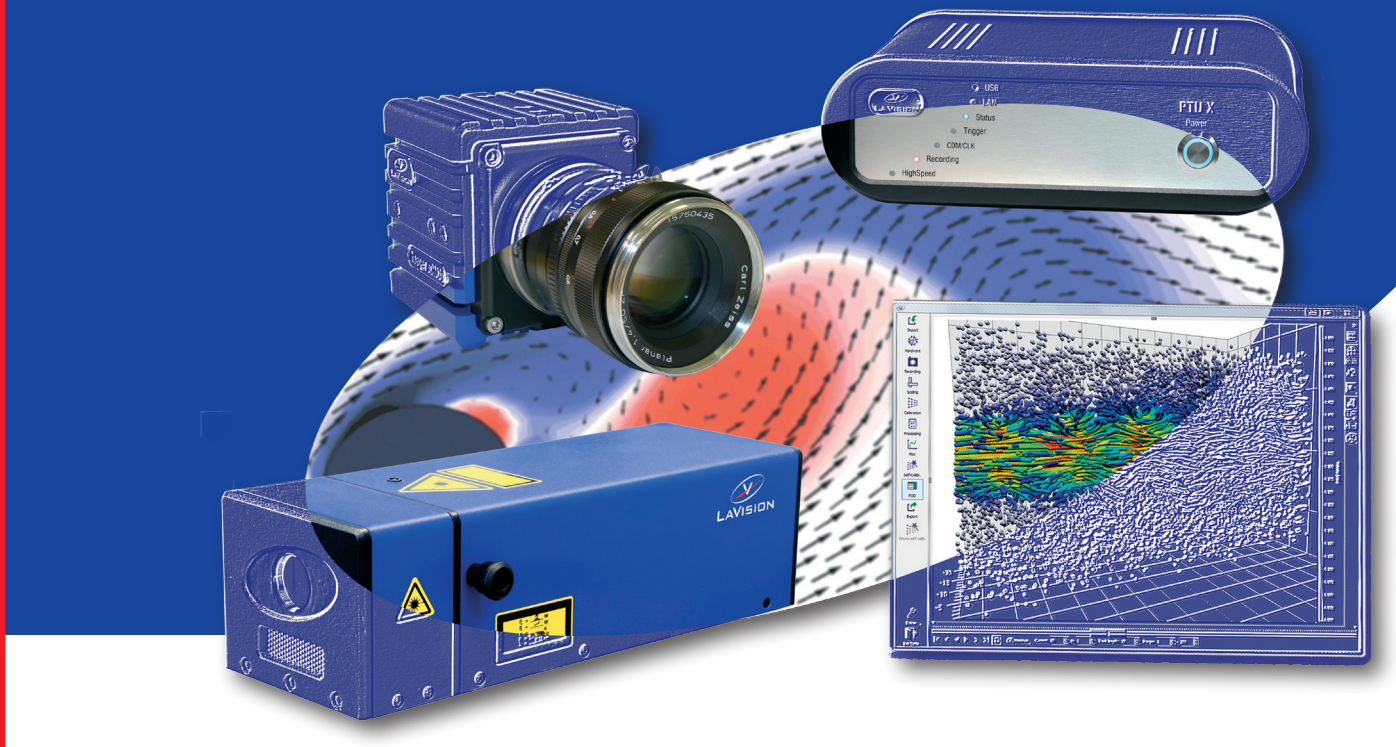

Product Manual

IRO App

Item Number(s):

LAVISION

FOCUS ON IMAGING

Product Manual for **DaVis / IRO App**

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Produced by LaVision GmbH, Göttingen
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Contents

1 Safety Precautions

Before working with your **LaVision** system, we recommend to read the following safety precautions. Observing these instructions helps to avoid danger, to reduce repair costs and downtimes, and to increase the reliability and life of your **LaVision** system.

1.1 Safety instructions for LaVision image intensifiers

The **operating voltage (= gain) should be gradually increased with a low light level** input, until the output screen begins to illuminate.

The recommended maximum operating voltage **should not saturate the sensor** of the connected camera.

It is recommended to operate image intensifiers in a **darkened room** and to put the **protective caps on the lens whenever the intensifier is not in use**.

Using a **short gate** and higher gain (e.g. 100ns, 80%) is in general the better option than a long gate and low gain.

Note that a strong light intensity (e.g. by laser illumination) may **destroy** the photocathode or the MCP.

If a HighSpeed IRO is not operated in **LaVision DaVis** software it is absolutely necessary to **use the DISABLE / ARMING inputs** in order to block

the trigger signals whenever the camera image is not read out. A permanent trigger signal connected to the intensifier might **reduce the life time of the IRO dramatically**.

Storage is recommended in a **dry, darkened environment** at room temperature.

LaVision intensifiers **do not have any built-in overload protection**.

> **Note:**
>
> Permanent intensifier gating at high trigger rate (> 50Hz) yields to an unnecessary load of the image intensifier which in long term operation would surely reduce the intensifier lifetimes! In case of significant light at the photo cathode it might be damaged also after short time.

1.2 Laser Safety

If a laser[1] is integrated in your system, it is important that every person working with it has fully read and understood these safety precautions **and** the laser manual of the specific laser/LED.

