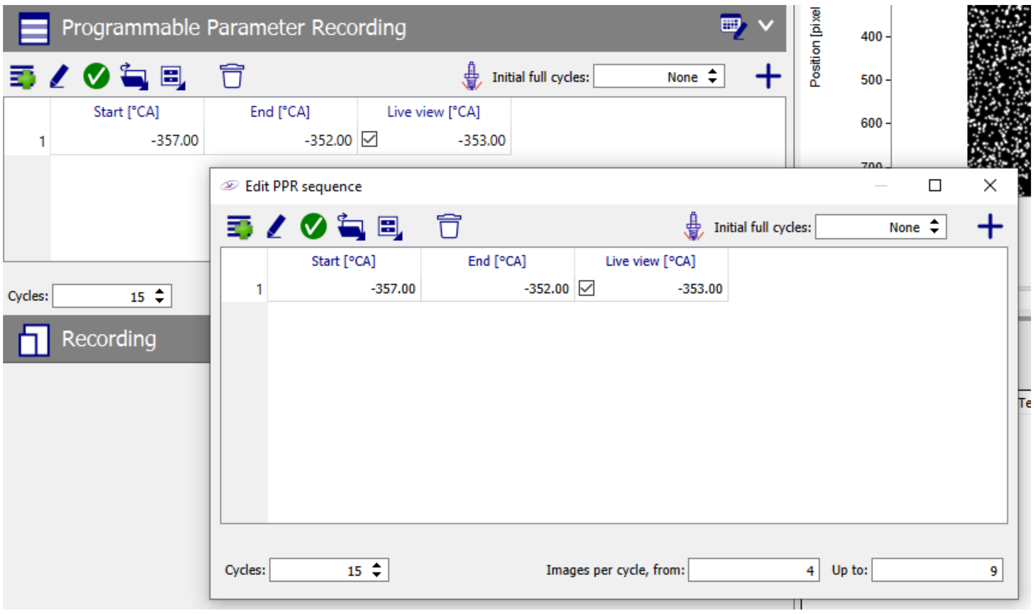
Light source # Pulse #: the pulse lenght (=illumination duration, light level) of a gated light source can be changed during the cycle.

I/I # Gate: The gate of an image intensifier can be changed during the cycle. The intensifier has to be set to Direct mode in this case.

I/I # Delay: the delay for the image intensifier can be changed during the cycle. The gate can be shifted relative to the reference time with this parameter. The intensifier has to be set to Direct mode in this case.

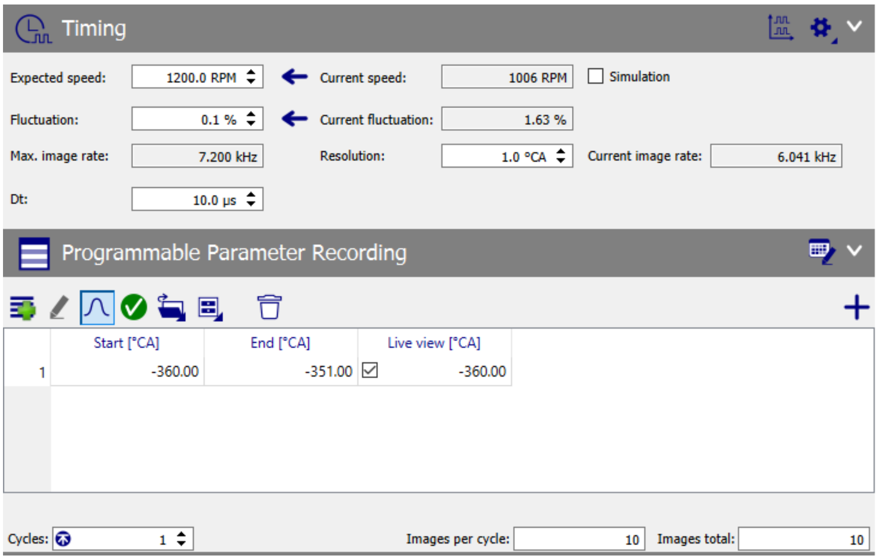
Another PPR sequence table can be opened in a free floating window, which is resizable. To do so, one has to click the Table edit button at the right of the Programmable parameter recording section header. This window is useful in case the PPR sequence contains more than a few entries. It stays open even if the PPR section is closed.

Both tables, the one in the PPR section and the one in the floating window, are always in sync, such that changes in one table affects the other table too.



PPR tables can be exported in csv format using the button. The tables can be edited or created in external software and also be imported into **DaVis**.

5.3.4 High-speed Engine Based measurement domain



The measurement domain High-speed engine based enables measurements on IC or other rotary engines. The devices are directly synchronised to the rotary decoder of the engine via the PTU.

The current engine speed and fluctuation is constantly measured by the PTU. The expected engine speed and fluctuation can be entered manually. The measured values can be transferred to the input text boxes using the ← buttons.

The resolution can be selected in the step width of the rotary decoder. Please refer to chapter Rotary Decoder Setup 4.3.2 for the configuration of the rotary decoder setup.

The engine signals can be simulated at a selected speed in order to test the measurement before the engine is actually turned on.

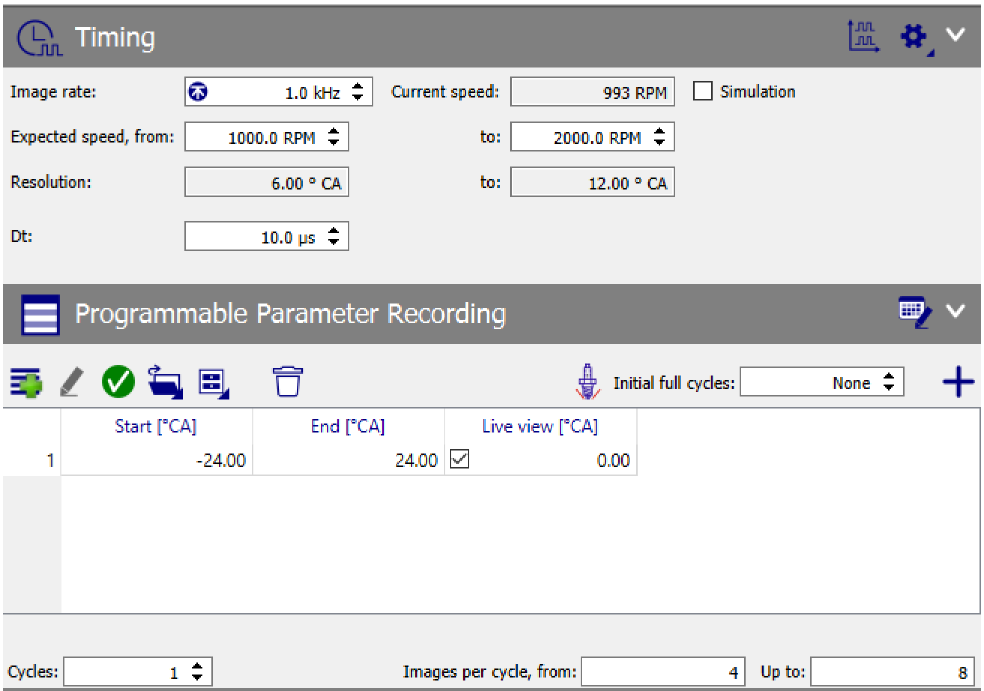
The image rate is based on the engine speed, the fluctuation and the resolution.

E.g. at 1200RPM, 5 % fluctuation and 1°CA resolution the maximum expected image rate is 7579Hz. The devices in the system are configured to this rate so that they also can be operated at frequencies below that.

The recording ranges (start and end) can be specified in °CA or image number. The live mode is phase locked, each displayed image is taken at the same position in the cycle. The image number for the live display can be selected in the Live view column.

If the PTU is equipped for Programmable Parameter Recording (PPR) the recording can be configured for multiple subsets within the cycle and the recording parameters can be adjusted dynamically during the cycle. Please see section Programmable Parameter Recording 5.3.3 for further details.

5.3.5 Hypersampling



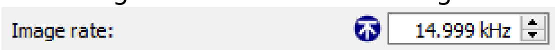
The measurement domain High-speed Hypersampling enables measurements on IC or other rotary engines with strong speed changes. In contrast to the measurement domain High-speed Engine Based the devices are **not** directly synchronised to the rotary decoder of the engine via the PTU.

The devices operate on a fixed selected rate. The digital sampler that is required for Hypersampling records the timestamps of the engine encoder as well as the timestamps of the devices.

The timestamps are used to display the recorded images either on a regular crank angle grid or with the exact angle information of the recording position.

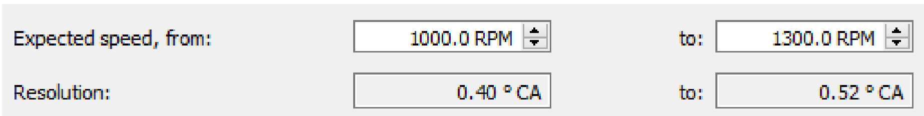
The PTU monitors the the engine position constantly. The recording is started if the engine reaches the selected start position and is stopped if the engine reaches the selected end position. Thus the number of images for a selected crank angle range changes with the engine speed and is not pre-determined. For this reason also the number of cycles that can be recorded are not pre-determined.

Photron cameras must be configured for 'f-sync only while recording' in the hardware setup.

The image rate for the recording can be selected in the Timing widget:


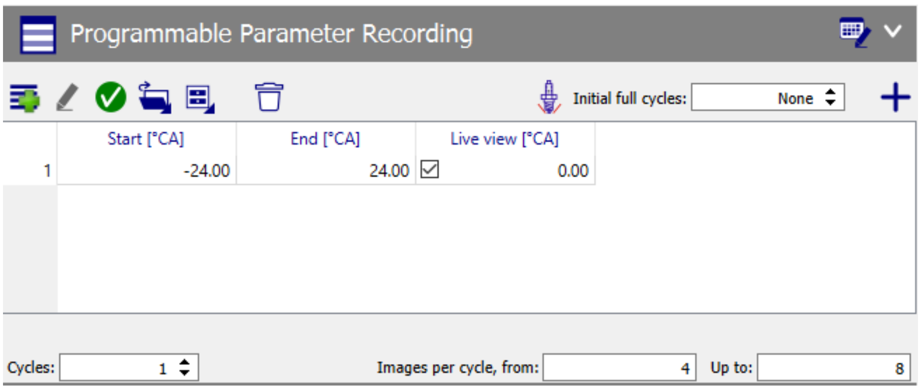
it can be set to the maximum possible value using the button. The maximal rate is limited by the slowest device in the system. The currently measured engine speed is displayed in the timing widget.

The user has to specify the expected speed range for the recording:

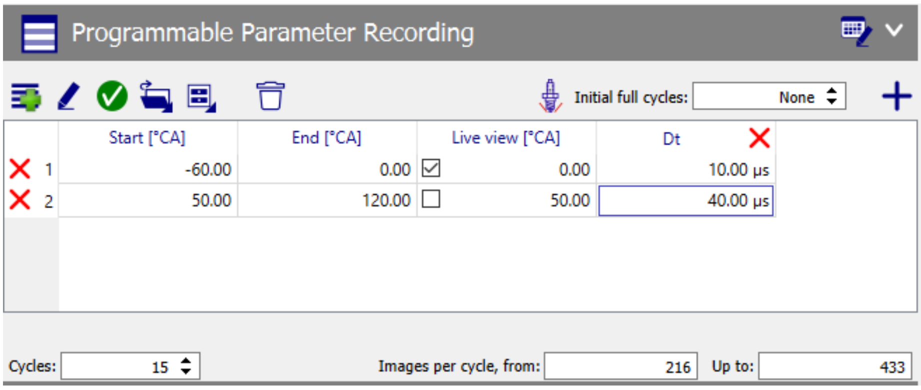


Based on the selected image rate the resolution is displayed. In the example an engine speed of 1000RPM and image rate of 15kHz the resolution is 0.4°CA, meaning images are recorded every 0.4°CA. At an engine speed of 1300RPM the resolution is 0.52°CA, an image is recorded every 0.53°CA at this engine speed.

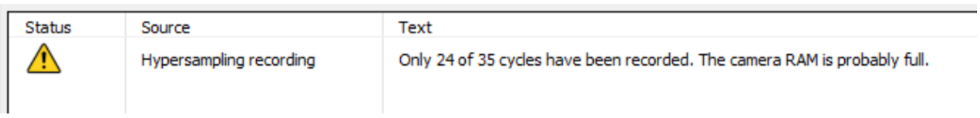
The recording range in the cycle and the number of cycles can be selected in the PPR table.



If the PTU has the PPR feature multiple sub-ranges in the cycle can be selected and different values - like the dt - can be changed during the cycle. The gap between consecutive PPR steps (sub-ranges in the cycle) has a minimum of two image clocks. Please see section Programmable Parameter Recording 5.3.3 for further details.

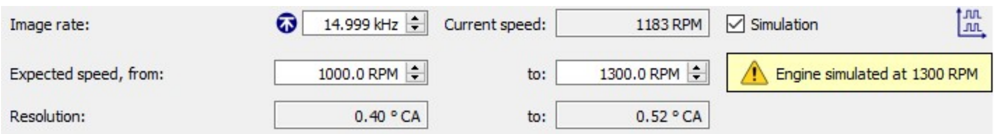


The user can select a number of cycles for the recording. The number of cycles that can be recorded is not pre-determined. It depends on the image rate, the °CA range and the engine speed - the number of images that are recorded during a cycle at a given image rate and recording range increases with decreasing engine speed and vice versa. In case the selected number can not be reached during the recording **DaVis** issues a warning:



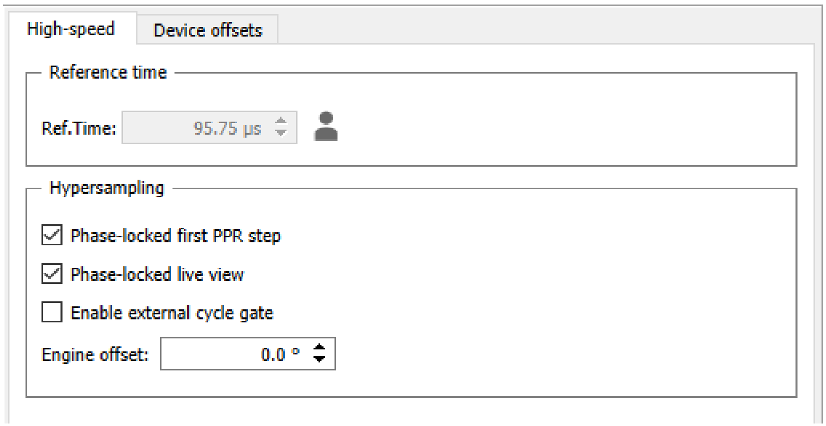
The recorded cycles can be stored and used for further data processing.

If the **Simulation** is checked the engine signals are simulated by the PTU at the speed of the higher value of the expected speed range.



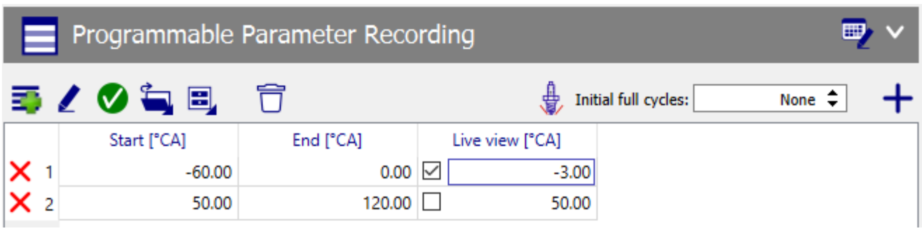
Details

The button opens the Hypersampling Timing details dialog:



Phase-locked first PPR step: If this option is checked (default) the recording is started at a fixed phase in each cycle. If the option is unchecked, the recording is started with the first selected recording phase. As the devices have no fixed relation to the engine, the actual start of the recording has an uncertainty. The actual start can jitter from cycle to cycle. The maximum delay is one image clock.