Lasers included in **LaVision** systems may belong to Class 4 laser devices, which are capable of emitting levels of both visible and invisible radiation that can cause damage to the eyes and skin. It is absolutely necessary that protective eyewear with a sufficiently high optical density be worn at any time when operating the laser. The goggles must protect against all wavelengths that can be emitted, including harmonics. See your laser´s manual for further details.

Class 4 laser beams are by definition a safety and fire hazard. The use of controls, adjustments or performance of procedures other than those specified in the **LaVision** manual and the laser manual may result in hazardous radiation exposure.

[1] In the following, 'laser' means any kind of laser, in particular Nd:YAG and dye lasers as well as Optical Parametric Oscillators at any wavelength and output energy. Also for high-power LEDs precautions should be taken.

AVOID EYE AND SKIN EXPOSURE TO DIRECT OR SCATTERED RADIATION. FOLLOW THE INSTRUCTIONS YOU CAN FIND IN THE CORRESPONDING LASER MANUAL FOR PROPER INSTALLATION AND SAFE OPERATION. USE PROTECTIVE EYEWEAR ALL THE TIME WHEN OPERATING THE LASER.

Important instructions for safe laser handling:

- Before operating the laser, contact your laser safety officer.
- Read and understand the instruction manual of the particular type of laser. Take special care with respect to laser emission, high voltage and hazardous gases if in use.
- Declare a controlled access area for laser operation. Limit access to trained people. Never operate the laser in a room where laser light can escape through windows or doors. If possible, cover beam paths to avoid obstacles getting into the beam.
- Provide adequate and proper laser safety goggles to **all** persons present who may be exposed to laser light. The selection of the goggles depends on the energy and the wavelength of the laser beam as well as on the operation conditions. Check the laser´s manual for a detailed description.
- While working with lasers do not wear reflective jewelry like watches and rings, as these might cause accidental hazardous reflections.
- Avoid looking at the output beam, even diffuse reflections can be dangerous.
- Operate the laser at the lowest beam intensity possible.
- Avoid blocking the output beam or reflections with any part of the body. Use beam dumps to avoid reflections from the target.
- Wear clothes and gloves which cover arms and hands to avoid skin damage when handling in the optical path. Especially UV radiation can cause skin cancer.

1.3 Seizures Warning

WARNING: HEALTH HAZARD! STROBE LIGHTING CAN TRIGGER SEIZURES! Some people (about 1 in 4000) may have seizures or blackouts triggered by flashing lights or patterns. This may occur when viewing stroboscopic lights or objects illuminated by such devices, even if a seizure has never been previously experienced. Anyone who has had a seizure, loss of awareness, or other symptoms linked to an epileptic condition should consult a doctor before operating systems which include flashing lights, strobe lights, or a pulsed or modulated laser.

Stop operating the system immediately and consult a doctor if you have one of the following symptoms:

- convulsions, eye or muscle twitching, loss of awareness, altered vision, involuntary movements, disorientation.

To reduce the likelihood of a seizure when operating a system:

- Do not look directly at flashing light sources or on illuminated objects, e.g. into a strobe light or a flashing LED panel.
- Operate the system in a well-lit room.
- Take frequent breaks in normally illuminated areas.
- Bright parts in the experiment, like reflections on walls or big particles, will limit the maximum laser power. Modify the optical arrangement of your setup in order to remove bright reflections from the camera image.

2 About this manual

2.1 Purpose

This manual contains the information on how to install and use the IRO App software.

2.2 Documents to be supplied

The following table provides an overview of the applicable documents to be supplied by **LaVision** on request.

Document to be supplied	**Manufacturer**
Manual 1013689_IRO_X	LaVision GmbH

3 Introduction

3.1 Precautions

The **IRO (Intensified Relay Optics)** has been supplied in a safe condition. Information and warnings of this manual have to be followed to ensure safe operation and to keep the camera system in a safe condition.

The photo cathode of the intensifier can be permanently damaged by excessive light input. To prevent damage the input light level following conditions must be held during operation.

- Avoid image saturation of your camera. If the camera gets saturated decrease light level at image intensifier immediately. For High-Speed cameras the signal level should not be higher than the linear limit for your camera (see test sheet of your camera system).
- Make sure the intensifier is only gated during camera exposure period.
- Do not operate the image intensifier below 300 V MCP (Micro Channel Plate) voltage. The MCP gain setting should be at least 3.00 at your control unit, or 30% if operated within remote mode. For lower MCP voltages the image intensifier is working as an attenuator. For low MCP voltages and higher signals a significant current appears inside the tube.
- If the intensifier is operated for several hours exposed to a fixed non-uniform scene, an image of this non-uniform scene can be burnt into the intensifier tube. Short gate times and low gain settings will avoid this image burn-in.
- The intensifier tube can be damaged by electrostatic discharge. Do not touch the intensifier tube before proper grounding procedures, especially not the front surface.

The **LaVision** camera units are designed to operate satisfactorily at temperatures between 10°C and 50°C and at a maximum humidity of 90% without any water condensation present.

- Put the protection cap on the input lens whenever you do not take images, especially when a laser light sheet is adjusted.
- Always make sure that the image intensifier is not overexposed by light. If you operate your camera using ROI (Region Of Interest) windowing, you should have checked before that the hidden area is not collecting higher signal levels than your ROI.

3.2 Operation Principle

The combination of a CCD/CMOS camera system with an image intensifier is required for:

- Single photon detection
- UV light detection extended spectral sensitivity down to 180 nm (with quartz input window) as usually CCD/CMOS cameras are not sensitive for wavelength $< \sim 380$ nm
- Most importantly: an extremely short shutter of several nanoseconds (optical gating)

The IRO is an electro-optical device which is mounted in front of a CCD or CMOS camera. It consists of a relay-optics (tandem lens system) and a gate-able image intensifier, in combination with a control unit for setting variable exposure time and intensifier gain.

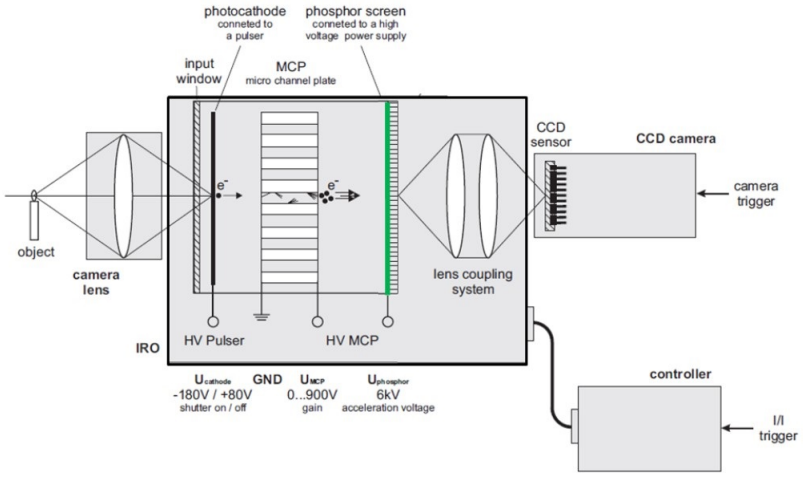


Figure 3.1: Schematic setup of a 1-stage IRO head with Controller, camera head and camera lens.

Image Intensifier Light Amplification Principle

The image intensifier is an electronic shutter device with an extremely variable exposure time. Whereas the minimum exposure time of a camera is usually in the millisecond range [1], the image intensifier can be opened (gated) for just several nanoseconds. The 2nd Gen proximity image intensifier is a vacuum tube consists of three elements, which are separated by small gaps:

- Photo cathode inside of the entrance window
- Micro channel plate (MCP) (gap photocathode – MCP $\sim$ 0.1 mm)
- Phosphor surface at output window (gap MCP – phosphor $\sim$ 1-2 mm)

The light is focused to photo cathode which converts the photon signals to electrons. A positive voltage pulls the electrons into the MCP, where the electron signal is amplified.

[1] High speed cameras feature μs exposure times

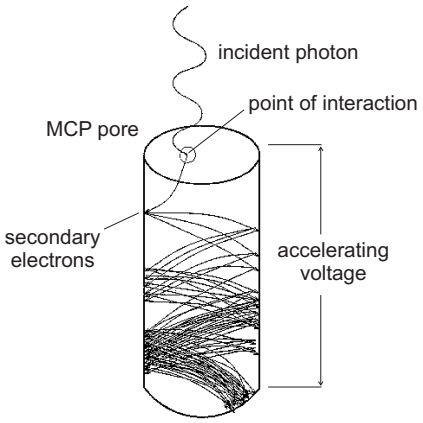


Figure 3.2: Electron amplification inside the MCP.

The amplification is based on a cascading process, where at each electron-wall collision secondary electrons are generated. The overall electron amplification is given by the MCP voltage which is varied between 300 V and 900 V. A high voltage (typically 6 kV) between MCP and phosphor plane accelerates the electron signal to the phosphor surface at the exit window where it is reconverted to a light signal.

The image at the exit window is focused onto the camera sensor by an optimized lens coupling. Fig. 3.1 shows a schematic setup of a lens coupled CCD-IRO system.
If the camera is combined with a gated image intensifier, the effective camera exposure is given by the image intensifier (photo cathode) gate, whereas the camera exposure is set to be at least long enough to integrate the time interval of the phosphor emission.

Intensifier Types

Image intensifiers may have different types of **photo cathodes** which vary in their color sensitivity. Possible choices are S20 or S20 UV (blue and UV sensitive), S25 (visible and red enhanced sensitivity) or 3rd generation cathodes for optimum visible and IR sensitivity.

Image intensifiers may have a **single MCP** (single stage) or **two MCPs** (2 stage). Single stage tubes have less amplification but higher resolution. Because of the high sensitivity of modern CCD/CMOS cameras, single stage tubes are sufficient even for single photon detection.

Another significant difference is given by the selection of the **phosphor material**. Of interest are usually only phosphors with significant emitting green light as this color matches the color response of CCD and CMOS cameras best. Most likely phosphors are P43 and P46.

Phosphor	Decay time to 1%	Relative emission	Comment
P43	~ 1-2 ms	100%	Used at low speed camera systems
P46	< 1 µs	~ 30%	Used for high speed camera systems and double pulse camera systems

Table 3.1: P43 and P46 decay times and relative emission.