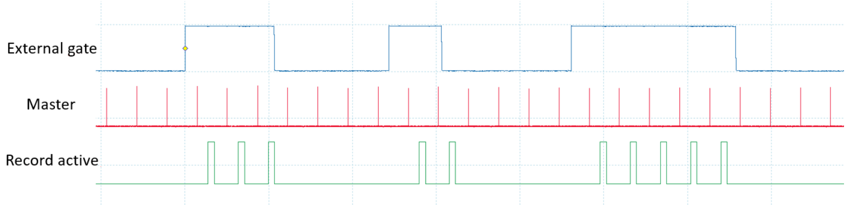
Phase-locked live view: If this option is checked (default) the displayed live image (on take or grab) is from a fixed phase position in the cycle. The phase of the displayed image can be selected in the Live view column of the PPR table:



If the option is unchecked, live images are taken as fast as possible and taken at arbitrary phases. The Live view column in the PPR table has no relevance in this case.

Enable external cycle gate: If enable external cycle gate is checked an additional TTL signal can be used to control the recording. The additional signal has to be connected to the **Start** input of the PTU X. A cycle is recorded if the external gate signal is high at the time of the Master signal from the rotary encoder of the engine ((before the engine offset is applied). A cycle is not recorded if the gate signal is low. This feature enables recordings of e.g. skip fire scenarios or the user can select the relevant parts from a test cycle (e.g. WLTP).

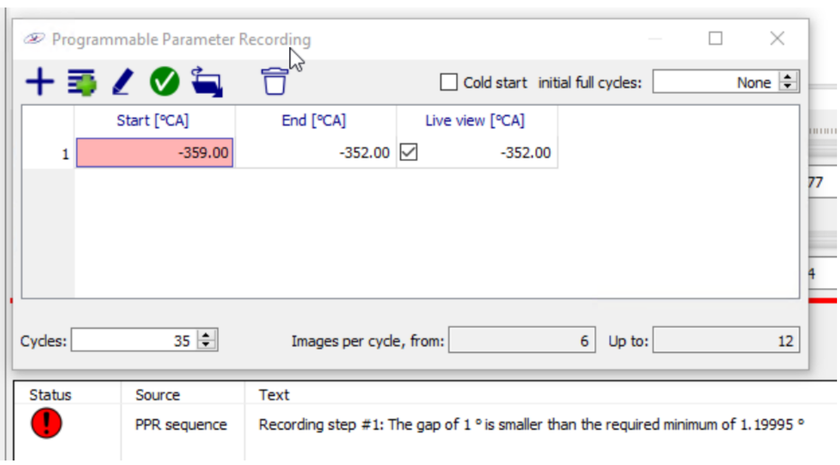
Example:



DaVis stores the cycle number information as attributes with the data. The attribute *AcqCycle* counts the number of recorded cycles. The value of the *AcqCycle* attribute for the first recorded cycle is 0. The value is incremented by 1 for each cycle. The attribute *Acq.AbsoluteCycle* counts the cycles of the engine. The value of the first recorded cycle is 0. For following consecutive cycles the value is incremented by 1 for each cycle. Cycles that are not recorded also increment the value by 1. For the example above the values for *AcqCycle* are 0,1,2,3,4,...,9. The values for *Acq.AbsoluteCycle* are 0,1,2,8,9,14,15,16,17,18.

Engine offset: the offset of the rotary encoder relative to the 0°CA position can be set here. For further details also see 4.3.2 Rotary Decoder Setup.

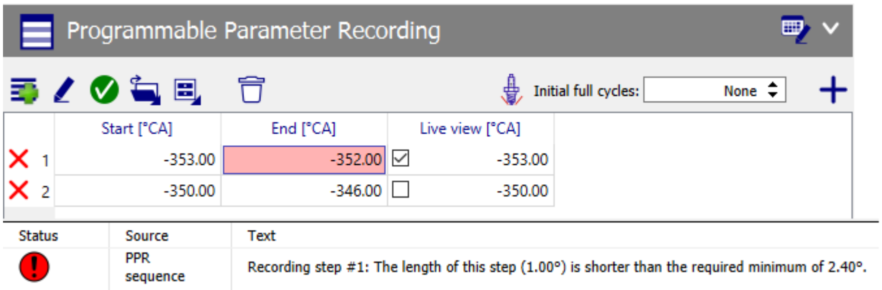
The earliest start CA is at the equivalent of one image clock after the start of the cycle (master trigger). **DaVis** issues an error in case the selected start value is not possible:



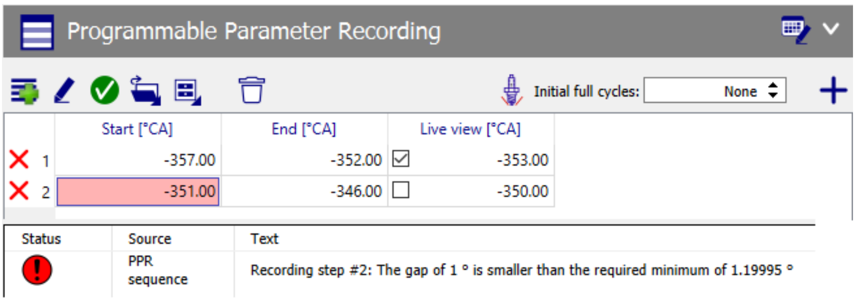
Example:
Image rate: 10kHz. Expected engine speed 1000 to 2000 RPM, resolution 0.6°CA to 1.2°CA. The earliest start °CA is 1.2° as the image period of 100us equals 1.2°CA at the expected highest engine speed of 2000RPM. Note: the selectable start and end values are limited by the resolution of the rotary decoder. If the decoder has a resolution of 1°CA, the earliest start ° would be 2°.

In order to avoid the error the start value or the image rate can be increased or the expected maximum engine speed can be reduced.

The minimum record active time is the equivalent of two image clocks. **DaVis** issues an error if the length of the recording step is too short:

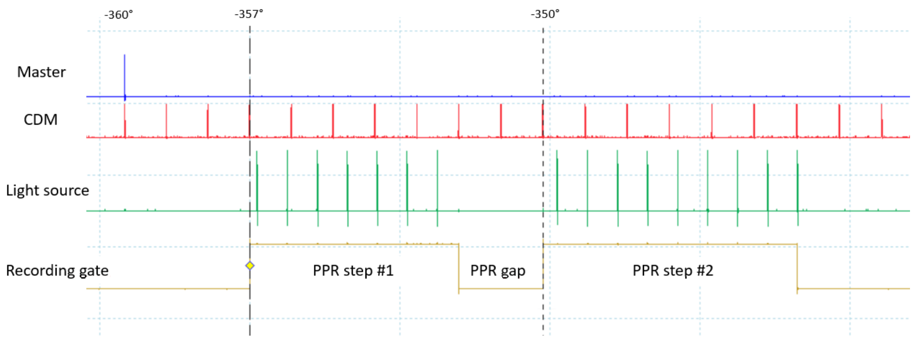


For PPR the recording of sub-ranges in the cycle is started and stopped in the same way. Therefore the gap between PPR steps has to be minimum the time equivalent of one image. **DaVis** issues an error in case the selected gap is to small for the selected parameters:

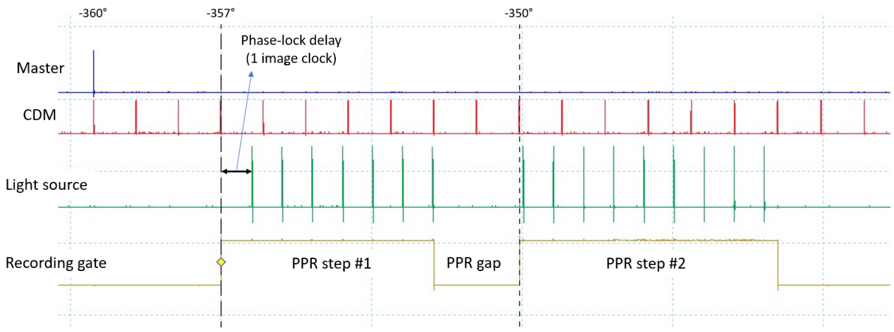


In order to avoid the error the start value of the second PPR step or the image rate can be increased.

Timing plot for recording without phase locked first PPR step. The delay between the selected start °CA and the first image differs from cycle to cycle:

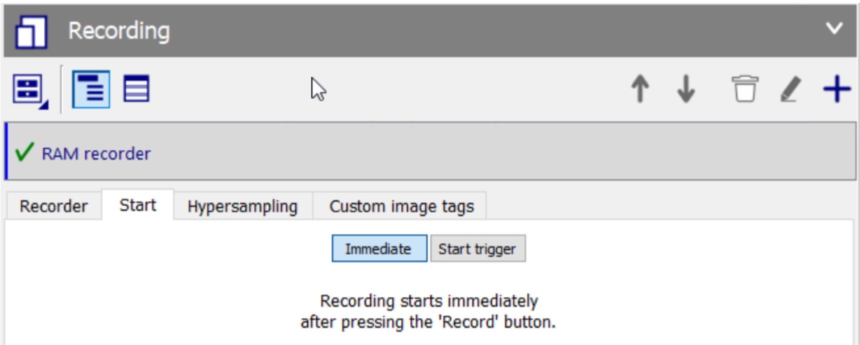


Timing plot for recording with phase-locked first PPR step. The first image is recorded with a fixed delay of one image clock relative to the selected start °CA:

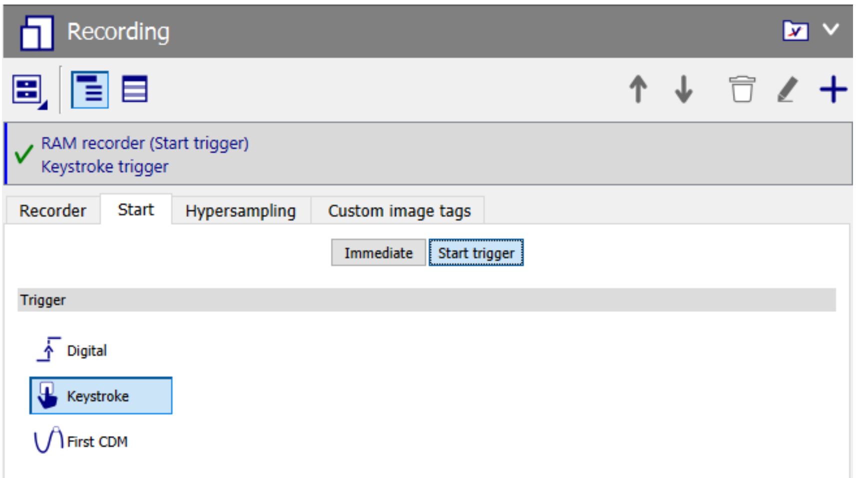


Start conditions

Immediate: after the Record button is clicked the devices are programmed and the recording is started with the next cycle start.

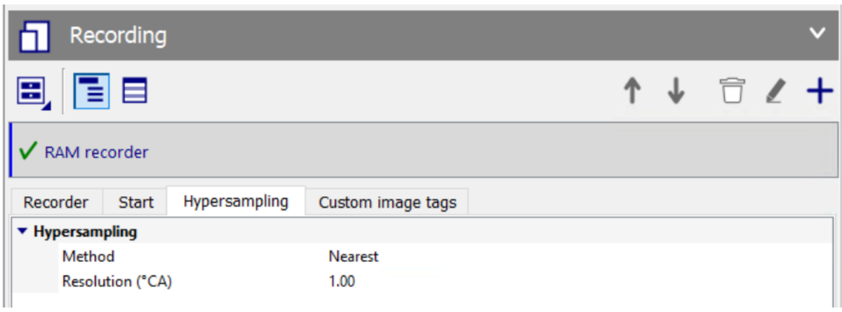


Start trigger: after the Recod button is clicked the system waits for a TTL signal on the PTU Start input or keystroke (whatever is selected as start condition) and starts recording with the next cycle start after that.



Hypersampling options

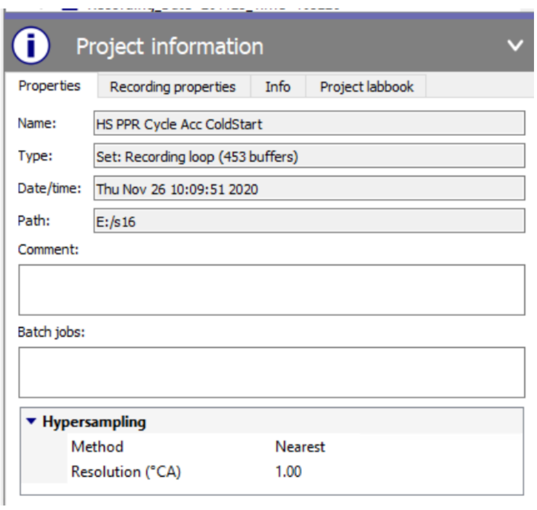
The Hypersampling display options can be set in the **Hypersampling** tab in the recording widget.



Method Nearest: the recorded images are displayed on a regular °CA grid with the selected resolution. The selected display resolution can be larger than the resolution of the rotary decoder. The minimal selectable resolution is limited by the resolution of the rotary decoder.The cycle and phase information can be displayed with the images using the attributes *AcqCycle* and *AcqPhase*.

Method Raw: the recorded images are displayed as recorded. The attribute *AcqPhase* contains the exact engine phase at the time of the image recording.

For stored data the Hypersampling options can be set in the **Properties** tab of the Project information widget:

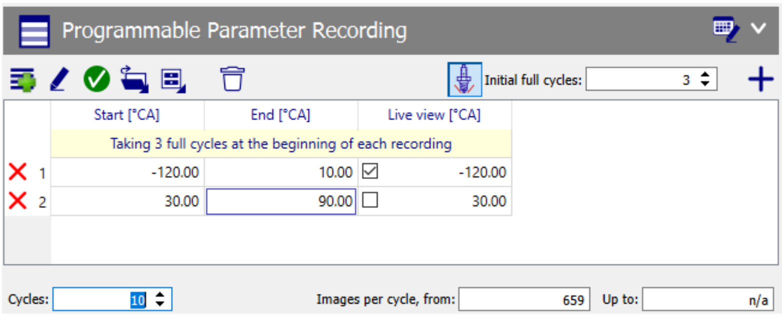


5.3.6 Hypersampling Cold Start add on

The Hypersampling recording functionality can be extended with the Cold Start add-on 1108260 or 1108267. Additional functionality is:

- selectable number of initial full cycle recording before switching to PPR recording.
- the recording can be started by the first CDM signal of the engine.
- the recording can be started by TTL input before the engine is started. The system records time based before the engine is started to capture initial engine relevant data before switching to crank angle based recordings.

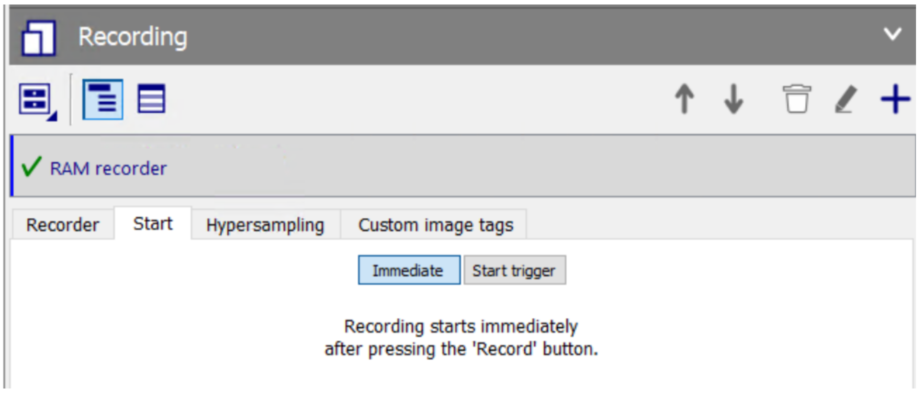
With the add on the Cold start option in the PPR dialog can be activated.



Please note: the initial full cycles can not be controlled by the external gate option (see chapter 5.3.5). the initial full cycles are recorded directly at recording start. Following cycles as defined in the PPR table can be controlled by the external gate option.