High speed IRO systems are usually equipped with an additional intensifier tube (booster) to enhance the brightness and signal dynamic of the system. The booster stage is fiber coupled to the first stage (2^{nd} MCP intensifier)[2].

Gating

The intensifier gate is achieved by a pulse generated by a high voltage pulse module. The output level of the HV pulse module is usually +50 V to block the image intensifier and drops to -180 V during the gate (i.e. the exposure time). Due to this pulse shape, photoelectrons escape the photo cathode only during the gate, i.e., the camera is only active during gate. Because of the close proximity of the photo cathode and the entrance side of the MCP, only a relatively small change in photo cathode voltage is required to prevent the emitted photoelectrons from entering the MCP. This characteristic, together with the high conductivity of the photo cathode, allows the intensifier to be gated down to a few nanoseconds. The strength of the applied negative field determines the spatial resolution of the image intensifier. Higher voltages yield higher spatial resolution. On the other hand, for very high negative voltages the electrons generate positive ions on the MCP. These ions are pulled back to the photo cathode (ion feedback) and may damage it. Therefore, the optimum voltage is -180 V.

> **Note:**
>
> During its lifetime, the photo cathode sensitivity is decreasing. From manufacturer side, an expected lifetime of >1000 h (for cw-operation) is given.
> For gated operation, the operation time is much smaller than the peak currents inside the tube are sometimes much higher than in cw operations.

[2] The photo cathode of the booster is a S20

Electronics

Image intensifiers are driven by high voltages. The DC voltages for MCP and Phosphor are generated by a HV Power supply (HV-MCP). The variable MCP voltage inside HV-MCP is set by an external control voltage of 0-3 V. The gate pulse is generated by the HV Pulser, which is driven by an external TTL pulse. The HV modules are powered by a DC voltage of 12 V. All high voltages only appear inside the image intensifier head. The external IRO control unit provides 12 V drive voltage, the MCP control voltage (0-3 V).

The control unit is equipped with a delay gate generator. This is triggered by an external trigger pulse that releases a TTL pulse according to the preset delay and gate length, which is coupled into the HV-Pulser.

The IRO controller is either operated locally at the LCD display or it is remote controlled from an external PC via a USB interface.

> **Note:**
>
> At very high MCP currents (due to high light inputs and/or amplification) MCP channels tend to saturate, reducing its intensification dramatically.
> A too high light input may produce a local photocathode etching or even destroy the whole device. Too long exposure times at room lighting or short but intense laser beams, even reflected ones, are already sufficient to yield black spots, an irreparable damage.

3.3 Be Aware of Intensifier Load

If the IRO is controlled by the **DaVis** software intensifier gates are released by **DaVis** only during the recording phase.

If the IRO System is operated outside of **DaVis** software it is strongly recommended to operate the IRO within DISABLE or ARMING mode! For HS-IRO the ARMING mode is the preferred operation mode.

Within ARMING the number of intensifier gates is limited and intensifier gating is enabled only for limited number of gates after the ARMING trigger pulse. The ARMING trigger has to be released at start of recording phase of the camera system. For details of ARMING operation see section 4.

4 Synchronization

4.1 Operation Modes ARMING (Internal & Direct)

Functionality

> **Note:**
>
> Permanent intensifier gating at high trigger rate (> 50Hz) yields to an unnecessary load of the image intensifier which in long term operation would surely reduce the intensifier lifetimes! In case of significant light at the photo cathode it might be damaged also after short time.

High-speed cameras are usually running continuously at a preset frame rate either in internal synchronization or triggered by an external DDG[1]. The live view display of the camera software grabs images from the continuous data stream released by the high-speed camera. The internal rate at camera inside live view may still be some kHz. This is definitively an extreme load for an image intensifier system.

Reliable operation conditions for HS IROs are:

- Continuous triggering at rates <= 50Hz
- Short time high frequency synchronization in kHz rate for a limited number of shots, e.g. N_{shots} = 1000.

For versatile synchronization with HS cameras the HS IRO has the ARMING feature. This enables the HS-IRO for a limited number of trigger pulses. The new IRO-X controller supports the ARMING feature also in DIRECT gating mode.

[1]The synchronization inside **DaVis** software is an exception, as here the camera is always synchronized externally by the PTU-X, which releases only trigger signals during **DaVis** data acquisition.

> **Note:**
>
> If the HS-IRO & HS-camera system is used outside of **DaVis** software is It is strongly recommended to operate the HS-IRO in ARMING modes.

The sequence start signal is a reliable signal to start the synchronization of the image intensifier. Inside the ARMING modes the user has only to enter the # of frames of the recording sequence as # shots. The sequence start signal connected to the DISABLE input of the IRO X enables the intensifier synchronization to the external trigger only for the entered # shots. Afterwards the intensifier gating is disabled until another Arming signal has been released. The timing diagram for **ARMING** operation is shown at Figure 4.1.