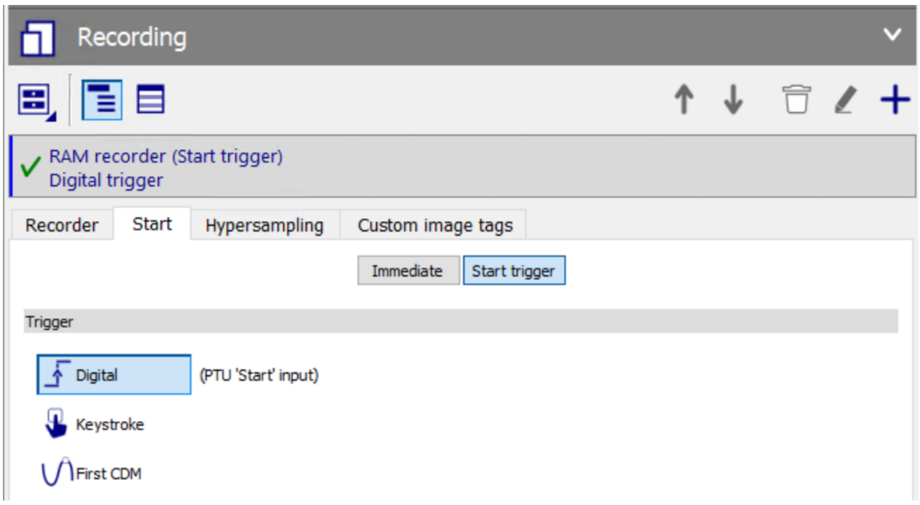
Initial full cycles: prior to the PPR cycles a selectable number of full cycles including a first part-cycle are recorded.

Start conditions Immediate:

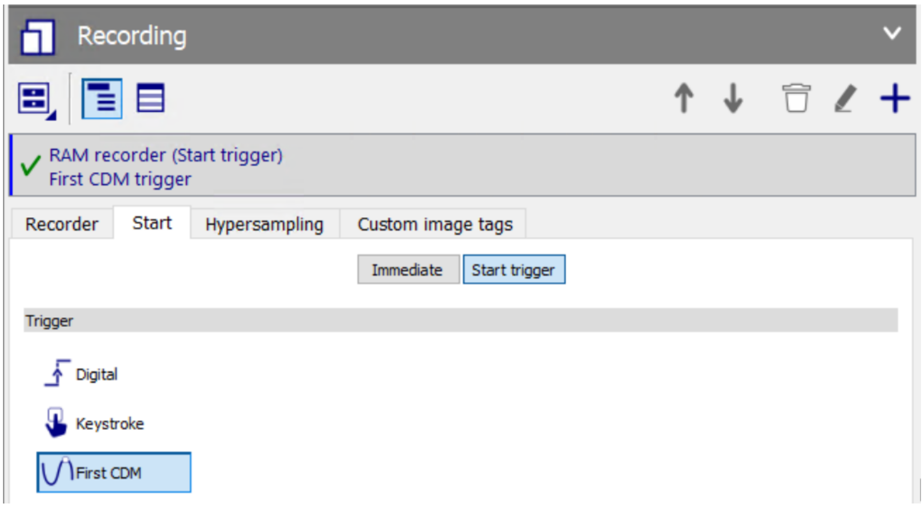


The recording is started immediately after the Record button is clicked.

Start trigger:



Digital / Keystroke: the recording is started if a TTL signal is send to the Start input of the PTU or a key is pressed (if this option is selected). In case the engine is already running, the initial cold start cycles are recorded before switching to PPR recording. If the engine is not yet running on recording start. The system starts a time-based recording. The engine can be started during the system is already recording to switch to crank angle based recording. The recording stops if all cycles are recorded or if the camera RAM is full. **First CDM:**



The recording starts with the first CDM signal that is send to the PTU after the Record button is clicked.

5.4 Reference Time

The "Reference Time" describes the time between the PTU trigger and the moment when the image is taken or illuminated by a pulse light source. This is limited by the intrinsic delay of all activated devices. In case of periodic triggers, the PTU has strategies to overcome this restriction and allow zero or negative Reference Times. Multiple independent Reference Times allow grouping of devices around a certain time with respect to the external trigger. Information about how to configure the Reference Times are described in chapter 4.2.2.

5.4.1 The Concept of Reference Time

When synchronizing lasers and cameras (and other triggered devices), a common reference point in time is needed. The most important moment for laser imaging systems is when the light pulse from the laser illuminates the measurement section and interacts with the fluid, which leads to camera exposure. This moment is called the "Reference Time" in the PTU timing schemes. All devices need an electrical signal before this Reference Time. Cameras need to activate their sensor, lasers need to be charged with a flash lamp, and other electronics also have an intrinsic delay. **DaVis** takes the individual timings into account and triggers each device individually earlier before the "Reference Time". The target is to have all devices ready for exposure at the same moment.

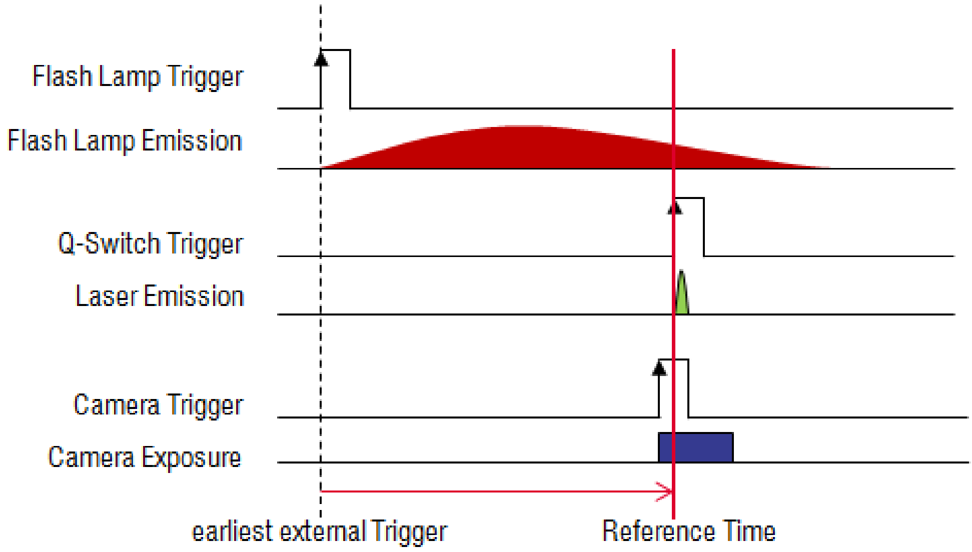


Figure 5.15: Reference time with a single laser and camera

The timing diagram in Fig. 5.15 shows the Reference Time ("red line") for a system consisting of a single frame camera and a single pulse Nd:YAG laser. The laser needs two trigger pulses. One directly at the emission ("Q-Switch") and one much earlier to activate the flash lamp for pumping the laser ("Flash Lamp Trigger"). Light is emitted at the Reference time, but the laser and the camera must be triggered before. When the PTU will be triggered externally, there is a minimum time between the external trigger (dashed line) and the emission of light. The important concept of the PTU is that it tries to keep the delay between external trigger and Reference Time constant. The timing scheme does not simply start with the first pulse, but it refers to the Reference Time. In order to determine the minimum delay, set the delay to zero ("0") and the PTU will correct this to the minimum. The determined minimum time depends on the state of activated devices: it could change when you activate / deactivate a device such as a laser or camera or change the laser's operation mode. It is recommended to set the Reference time to a meaningful delay longer than the intrinsic delay of all devices, e.g. to 0.5ms.

Example: The laser power is varied by changing the time between Flash Lamp Trigger and Q-Switch Trigger. For maximum power, it is set to 180 μs, and for lower power to 400 μs.
Once the Reference Time is set to 0.5 ms after external trigger, the PTU

keeps this moment constant. While changing the laser power, the Flash Lamp Trigger becomes earlier or later, but the moment of light emission stays the same.

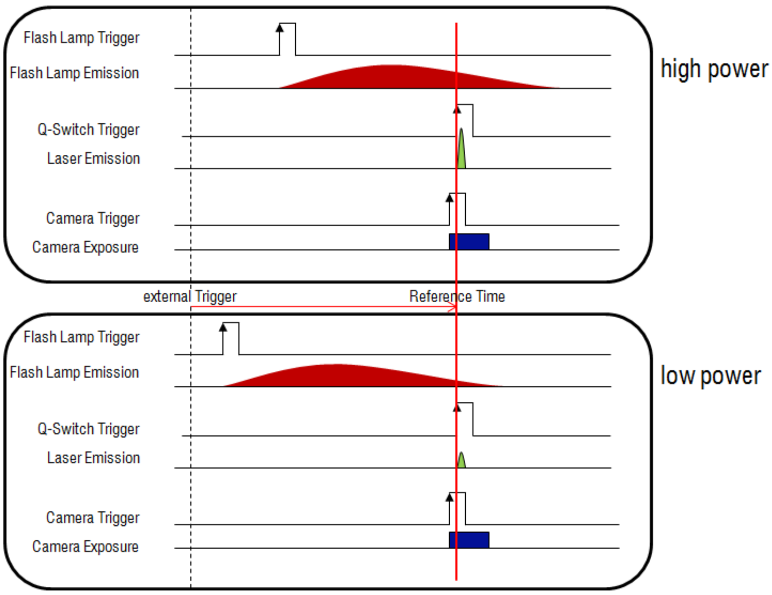


Figure 5.16: Changing the laser power by shifting the flash lamp trigger to an earlier time, while keeping the Reference Time constant.

The reference time is set in the Recording/Timing card and given in milliseconds, or in degree phase angle.

5.4.2 Reference Time and Phase Angle

The Reference Time could also be given as a phase angle instead of a time delay, as long as the trigger is periodically repeated and the definition of "phase" makes sense. This is true for the trigger modes "internal", "external cyclic" or in combination with a physical rotary encoder. Without a rotary encoder, the PTU measures the trigger frequency and converts the phase angle to time. With a rotary encoder, this conversion is based on counting the encoder signals. A full cycle between two triggers corresponds to 360° phase angle. The fundamental setting whether the time axis is given in time (milliseconds) or phase angle (degree) is made in the Hardware Setup/Timing card.

5.4.3 Reference Time for PIV

In case of PIV, the reference time is split into two points. The main setting refers to the first laser pulse, while the second laser pulse is delayed by the "PIV dt". In order to allow the Reference Time to have "double pulse" capabilities, it has to be marked as a double event in the Hardware Setup/Timing card.

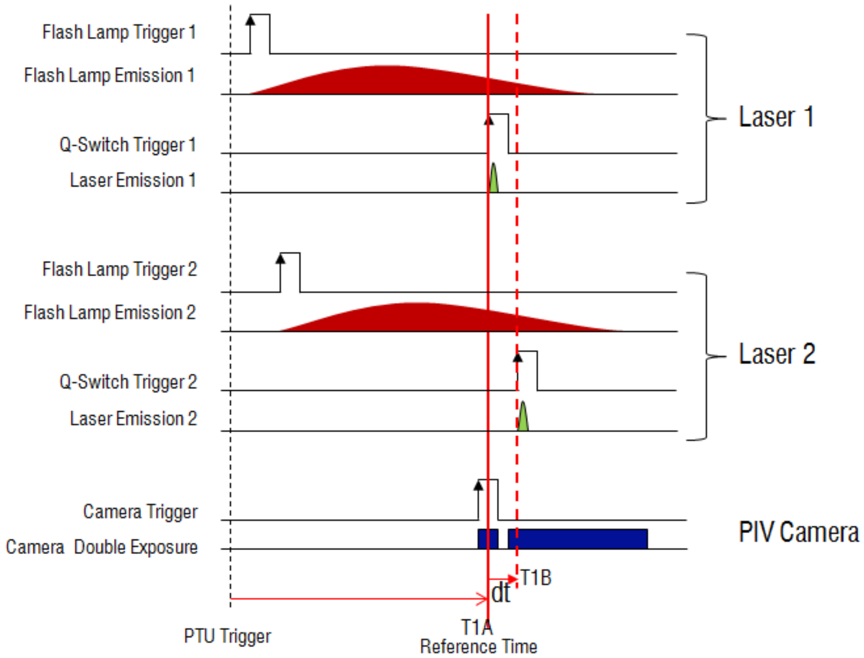


Figure 5.17

5.4.4 Notation of Reference Times

The PTU can handle up to 8 independent Reference Times, each with single, double or quad pulse capability. In order to distinguish the Reference Times, they are labeled according to the following scheme:
T<number_of_Ref_Time><A/B/C/D>
They are numbered from 1 to 8 for each independent Reference Time, and labelled "A" and "B" for the first and second pulse of a double pulse event, respectively. Single pulse events are labelled "A", quad evets "A", "B", "C" and "D".

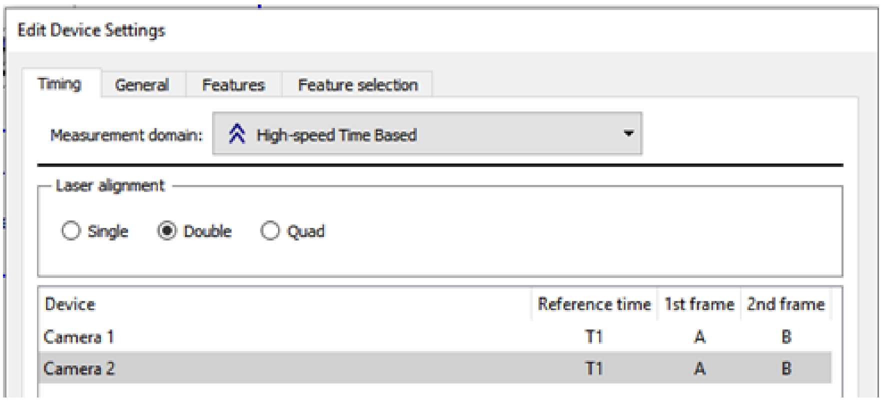
Example:
T1A = first Reference Time, first laser pulse
T1B = first Reference Time, second laser pulse
T2A = second Reference Time, first laser pulse

The "B" pulses are by "dt" later than the "A" pulses. This difference is always given in microseconds, whether the Reference Time itself is given in time or phase angle.

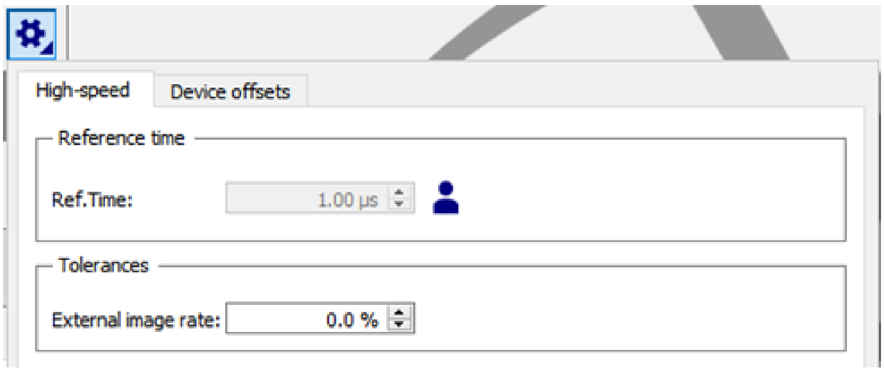
Example:
time based: T1A=1 ms, dt=10 μs $\rightarrow$ T1B=1.01 ms
phase angle based: T1A=60°, dt=10 μs $\rightarrow$ T1B=10 μs after 60°

5.4.5 Reference time in high-speed recordings

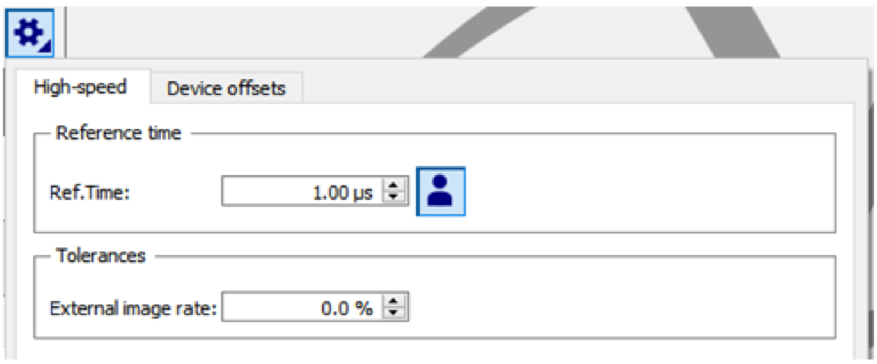
In high-speed recordings one reference time is available. Multiple referecne times are an exclusive feature of low-speed recordings.
The laser alignment fort he reference time can be configured to single, double or quad events:



The reference time can be accessed in the details of the timing widget:

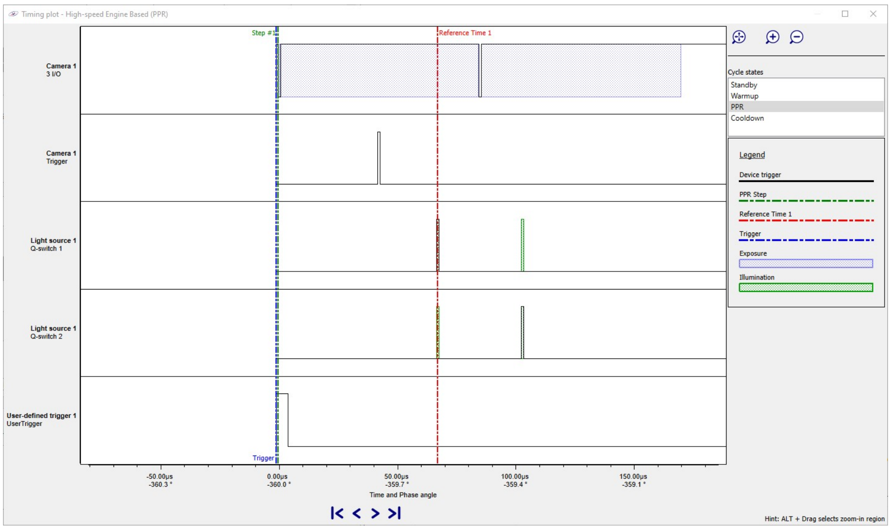


As default it is set to the earliest possible time automatically.
If required it can be set manually by the user:

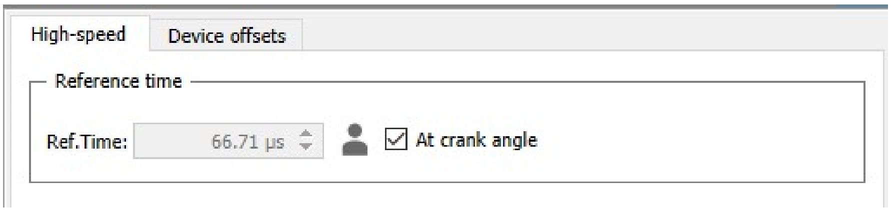


5.4.6 Reference time in high-speed engine based recordings

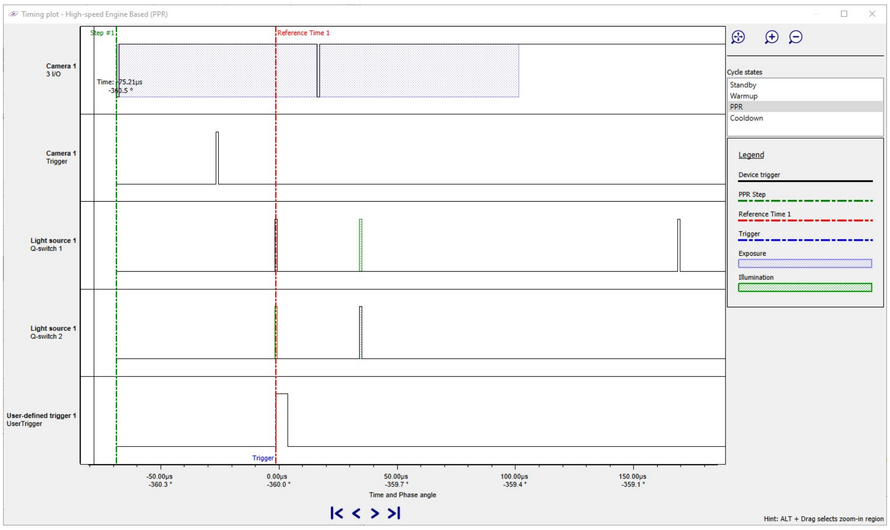
For high-speed engine based recordings the PTU sequence for an image is started at the desired crank angle. Depending on the recording settings like single or double frame, single or double aligner the reference time position is slightly later. The example shows double frame, double aligner, start image at -360°C CA.



In the details of the timing settings the reference time can be positioned closer to the desired crank angle by checking the 'At crank angle' option:



With this setting the PTU sequence is started earlier, so that the reference time is as close as possible to the desired crank angle position. By checking this option the automatic/user defined button is disabled.



Please note: the correction of the sequence start is based on the period of the incoming CDM signal and the expected speed. The reference time might be slightly off the crank angle position in case the CDM period is not an integer divider of the reference time. Fluctuations of the engine speed will also result in shifts between the desired crank angle and the reference time position.

> ⚠ **Note:**
>
> **The following chapters describe settings for the reference times that are only available for low-speed recordings.**

5.4.7 Negative Reference Times and Use of Phase Shifter

Once the trigger is periodic, i.e., it has a frequency, the PTU can predict subsequent triggers from the measured frequency. This allows to go to Reference Times which are shorter than the PTU Sequence or even to negative Reference Times. The length of the PTU sequence is derived from the intrinsic delay of activated devices, and determines the latest moment when the PTU sequencer needs to start.

Once the PTU detects that you enter a reference time shorter than the longest intrinsic delay of the activated devices, it will automatically take the trigger before. Or from another point of view: it elongates the Reference Time beyond the next trigger. A reduction of trigger rate is a consequence.

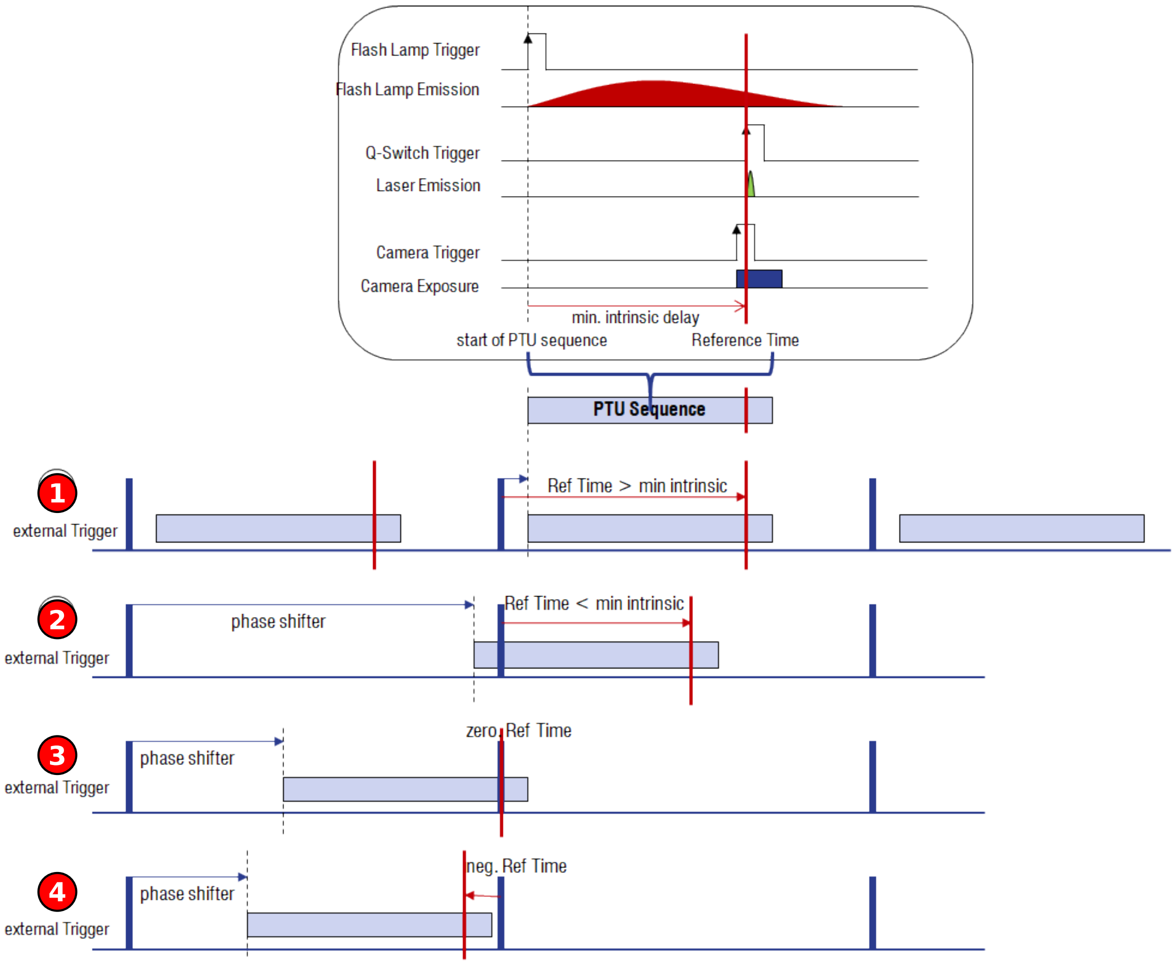


Figure 5.18: Reference Time in comparison to the length of the PTU sequence and its position relative to the external trigger.

Fig. 5.18 shows 4 cases with different conditions for the Reference Time and Start of PTU Sequence. The example in the screenshots is based on a PIV camera with a PIV laser. The laser needs the flash lamp 186 μs before Q-switch, therefore the minimum intrinsic delay is 0.186 ms.

1. The Reference Time is later than the minimum required intrinsic delay for all activated devices. This is the most common case. The start of PTU sequence is with or after the external trigger. The Reference Time (when light is emitted) has a fixed relation to the external trigger.

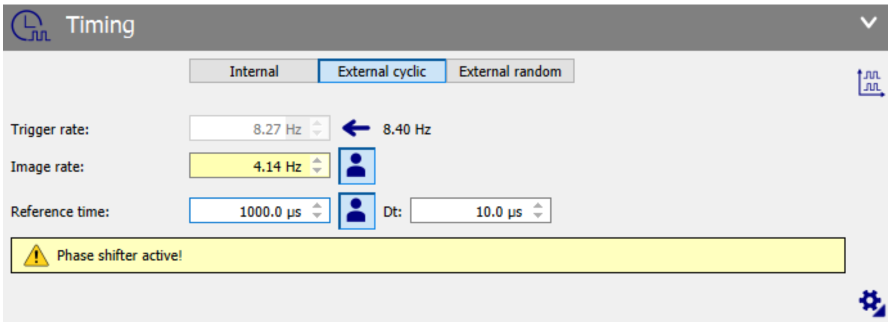


Figure 5.19: Reference Time (1 ms) is later than the minimum intrinsic delay (186 μs in this example).

2. The Reference Time is still after the external trigger, but it is shorter than the PTU needs to generate the entire sequence, e.g. the laser flash lamp is shifted to earlier time due to using the power control. Then, the PTU sequencer already has to run, before the external trigger arrives. This is only possible by trigger prediction when the trigger frequency is known. In this case, the previous external trigger is used instead, called "external pretrigger". Due to this need, the image rate is reduced, because only every 2nd trigger can be used.

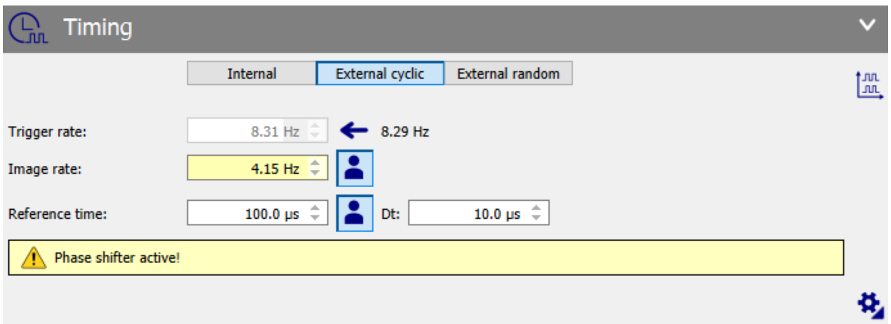


Figure 5.20: The Reference Time is still positive (0.1 ms) but shorter than needed to trigger the laser's flash lamp in time (0.186 ms).

3 The Reference Time could be exactly zero. I.e. the light is emitted while the trigger arrives. Same as in case 2 , this is obtained by using the previous trigger to start the sequence.

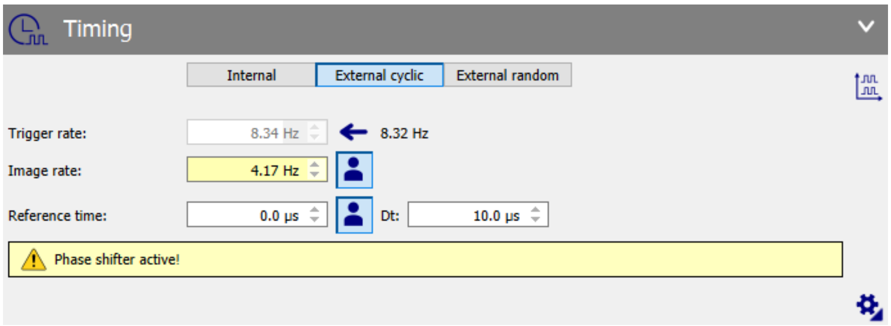


Figure 5.21: The Reference Time is zero. Light is emitted at the same time the external trigger arrives.

4 Even negative Reference times are possible.

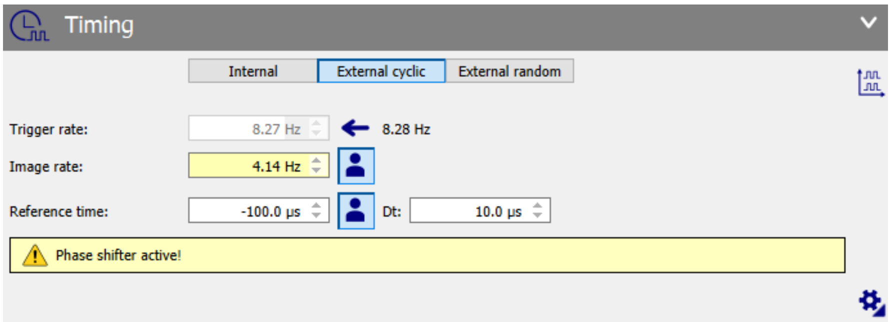


Figure 5.22: With a negative Reference Time light is emitted even before the external trigger arrives (trigger prediction).

"Phase shifter active"

When predicting the next trigger for the above cases 2 - 4 , good stability of the external trigger frequency is essential. The more stable the trigger frequency is, the more precise the prediction and timing is. If the frequency of the external trigger varies, then the moment when the measurement takes place will also vary with respect to its nearest trigger.

In some cases, the external trigger is not sufficiently stable. In that case, the phase shifter gets automatically activated and the trigger prediction can be timed appropriate.

5.4.8 Multiple Reference Times (optional)

With **LaVision**’s advanced Intelligent Imaging Systems, you can simultaneously combine different techniques for your measurement task. This could mean that you have to measure at several independent times or phase angles at the same event.