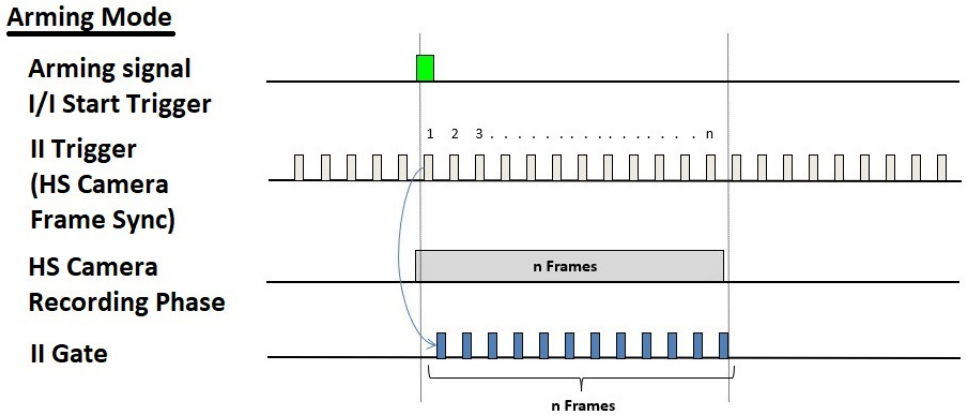


Figure 4.1: Arming Mode Timing diagram.

 # Frames gives the number of high-speed camera images. The **Arming signal = I/I Start Trigger** is sent by the camera at start of camera at start of recording. The intensifier controller is triggered by the **Frame Sync** pulses of the high-speed camera. On receiving an Arming trigger signal the intensifier gating (**II Gate**) is enabled for the fixed # of gates (**blue**). All gates before and after end of the gate burst are disabled.

The HS IRO "Arming" signal must be a TTL signal. The IRO can be programmed to start either on rising edge or on falling edge of the "Arming" signal. The signal length of the Arming signal should be at least µs .

→ The Arming trigger has to be connected to the **Disable** input at IRO X controller.

Figure 4.2: HS- IRO back panel: Connect the "Arming" signal to the "Disable" connector.

4.1.1 ARMING Modes

If the HS-IRO is operated outside of **DaVis** program it is strongly recommended to utilize the ARMING mode disable/enable functionality.

Use Arming Modes:

For systems with IRO-X controller the operation modes are

- ARMING
- DIRECT ARMING

For older HS-IRO systems with IRO controller the DIRECT ARMING is not available.

Add ON Components for versatile live view operation in ARMING modes.

For versatile handling in live view the system has been extended by 2 additional components: OR-Gate and Manual Trigger Release.

Internal / Direct Arming:

- **Internal Arming:** The external signal is a trigger signals the intensifier gate is set by the programmed delay/gate. The delay/gate is programmed at the FPGA of IRO X. It shows the sync. in clock jitter of 5ns with respect to the external trigger.
- **Direct Arming:** The external signal gives the intensifier gate width as it is passed directly to the HV- pulser.

OR Module Add on for HS-IRO ARMING control (HS-IRO operation outside of DaVis software)

ARMING Mode at Live view acquisition:

An add on tool consisting of an OR-gate module and a manual trigger allow to use the HS-IRO within ARMING modes also during live view.

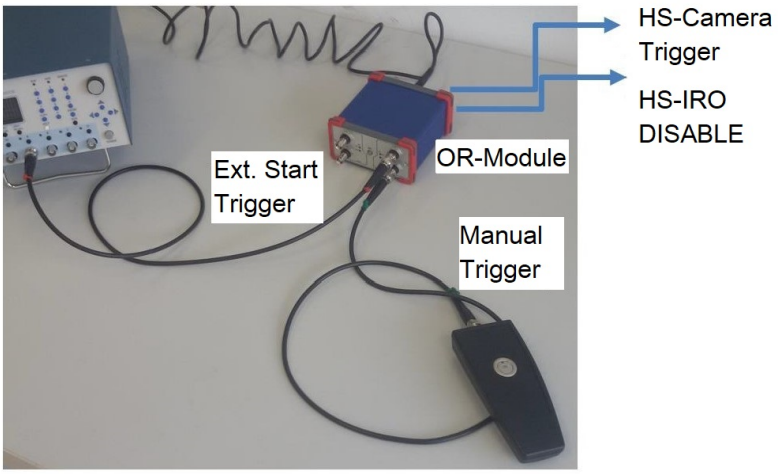


Figure 4.3: Add On Tools for HS-IRO control within ARMING modes.

The OR Module (see Figure 4.3) is triggered either by an external start trigger (here by a DDG) or by the manual trigger device. The output of the OR module is connected to the HS-camera Start trigger input and to the HS-IRO DISABLE input. A series recording is started by the external start trigger. To activate the HS-IRO during live view the manual trigger is released. This enables the intensifier gating for a limited number of shots. The number of shots has to set at the IRO controller. **Assuming a number of shots of 1000 at a HS camera sync. rate of 50Hz will activate the image intensifier for 20sec. For live view acquisition with HS-IRO it is recommended to operate the camera at lowest possible sync. rate**.

The HS camera can be operated either with internal and external frame synchronization. Figure 4.4 and Figure 4.5 show the cabling for internal and external HS camera synchronization. The signals for ARMING and HS-camera start trigger are indicated by green lines. The frame sync triggers are shown as red lines.