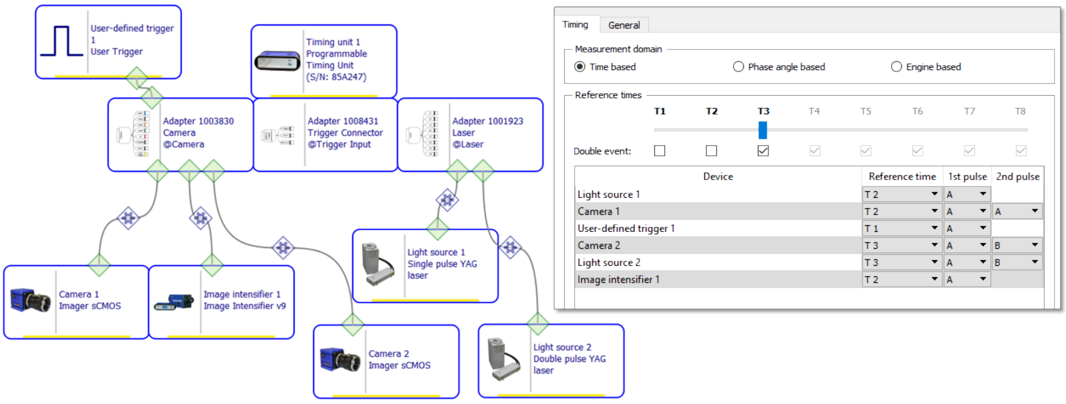


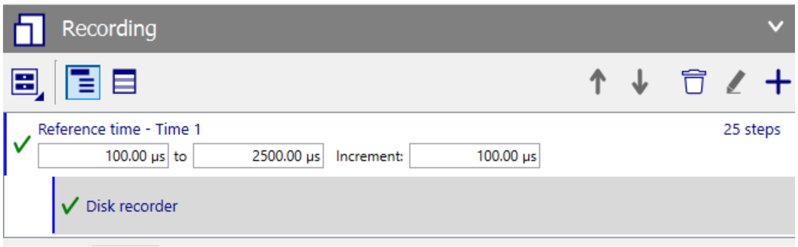
Figure 5.23: Example for a combined system with multiple reference times.

Example:
You want to measure a flow field in an early stage of an automotive fuel injection with LIF and a bit later with PIV. Both events are independent from each other, so your LIF is somewhere just after the injection trigger and the PIV must come later, but both are from the same main trigger. The PTU X supports this independent timing behavior with the reference times feature. You can upgrade your PTU according to your model to up to 8 independent events (reference times) per trigger. The software allows you to easily combine your devices with the reference times (see Fig. 5.23).

In the example above, you would go for three reference times. The 1st reference time (T1) actively triggers the injection as a user trigger, the 2nd reference time (T2) is bound to the LIF camera, the image intensifier (IRO) and the LIF laser, while the 3rd reference time (T3) is for the PIV camera and the PIV laser.

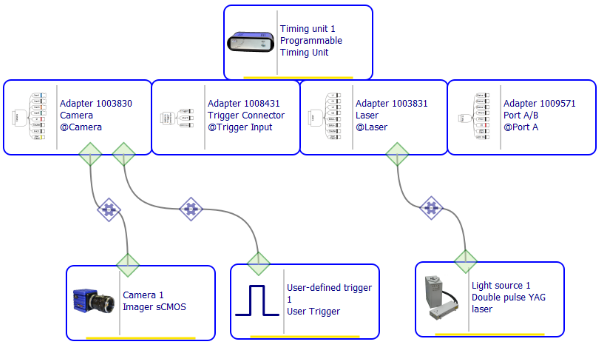
5.4.9 Time scan capability

The entire system can be triggered with respect to an external event or to an additional trigger output (user-defined trigger). The time scanning module of the **DaVis** software allows to record a certain number of images at different times automatically. To specify a time scan, select a start and end position of the reference time, as well as the increment. The latter defines the amount of steps taken during the reference time scanning.



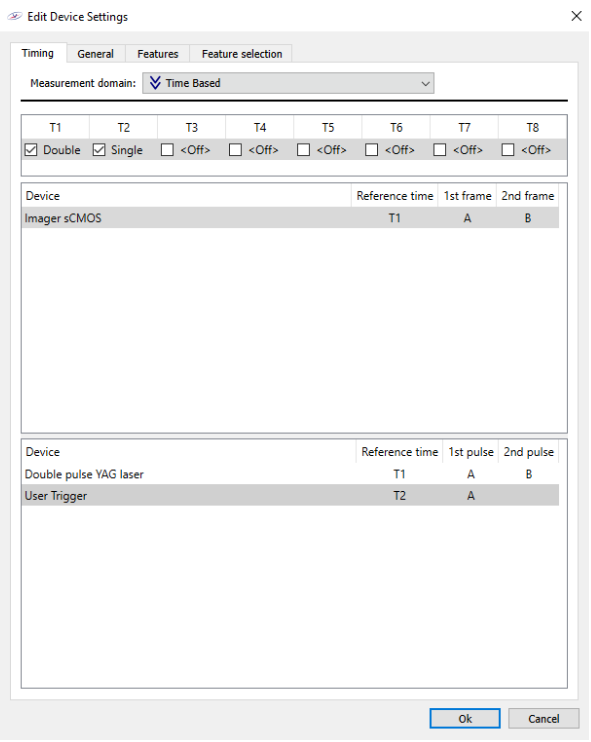
6 User-defined trigger

6.1 Hardware Setup Configuration



Additional to the trigger lines reserved for the laser system devices (e.g. camera and laser trigger), you can add up to eight programmable lines (restricted by the total number of lines, which is 24, including the device trigger lines), each with the full precision of the PTU X (10 ns). Each user trigger line can be bound to any reference time with an offset and a burst of up to five pulses. A burst consists of up to five pulses which are defined with respect to the reference time and an offset, freely programmable in its delay and length and polarity.

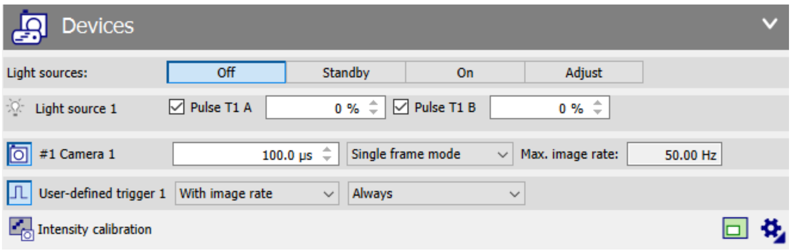
In order to add a user-defined trigger line in addition to other devices, drag-and-drop this device to the PTU. Click **Edit device settings** of the PTU in the **DaVis** hardware setup. On the **Timing tab** card you may select to which reference time the user trigger signal should be phase-locked to.



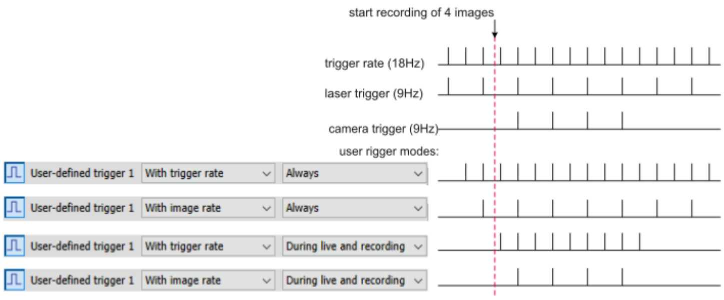
6.2 Recording

6.2.1 Low-speed Recording

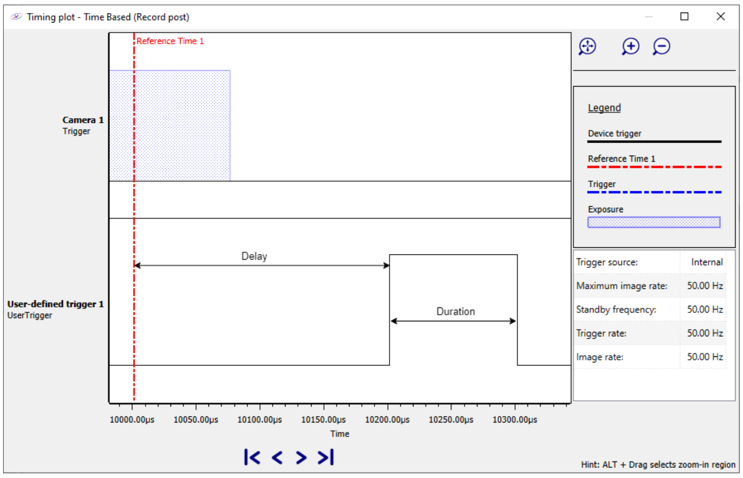
After the user trigger has been added to the hardware setup you may select the parameter for the user trigger in the **Device** section in the **Recording** dialog.



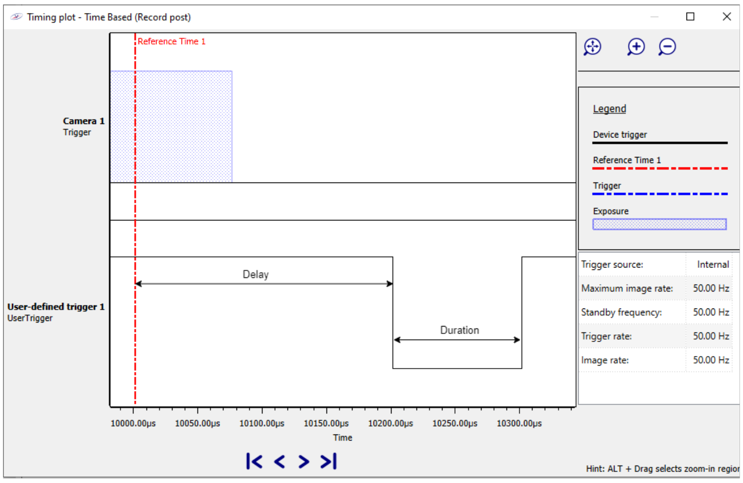
You can further select when the user trigger should be sent. This can be either **always**, **during live and recording**, **during recording**, or **during live**. And you can select the frequency of the user trigger. This can be **with trigger rate** or **with image rate**. Find an example of the resulting sequence for the user trigger below.



In the **User-trigger** tab, the **Polarity** of the trigger signal can be defined. Using the **Inverted trigger line** option you may determine the polarity of the trigger signal (off is positive 0V→5V, on is negative 5V→0V), as depicted in Fig. 6.1.



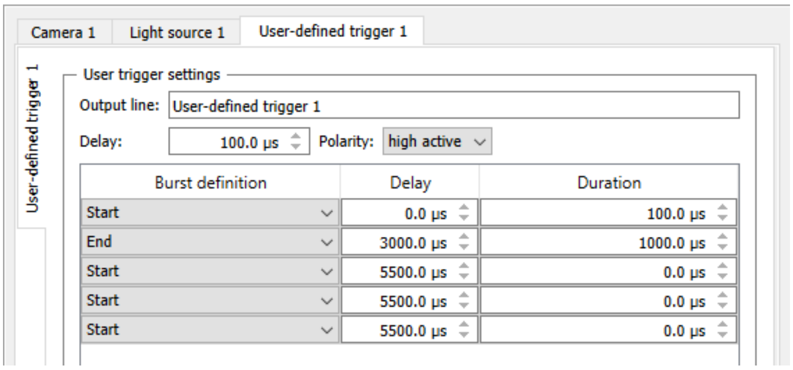
(a) High active polarity.



(b) Low active polarity.

Figure 6.1: Polarity of the trigger signal.

On the **User-trigger** tab you can select the delay with respect to the selected reference time and up to five delay-gate pairs. Further, the burst can be defined. Select the start point or the end of the burst and its respective delay and duration. For example: If burst **Start** is chosen, the burst starts at the time as defined in **Delay** and lasts for the time as selected as **Duration**. If burst **End** was selected, the **Delay** represents the end point of the burst and the starting point is referred to as the difference between **Delay** and **Duration**.



6.2.2 High-speed Recording

User-defined trigger settings for High-speed Cyclic Time Based and High-speed Engine Based measurement domains differ from low-speed measurement domains in some configurations.

The user trigger frequency can be set either **With active image clock** or **With each image clock**. If active image clock is selected, the user trigger is only active in the defined recording range that can be set in the **Programmable Parameter Recording** (PPR) dialog in the Timing section. More detailed information about the PPR dialog can be obtained from Section 5.3.3. In case each image clock is selected, the user trigger is active with each image clock. You can again specify when the user trigger should be sent. Choose between **always**, **during live and recording**, **during recording**, or **during live**.

7 PTU X Feature Upgrade

7.1 Preconditions

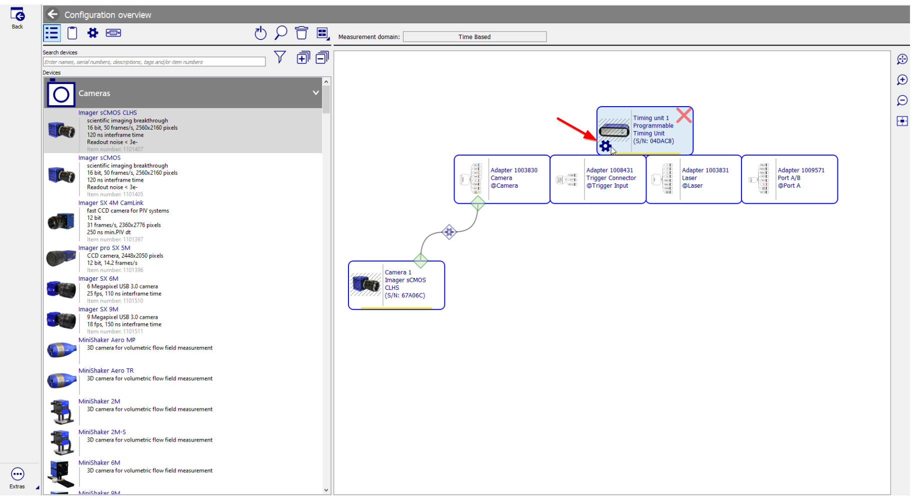
Before upgradig the PTU, please consider the following preconditions:

- A feature file for the PTU (ptu_*.bin)
- The serial number of the bin file has to match the serial number of the PTU to be upgraded
- A running **DaVis** should be connected with the PTU

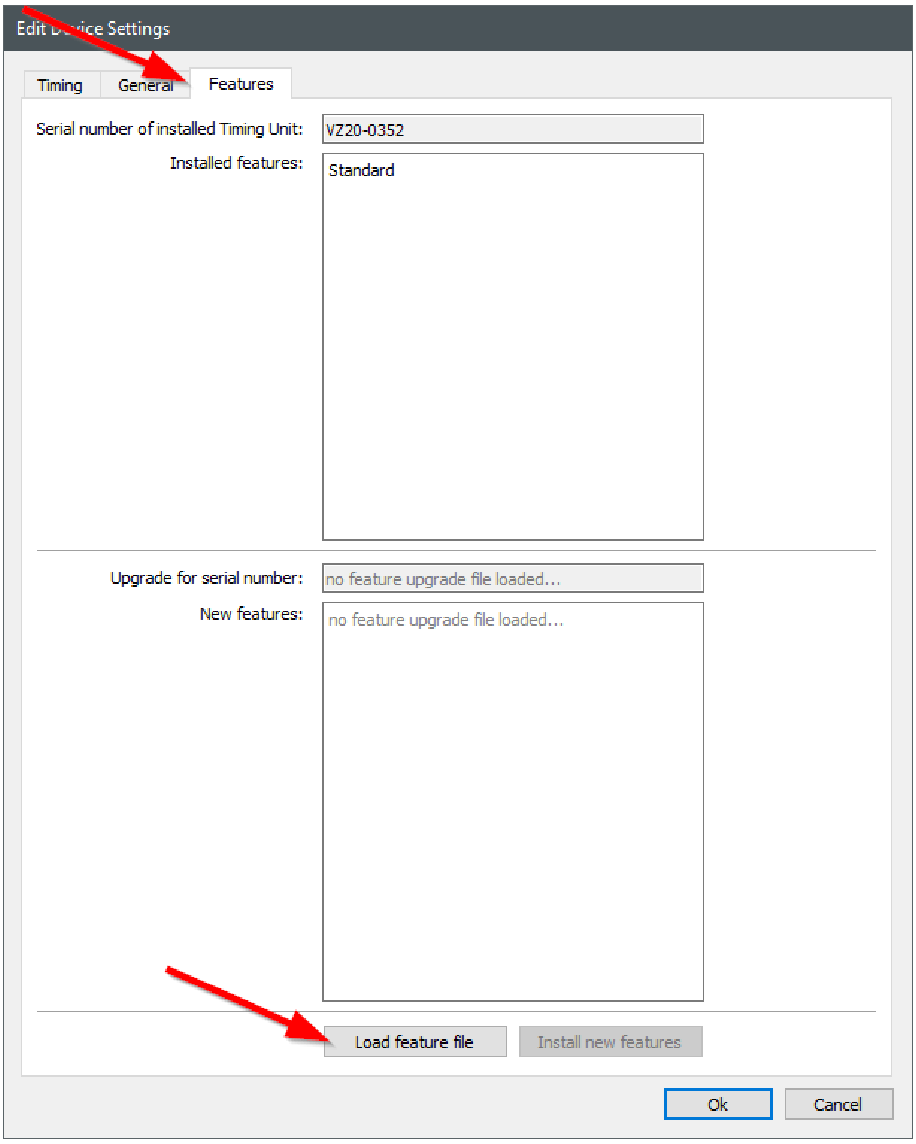
7.2 Upgrade procedure

To upgrade your PTU please follow the subsequent steps:

1. Save the feature upgrade file on your PC.
2. Start **DaVis** and enter the Hardware setup.
3. Initialize a PTU and camera devices.
4. Open the device settings of the PTU.

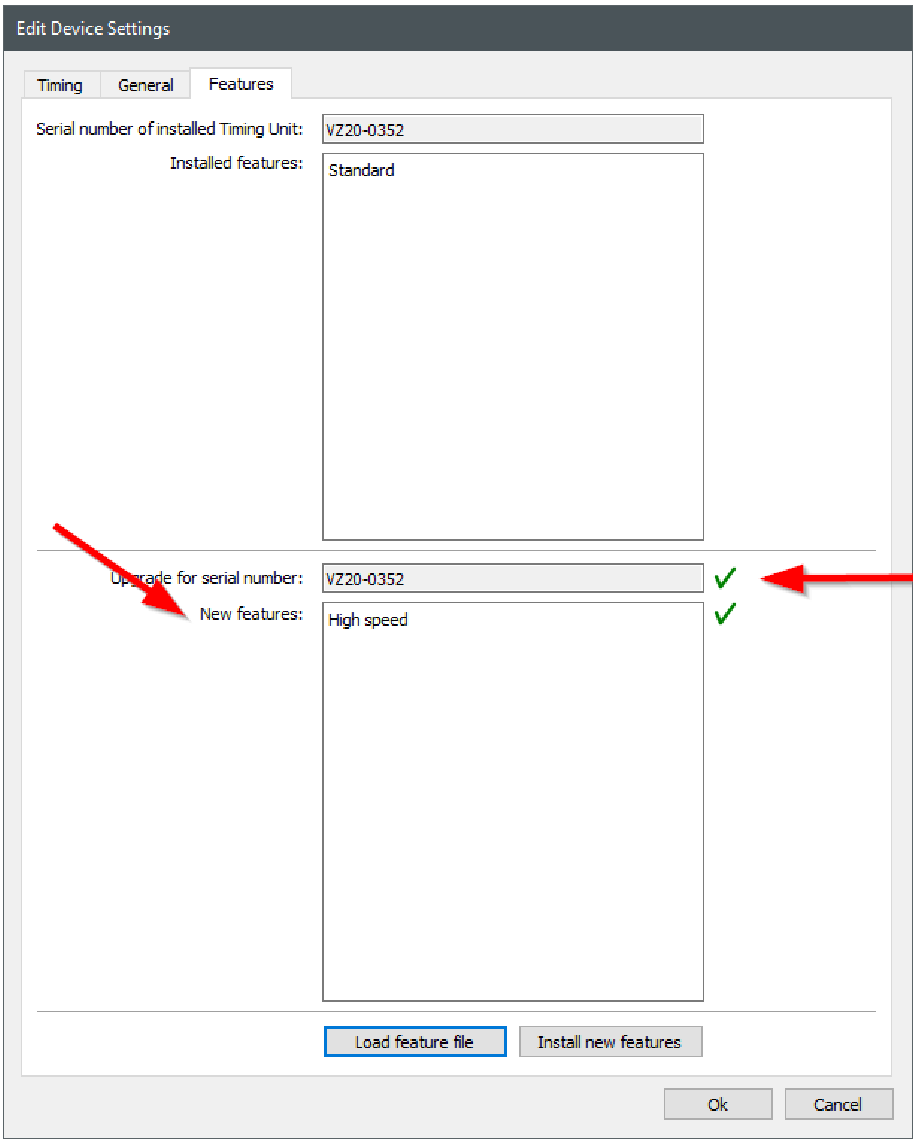


5. Switch to the **Features** tab an press **Load feature file**.

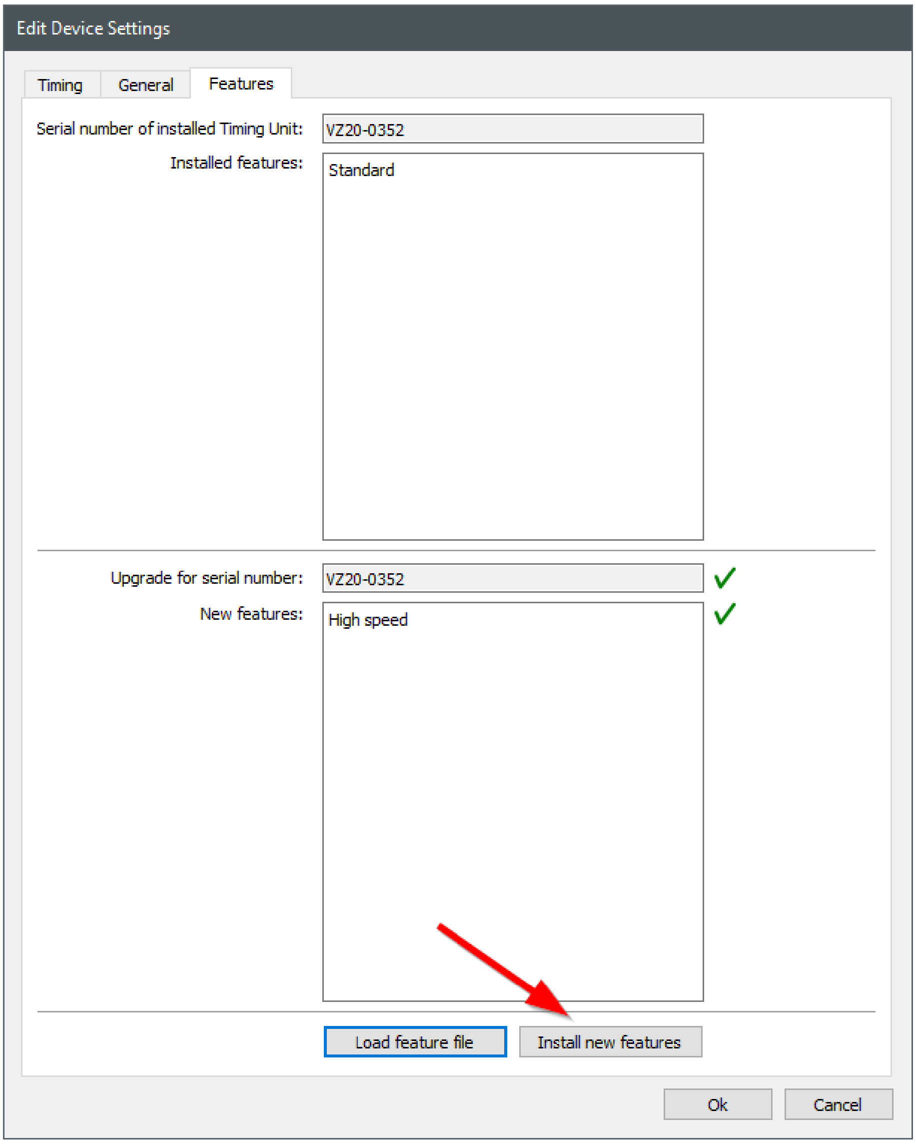


6. Navigate to the location of the feature upgrade file that was stored in the first step and select this file.

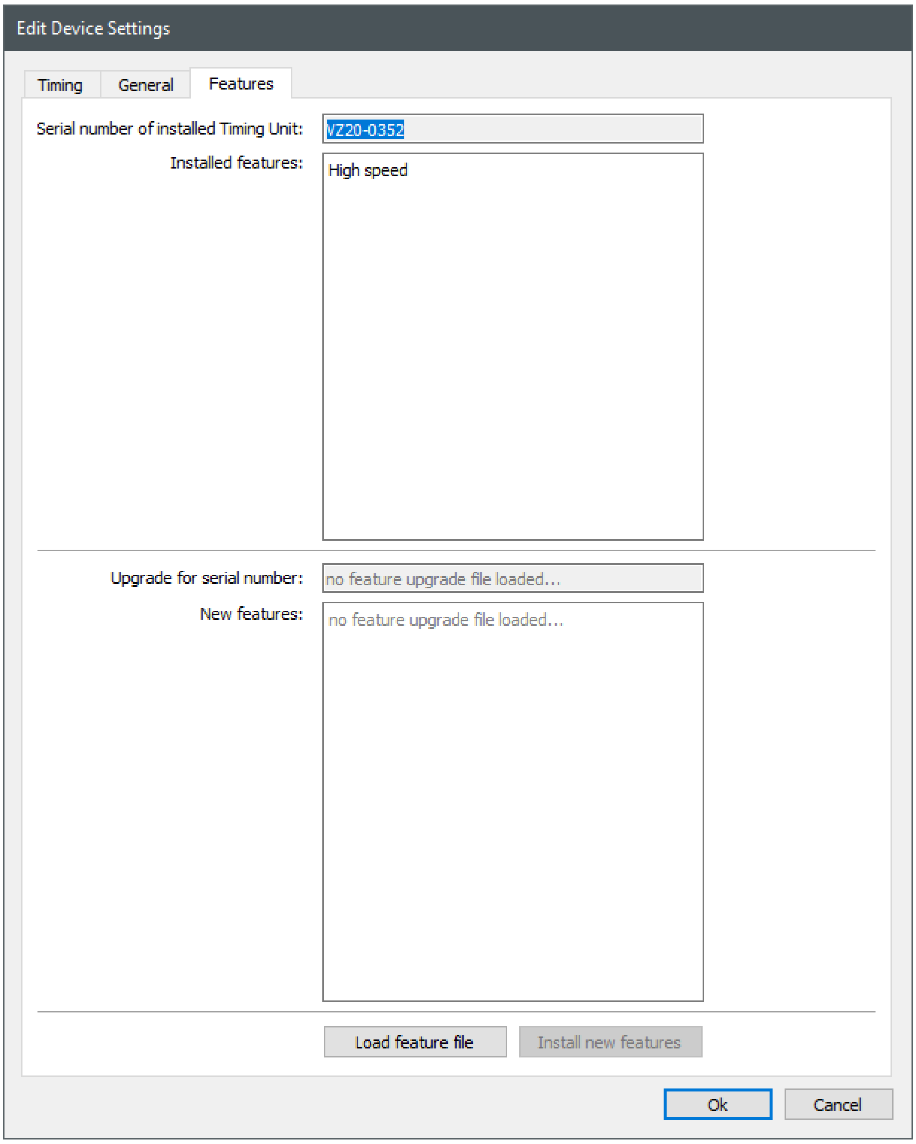
7. New features are shown in the lower part. If both the serial number of the PTU and the serial number of the bin file match, and new features are available, green check marks appear and the **Install new Features** button becomes enabled.



8. Press the **Install new Features** button.



9. Reinitialize the hardware setup.
10. Check the initialized features of the PTU in the device section. All new features that were listed in the lower part are transferred to installed features in the upper part. It should look like this:



8 PTU X Troubleshooting

8.1 USB Communication Issues

There are known communication issues found to occur in the older version of the PTU X USB (with LAN connectors) operated on a USB3 port with certain Intel USB 3 chipsets and XHCI host controllers. Though this problem has been resolved in the latest version of PTU X, but if one of the following situations occur on the older system, it is most likely caused by this USB 3 issue:

- problems detecting the PTU in the Windows Device Manager
- error messages in DaVis during operation, such as `"Error while sending a packet"`
- messages in the DaVis info window, such as `"PTU_CMD_YEX_PARMS: err ="`
- errors during firmware update

8.1.1 Quick Solutions

- Use a different (USB 2.0) USB port on the PC (see mainboard-specific information in section 8.1.4)
- Use an Active USB 2.0 Extension Cable such as **LaVision** item #1003102.
- Uninstall the Intel Driver (works for Windows 7)
- Disable USB3 or XHCI support in the BIOS of the PC (see mainboard-specific information in section 8.1.4)
- Use an extra USB card

8.1.2 Use an Active USB 2.0 Extension Cable

Using an active USB 2.0 Extension cable such as LaVision item #1003102 will be a reliable solution on all systems and USB ports. Instead of connecting the type-A plug of your PTU's USB cable directly to one of the PC's on-board USB ports, connect it to the receptacle of the active extension cable and plug that into your PC's USB port.

8.1.3 Uninstall Intel Driver

Uninstalling the Intel XHCI driver helps on Windows 7 but **NOT** on **Windows 10** systems. To uninstall the "Intel USB 3.0 eXtensible Host Controller Driver", open the "Programs and Features" window (e.g. by pasting "`Control Panel\Programs\Programs and Features`" into the address field of the Windows Explorer). Enter "`Intel`" into the search field on the top right (cf. Fig. 8.1).

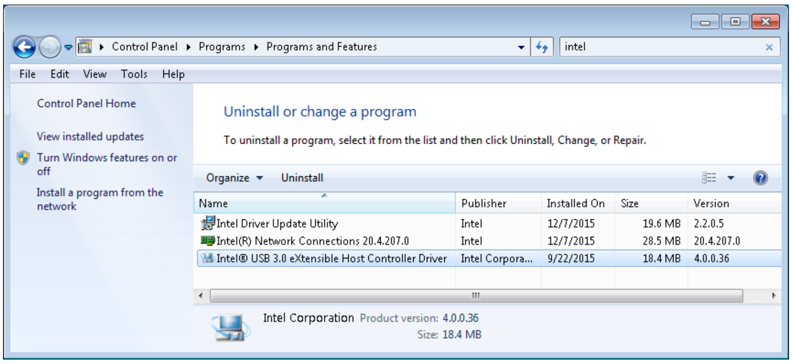


Figure 8.1: Uninstall Intel XHCI Driver

Double-click the entry "Intel USB 3.0 eXtensible Host Controller Driver" to open the uninstaller and basically run the uninstaller by pressing **Next** until it is finished (see the screenshots in Fig. 8.2 - 8.4).