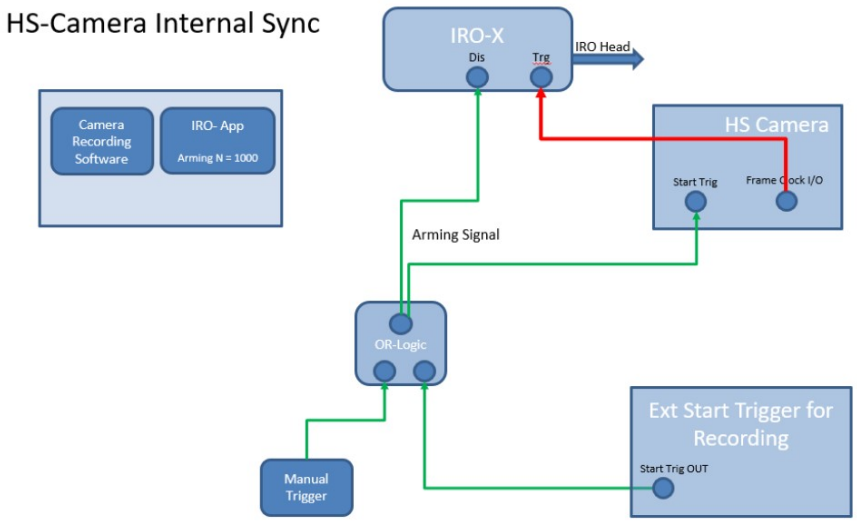


Figure 4.4: Connection diagram for HS-Camera running at **internal synchronization**. Only the trigger lines (coax lines) are shown. The frame sync is released by the HS-camera. It triggers the image intensifier (IRO-X Trig IN). The ARMING signal trigger is connected to the IRO-X Disable IN and to the HS-camera Start Trigger. The ARMING is either initiated by the external Start Trigger for Recording or by the manual trigger (press button).

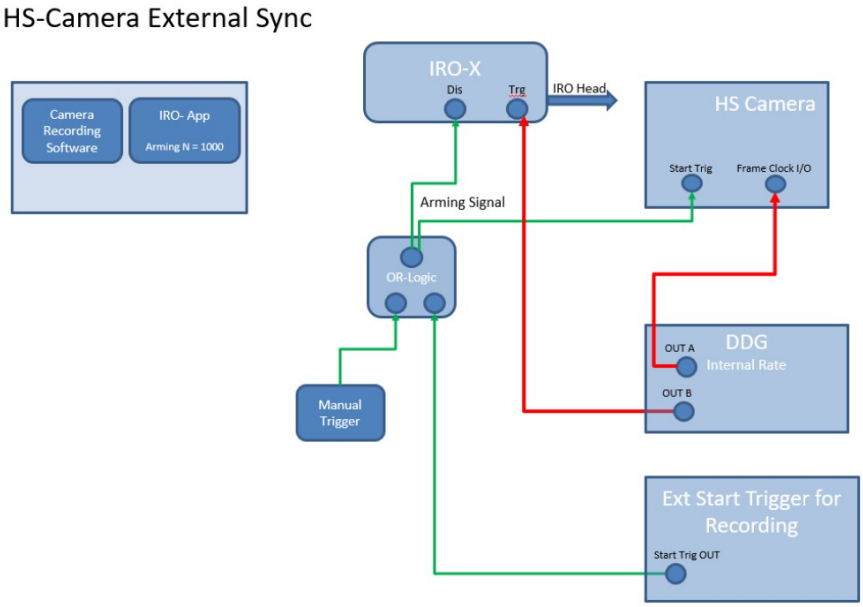


Figure 4.5: Connection diagram for HS-Camera running at **external synchronization**. The sync. trigger signals are released by an external DDG, either by two different or by the same output. When using 2 separated outputs the intensifier gate width can be controlled in DIRECT ARMING mode by the pulse length of output channel B.

IMPORTANT:

- After turn on of IRO controller the N-shots for ARMING has to be set, as the default value at power on is set to 0.
- For live view acquisition set the N-shots to 1000 (or 2000) and reduce the frame sync rate to minimum possible value.
- Make sure, not to gate the image intensifier inside dead time phase inside HS-camera cycle. Check phase relation of HS-IRO gating and HS-camera frame-sync.

4.2 Focus Adjustment

The IRO-X manual section "Focus Adjustment" gives detailed advices for the internal focus adjustment procedure. Keep in mind: As the focal depth of the IRO lens system is very short ($< 100\,\mu m$), the camera focus has to be checked whenever the individual HS-camera is exchanged even if the same camera model is attached.