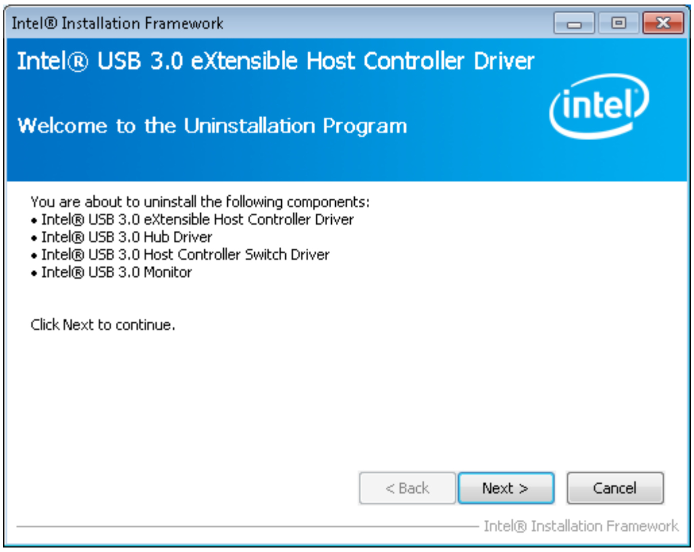


Figure 8.2: Uninstall Intel XHCI Driver

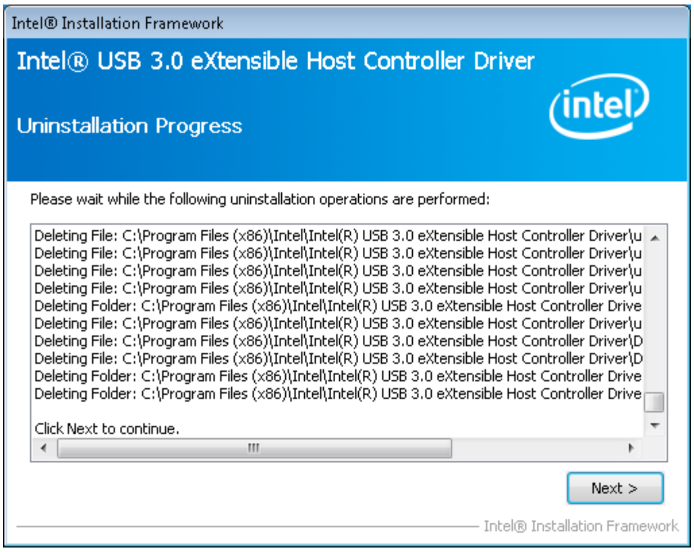


Figure 8.3: Uninstaller 2: press "**Next**"

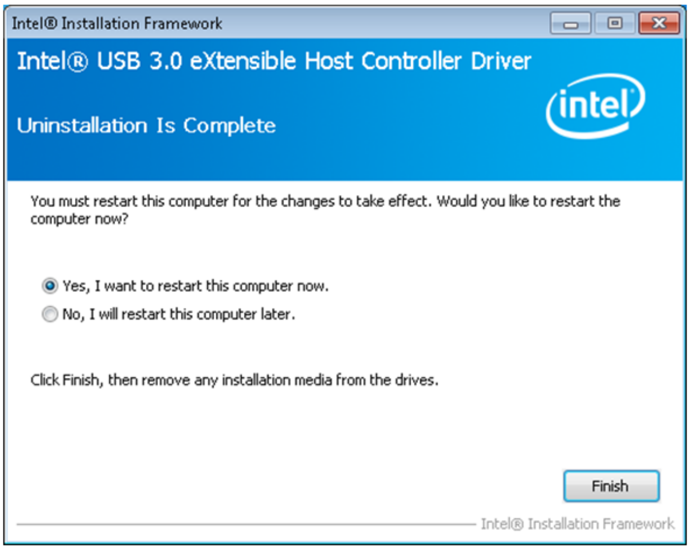


Figure 8.4: Uninstaller 3: select "Yes,..." press "**Finish**" to reboot the machine

8.1.4 Mainboard-Specific

The following chapters describe the solutions for the different mainboards provided by **LaVision**. The mainboard information can be found in the "Windows System Information" window. To open it, just type "`System Information`" into the search field in the start menu and press ENTER. In the "System Information" window look for "System Model" (see screenshot in Fig. 8.5). This gives you the mainboard type.

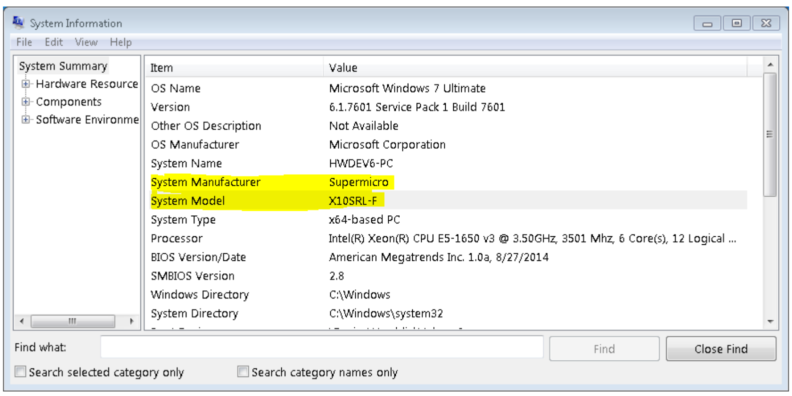


Figure 8.5: System Information: Mainboard Type

Supermicro X10DRi

This mainboard is used in the following **LaVision** PC items:

- #1104223
- #1104224
- #1104225
- #1104226

For this mainboard, the easiest way to fix the communication issue is to connect the PTU X to another USB port. The two USB 3 ports (5. *Backpanel USB 3.0 Port 6* and 6. *Backpanel USB 3.0 Port 7*, see Fig. 8.6). do not work properly with the PTU X. All other ports work fine. Prefer to connect mouse and keyboard to the USB 3 ports.

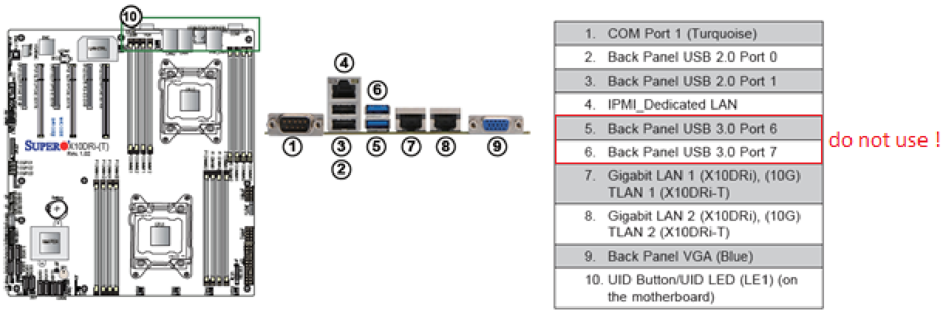


Figure 8.6: Back panel of the *Supermicro X10DRi*

If that solution is not applicable, uninstalling the Intel Host Controller driver would also help (see section 8.1.3) on Windows 7 computers. Alternatively, the USB 3.0 support could be disabled in the BIOS of the computer. The relevant settings can be found in the BIOS under **Advanced** → **Chipset Configuration** → **South Bridge**. Fig. 8.7 is a screenshot of the relevant settings.

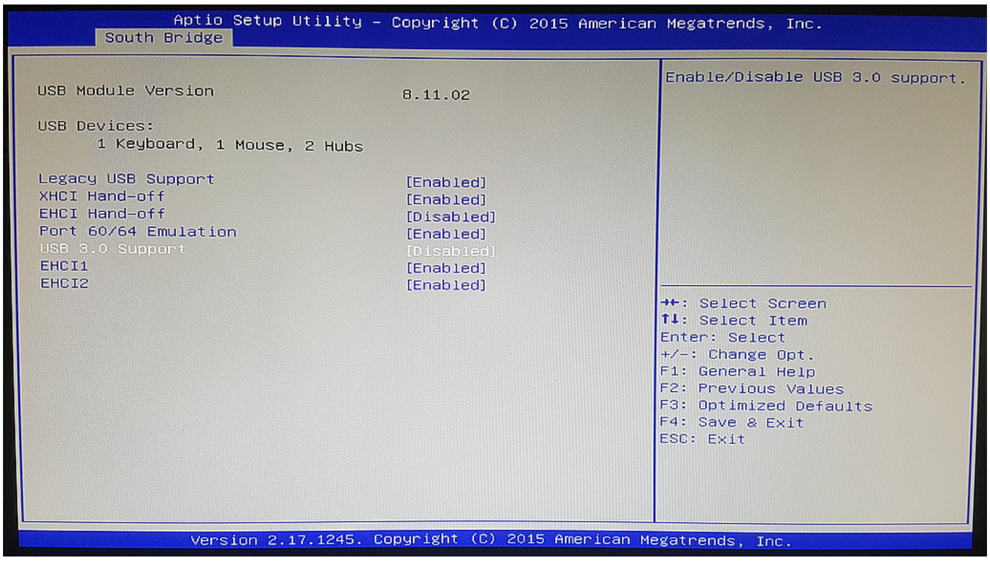


Figure 8.7: BIOS settings for Supermicro X10DRi to disable USB 3.0 support

For Windows 10, changing the BIOS settings is the only alternative to changing the USB ports.

Supermicro X10SRL-F

This mainboard is used in the following **LaVision** PC items:

- #1104221
- #1104222
- #1104219
- #1104220

This mainboard behaves much like the *Supermicro X10DRi* regarding this issue. For this mainboard, too, the easiest way to fix the communication issue is to connect the PTU X to another USB port. The two USB 3 Ports (E USB Port 3 and F USB Port 4, see Fig. 8.8) do not work properly with the PTU X. All other ports work fine. Prefer to connect mouse and keyboard to the USB 3 ports.

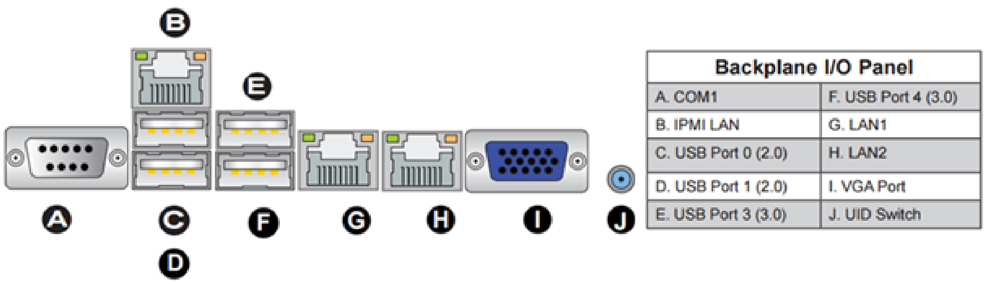


Figure 8.8: Back panel of the Supermicro X10SRL-F

Accordingly, if that solution is not applicable, uninstalling the Intel Host Controller driver would also help (see section 8.1.3) on Windows 7 computers. Alternatively, the USB 3.0 Support could be disabled in the BIOS of the computer. The relevant settings can be found in the BIOS under **Advanced** → **Chipset Configuration** → **South Bridge**. Fig. 8.9 is a screenshot of the relevant settings.

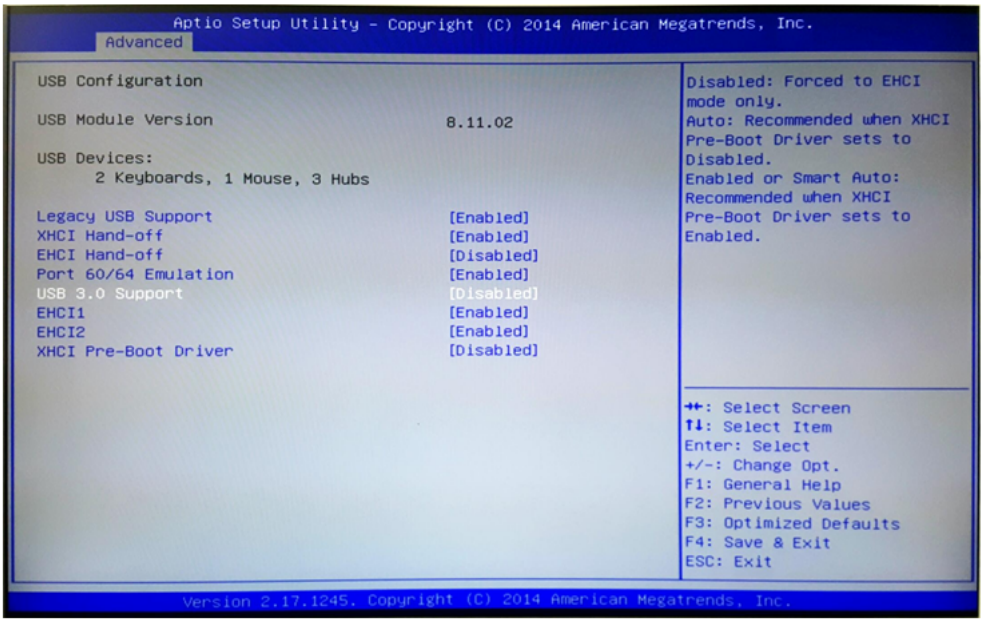


Figure 8.9: BIOS settings for Supermicro X10SRL-F to disable USB 3.0 support

For Windows 10 changing the BIOS settings is the only alternative to changing the USB ports.

Supermicro C7X99-OCE

This mainboard is used in the following **LaVision** PC items:

- #1104243
- #1104244

This mainboard has on-board USB 3.0 ports exclusively. For this reason, none of the ports work properly with the PTU X by default.

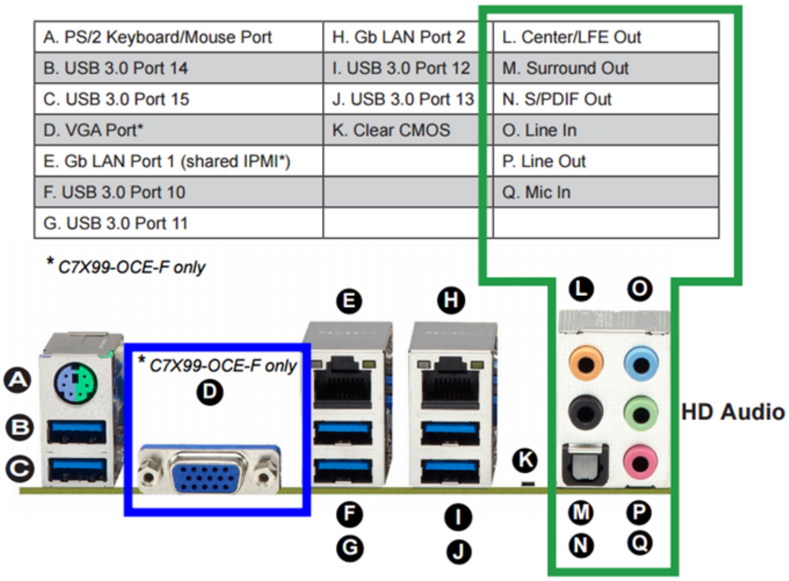


Figure 8.10: Back panel of the Supermicro C7X99-OCE

Uninstalling the Intel Host Controller driver (see section 8.1.3) will be a solution for USB ports 10 to 13 but not for ports 14 and 15. Setting the xHCI mode to "Disabled" in the mainboard's BIOS does not reliably solve the problem either. The only general solution to the problem on all of the ports is using an Active USB 2.0 Extension Cable (see section 8.1.3).

Supermicro X10SAE

BIOS settings to disable xHCI mode for X10SAE mainboards

This mainboard is used in the following **LaVision** PC items:

- #1104009
- #1104010

None of this mainboard's USB 2.0 and USB 3.0 ports will work correctly with the PTU X by default. However, setting the xHCI Support to 'Disabled' in the BIOS will work for this mainboard, too. To do so, after opening the BIOS settings, go to **Chipset Configuration** → **PCH-IO Configuration** and you will find the xHCI mode setting (Fig. 8.11). Additionally, a general solution to the problem on all of the ports is using an Active USB 2.0 Extension Cable (see section 8.1.2).

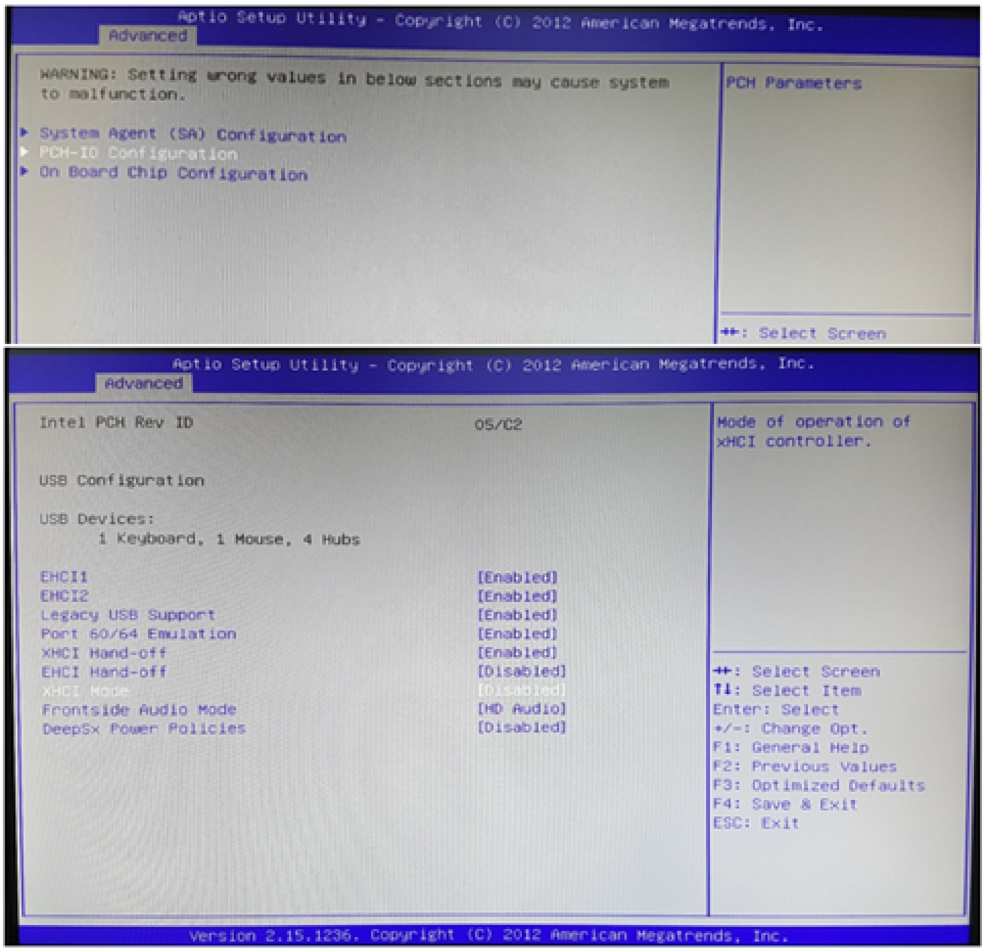
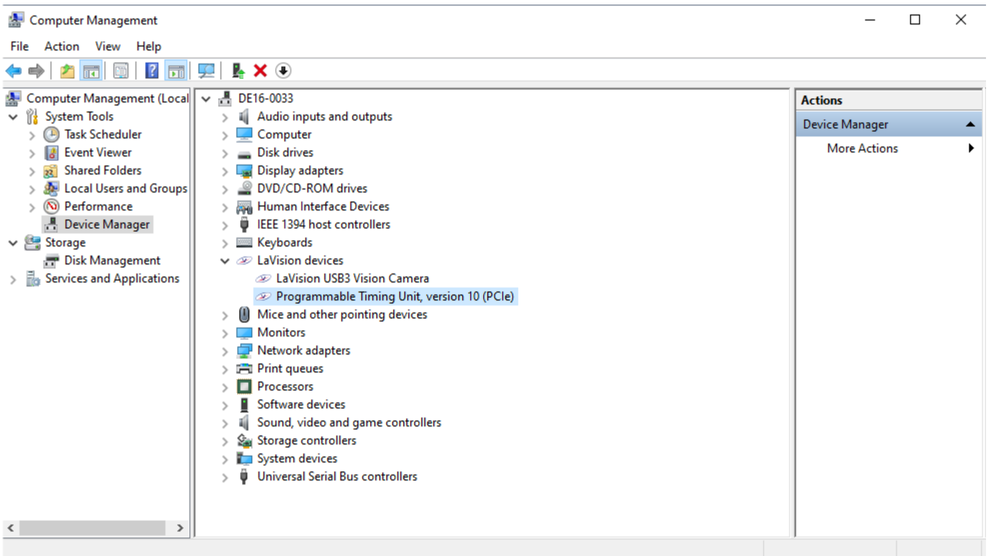


Figure 8.11: BBIOS settings to disable xHCI mode for X10SAE mainboards

8.2 PCIe PTU first usage

When installing the PCIe driver for the first time on a system (either manually or automatically through the **DaVis** installer) a reboot of the PC is required in order to properly load and start the driver. After installing the driver and restarting the PC the PTU should be available in the **Windows Device Manager** as shown in the following screenshot:



Please refer to chapter 3.1 for further details on PCIe driver installation.

9 Support

If you have a technical problem or a question regarding hardware or software which is not adequately addressed in the documentation, please contact your local representative or **LaVision** service directly.

You can contact service at **LaVision** GmbH by:

e-mail: **service@lavision.de**

phone: **+49 551 9004 229**

Alternatively, you may submit your problem using the **Support Request Form** in the **Support** section of the **LaVision** website `www.lavision.com`.

In order to speed up your request, please include the following information:

- The order number of your system (see section 9.1).
- The number of the used dongle (see section 9.1).
- A short description of the problem.
- The **LaVision** service file (see section 9.2).
- Some logfiles if you have a reproducible software problem (see section 9.3).
- Information on the Windows operating system and service pack used on the corresponding computer.

9.1 Order and Dongle Number

To be able to find information on the delivered hardware components and customer details in the **LaVision** database, your order number is required. This number can be found in the toolbar menu **Extras – About** or on the original **DaVis** installation medium (see Fig. 9.1).

In the **About DaVis** dialog you find the dongle number and order number information. The **Version ID** is the build number of the **DaVis** version, shown on top of the dialog.

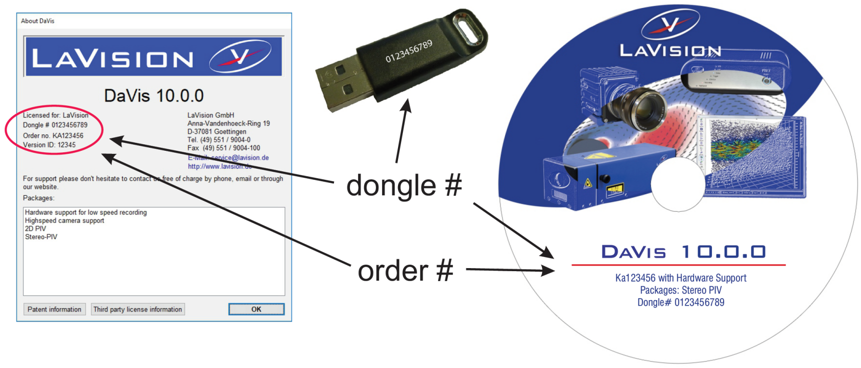


Figure 9.1: Dongle and order no. in **Extras - About** and on the installation DVD.

The dongle number is required to exclude possible license problems. This number is printed on the hardware key as well. The dongle number and the order number can also be found on the original **DaVis** install medium.

Please include the order number and/or the dongle number in your service requests.

9.2 LaVision Service File

In order to be able to reproduce a software problem, it could be essential to know the exact hardware setup and software parameters in **DaVis**. All currently used parameters and all error messages that have been shown since the last **DaVis** start can be extracted using the toolbar menu **Extras – Service – Create service file for LaVision support**.

After you have selected this menu, the system will write all values for the relevant variables into a `LSFX` file. This file will also contain the current settings of the hardware setup, acquisition setup and processing operation lists. The procedure will take some seconds!

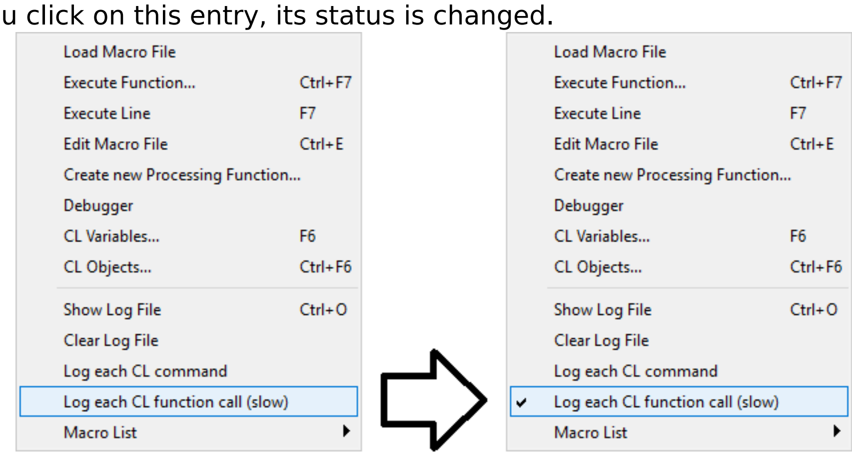
The `LSFX` file will be written automatically to a folder selected by the user and the Windows explorer opens at the end with this folder. The name of the file contains the order number and dongle number that is extracted from your software (`#ordernumber_donglenumber.lsfx`). Send the `LSFX` file as attachment to your email together with the description of your problem to `service@lavision.de`.

9.3 Log File

During startup of **DaVis**, some log files are generated in the **DaVis** subdirectory `Users/<name>/log` (until version 10.2.0) or in **DaVis** subdirectory `ProgramData/log` (since version 10.2.1). The standard log files are separated for certain areas of the software and get corresponding names for easier access by service. The log files from the Command Language are named like `LOG_<date>_<time>.txt` with date and time of the **DaVis** startup, e.g., `LOG_170615_150343.txt`. **DaVis** holds the last ten CL log files and removes older ones automatically.

If you have a reproducible software problem in **DaVis**, please send the complete log folder together with your email. These files contain all functions you have called and all error messages that have been displayed after you activated the log. Please proceed as follows:

1. Start **DaVis** and use the toolbar menu **Extras – Macro – Clear Log file**.
2. Enable the **Log each CL function call (slow)** entry in the menu. This feature is active if you see a flag at the left side of the entry. Every time you click on this entry, its status is changed.

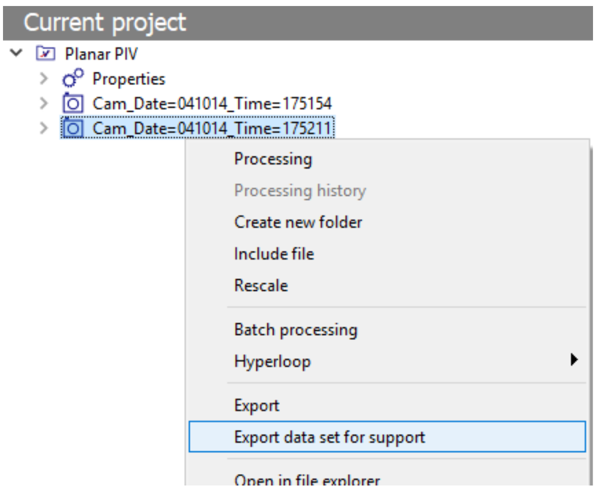


3. Try to reproduce your problem, e.g., until an error message is displayed.
4. A log file has been generated in the **DaVis** main directory. Send this text file attached to your email.
5. Disable mode **Log each CL function call (slow)**. This function is deactivated if you do not see a flag next to the entry.

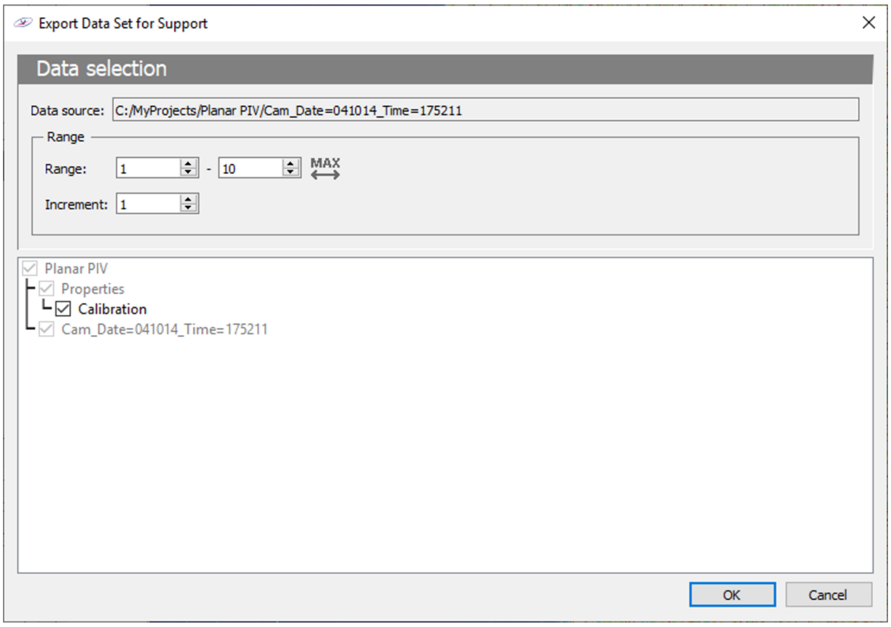
9.4 Export Data Set for Support

Some problems can only be reproduced using images or data that contain particular information or artifacts. For error analysis, it can be necessary to provide exemplary data that need to be extracted from the corresponding project.

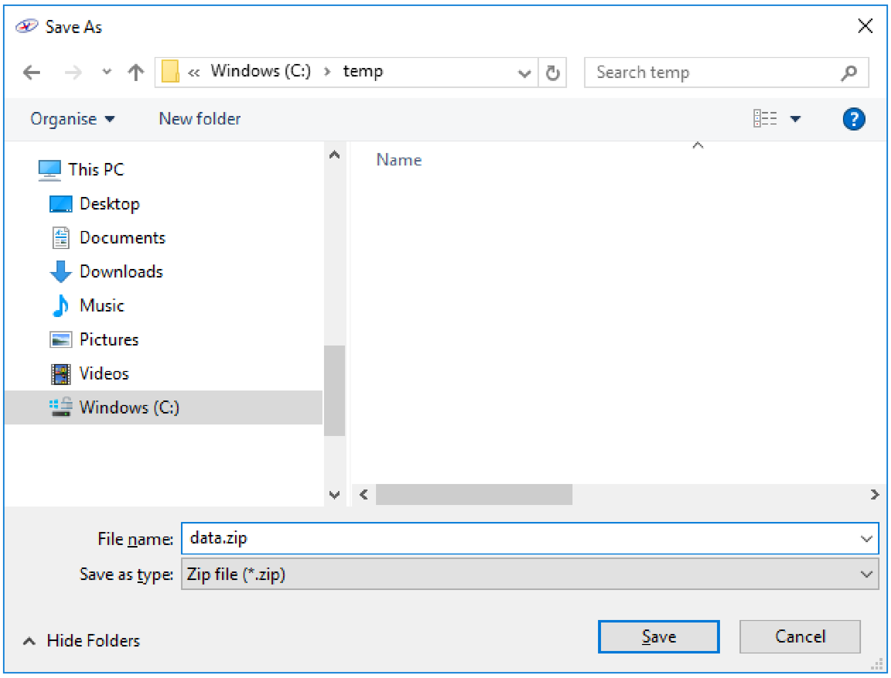
Depending on the project type, the number of cameras used, and the error, it can be necessary to provide the corresponding calibration (spatial, temperature, etc.) and derivative data as well. A convenient way to extract the data from the project is the **Export data set for support** option, which you can select by right-clicking on the corresponding data set in the tree view of the **Project manager**.



In the **Export data set for support** dialog, specify the range of data which you would like to extract from the data source by entering the range (i.e., first and last image). If a calibration is available in the project, this will be added by default. You have the option to deselect this part if it is not relevant.



After clicking the **OK** button, you need to specify location and file name for the `zip` file that contains the selected data.



DaVis will ask to open the containing folder or to send an email to `service@lavision.de`.

Note: Files with a size of more than 20 MB should not be sent by email. **LaVision** can provide a link for uploading data via file drop. Please contact `service@lavision.de` for details.

9.5 Shipment of Defective Items

If any item needs to be returned to **LaVision** GmbH for service or repair, please contact the **LaVision** service to obtain a **RMA** (Return Material Authorization) number together with an RMA form. This will list all items with SN and a short description of the problem. Place the RMA form in the box with the item(s) being returned. Return the authorized item(s) according to the shipping instructions.

Shipping instructions:

- Be sure to obtain an RMA number and RMA form.
- Add the signed RMA form to the shipping documents.
- Ship only the items that are authorized.
- Use the original boxes to avoid damages during transportation.
- **Remove cooling water from the laser!**
- **Use antistatic bags for computer boards!**
- Ship returned items to:

  LaVision GmbH
  Anna-Vandenhoeck-Ring 19

  37081 Göttingen

  GERMANY

Note: Shipments received by **LaVision** without an RMA number may be refused.

Manual No 1008606 - December 2, 2022

FOCUS ON IMAGING

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