Focus Adjustment at low gain imaging an external object

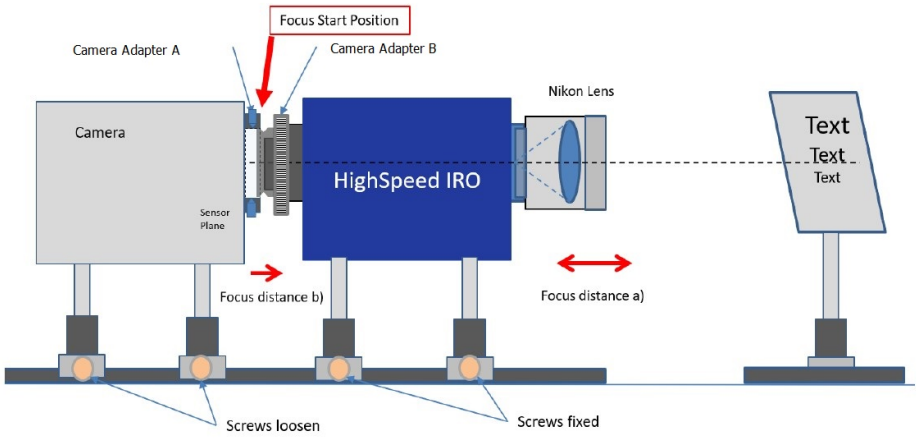


Figure 4.6: Optical setup & rough adjustment

Alternative Adjustment on Single Photon Signals

Instead of imaging an external object to the Intensified camera system you may operate the intensifier at high MCP gain with short gating so that single photons get visible. Adjust the system to achieve smallest possible event sizes. This method does not require focus optimization of the front lens.

4.3 Change IRO Power Button Configuration

A) Default configuration: If the 12 V power supply is switched ON the IRO controller is switched on locally at the IRO power button.

- IRO power OFF: power The LED at IRO control is blinking at ∼1Hz.
- IRO power ON: power The LED at IRO control is ON.

B) IRO controller power is controlled exclusively by the external power supply, i.e. it is switched on/ off by switching the external 12 V power supply.

Change power configuration between A) and B):

- Switch off the external power supply and wait until the capacitors are discharged, i.e. the green LED at 12 V power supply = off.
- Press power button at IRO controller continuously while switching ON the 12V power supply. The controller power LED must now show blinking at several Hz. Hold the power button pressed until the power LED is ON continuously. Now the configuration has changed.
- Test via turn off the 12 V power supply and turn ON again.

5 Remote Control

5.1 Driver Installation

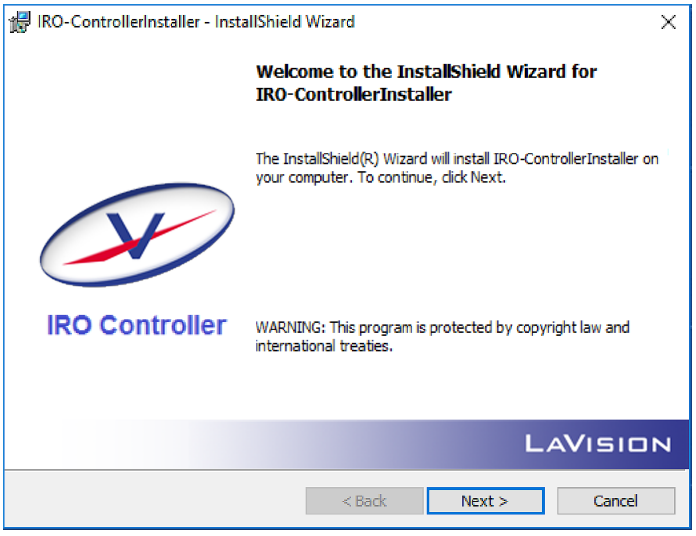
If the **IRO X** is connected via USB to the PC and the device has been identified, then can be operated by the **IRO APP**.

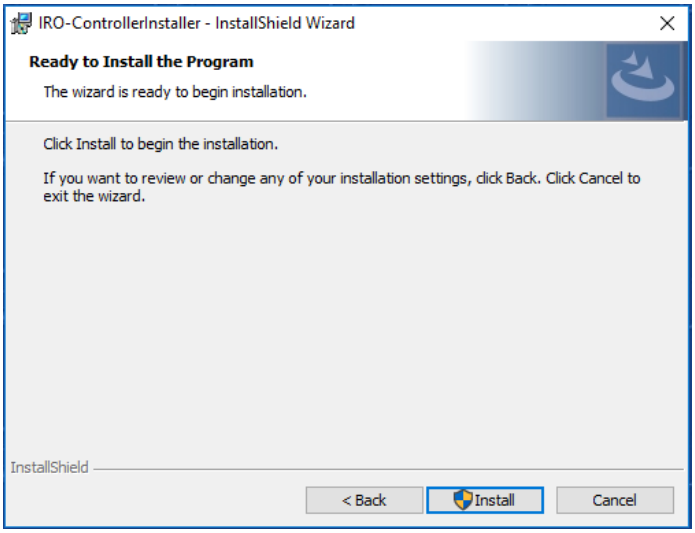
In order to do so it needs to be connected to the system PC via USB interface cable. This section describes how to install the corresponding driver for your **Windows** operation system.

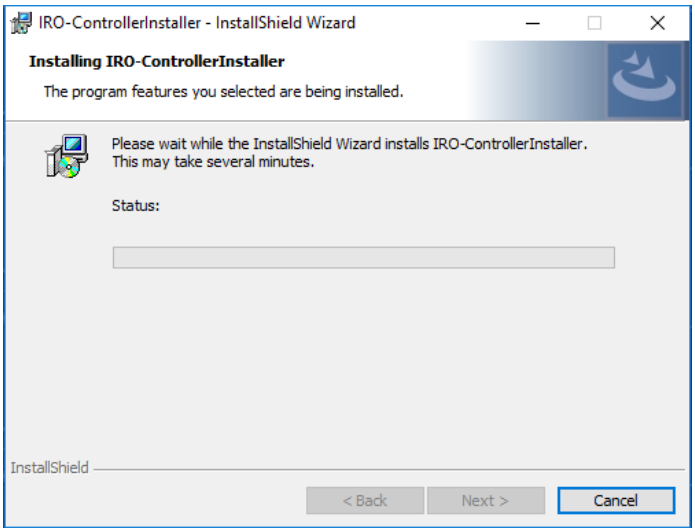
Furthermore the driver is located on the IRO APP CD.

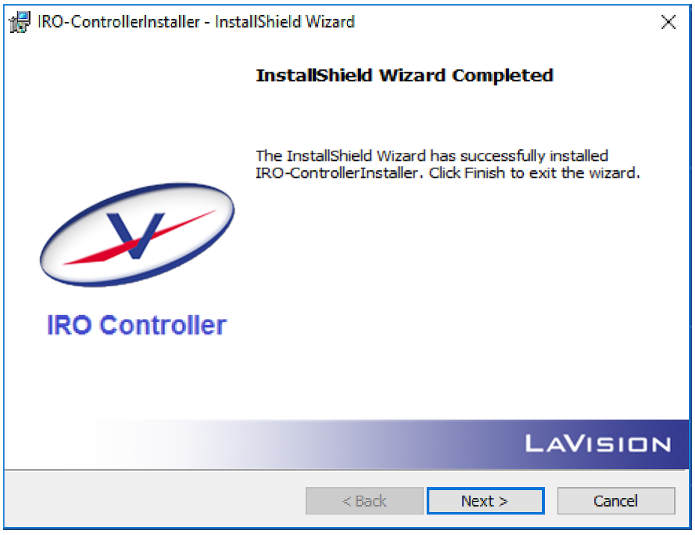
5.2 Installation of IRO APP

Copy `IRO-ControllerInstaller.msi` from your CD to the desktop. Execute the msi file. The IRO controller installer will appear.




IRO-ControllerInstaller - InstallShield Wizard
Ready to Install the Program
The wizard is ready to begin installation.
Click Install to begin the installation.
If you want to review or change any of your installation settings, click Back. Click Cancel to exit the wizard.
InstallShield
< Back
Install
Cancel


IRO-ControllerInstaller - InstallShield Wizard
Installing IRO-ControllerInstaller
The program features you selected are being installed.
Please wait while the InstallShield Wizard installs IRO-ControllerInstaller. This may take several minutes.
Status:
InstallShield
< Back
Next >
Cancel


IRO-ControllerInstaller - InstallShield Wizard
InstallShield Wizard Completed
The InstallShield Wizard has successfully installed IRO-ControllerInstaller. Click Finish to exit the wizard.
IRO Controller
LAVISION
< Back
Next >
Cancel

5.3 Remote Control with IRO APP

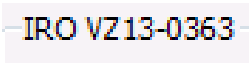
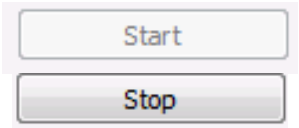
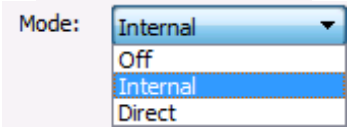
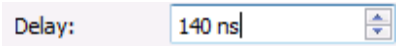
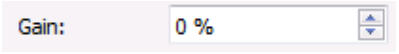
After Installation of the **IRO APP** you should find the symbol **IRO APP** on your desktop.

Before starting the **IRO APP** you should have switched on the IRO X controller. After starting the program the IRO APP control view appears (see Fig. 5.1).

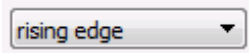
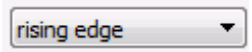
Figure 5.1: IRO APP control view.

5.4 Remote Control Items

Beyond the local control commands the **IRO APP** allows further parameter controls. The various controls are given in the list below. Various controls are only available in specific operation modes. If a parameter is not available in the selected operation mode the control for it is disabled.

Display/Control	Comment
	The device identifier (individual for each IRO X controller).
	Switch to previous mode. Any mode else Off has to be selected before. Switch to Mode "Off".
	Operation modes.
	Set the delay within the range: 5 ns - 10000000 ns (= 10 ms). Only available within the operation modes "Internal" and "Arming".
	Set the gate width within the range 5 ns - 10000000 ns (= 10 ms). Only available within the operation modes "Internal" and "Arming".
	Set the gain in the range of: 0% - 100% corresponding to the MCP voltage 0 - U_{max}.
	Slider to change MCP voltage.

The following settings cannot be controlled locally:

Display/Control	Comment
Trigger Input:	
	Switch: rising / falling edge
	Select termination 50R = 50 Ω or High Z = 200 Ω
Arming Trigger:	
	Switch: rising / falling edge
	Select termination 50R = 50 Ω or High Z = 200 Ω.
	# of triggers accepted after Arming pulse. Only available within **Arming** mode.

6 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.
- The number of the used dongle (if available).
- Article number (if available).
- Serial number (if available).
- A short description of the problem.

6.1 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.
- **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.

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LaVision
FOCUS ON IMAGING

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