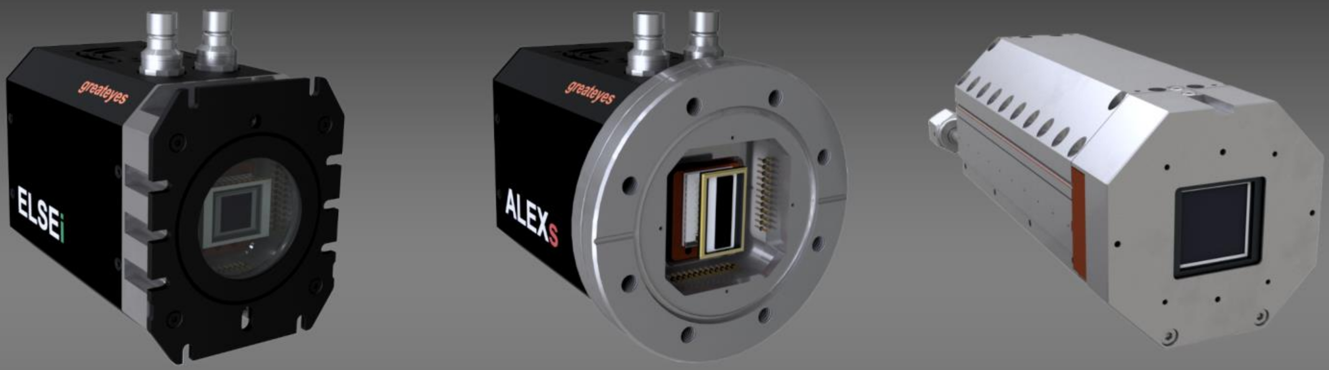
greateyes

DISCOVER WHAT
THE EYE CAN'T SEE

# Instruction Manual

## greateyes CCD Cameras with Software Vision




Version 9.3

# CONTENT

# GREETINGS

Dear valued customer,

Thank you so much for choosing a scientific camera from greateyes! On behalf of the whole greateyes team I can tell that your trust in our technology is highly appreciated and makes us even more committed to meet your expectations. We all will do our very best to serve you well and make you yet another happy customer among the growing greateyes user family.

For us support does not end by selling this product to you but it actually starts here! You may want to reach out to our support department during the hardware installation or request assistance during the software integration process. Just drop a message to support@greateyes.de or get a support ticket on our web page (https://www.greateyes.de/en/support.html). My team will be glad to assist you.

We strive towards a long-lasting cooperation and partnership with you. Feedback of all nature will help us to improve our products and greateyes as a company further. Therefore, we kindly ask you to share your experience with the product right in front of you. Thank you once more! We look forward to hearing from you.

For now, I wish you smooth set-up time with the camera and nice first results with your imaging or spectroscopic system!

Kind regards,

Roman

CEO

# 1 SAFETY INSTRUCTIONS & SYSTEM REQUIREMENTS

Dear User, this manual is regularly updated before printing. However, we cannot fully exclude all possible errors and mistakes. If you notice anything in this document that should to be corrected or improved, you are welcome to send us suggestions via support@greateyes.de. Thank you.

## 1.1 SAFETY INSTRUCTIONS

The greateyes cameras contain fragile components such as delicate wiring and photosensitive materials. Any abrupt handling could lead to irreversible damages to the cameras. Therefore, please handle the camera very carefully. The cameras are designed for precise detection of weak light or radiation signals in spectroscopy or imaging applications. greateyes is not liable for any damages caused while using the cameras for other purposes.

All components within the camera body do not need adjustment by the user. The warranty of the camera will be void once the warranty seals are erased, defaced, tampered, or otherwise, altered and rendered unintelligible. Only authorized service personnel are eligible to open the camera. Please use only the power and connection cables provided by greateyes. Please Contact greateyes in case a replacement or an additional cable is required.

**The standard procedure to turn on the camera** is:
1. Turn on the cooling unit if purchased, and wait for several minutes until the coolant flows properly.
2. Turn on the power supply of the camera. The fan of the camera should be running and the Power On LED light should light up now.
3. Open software and connect the camera.

⚠ **ATTENTION: For camera type LOTTE, water cooling must be enabled at all times of camera operation. Operating the camera without water cooling leads to damage of the camera.**

**The standard procedure to turn off the camera** is:
1. Disconnect the camera via software and wait for several minutes until the detector returns to room temperature;
2. Shut down the camera. You find the POWER button of the camera on the backside. The POWER button of the camera type LOTTE you find on the CF DN100 feedthrough flange. Press the POWER button for ca. 5 s to shut down the camera (similar to a PC) and wait until the green Power LED stops blinking. Then switch off the power supply of the camera.
3. Turn off the water cooling unit if connected.

Do not use the camera in environment of high humidity, strong electric fields, and strong magnetic fields. These circumstances will affect the cameras' performance and may cause serious damages to cameras.

greateyes is not liable for personal injuries or other damages which are caused by neglecting the above safety instructions and/or operating the camera or accessories outside their recommended operating conditions.

## 1.2 SYSTEM REQUIREMENTS

The greateyes CCD cameras can be operated with the associated greateyes Vision software on the following operating systems: Windows 7/8/10/11 in 64bit version (limited 32bit support possible on request). In addition, an Ethernet port (10 / 100MbE or 1GbE) or USB port (USB 2.0 / 3.0) is required to connect the camera directly to a PC or via a local area network (LAN). An optional SDK for Windows and Linux compatible with C/C++, Delphi as well as LabVIEW and EPICS drivers can be provided in order to integrate the camera into an existing software control framework or for using the camera with different operating systems.

# 2 THE INTERFACE OF CAMERAS AND POWER SUPPLY UNITS

## 2.1 THE INTERFACE OF CAMERAS

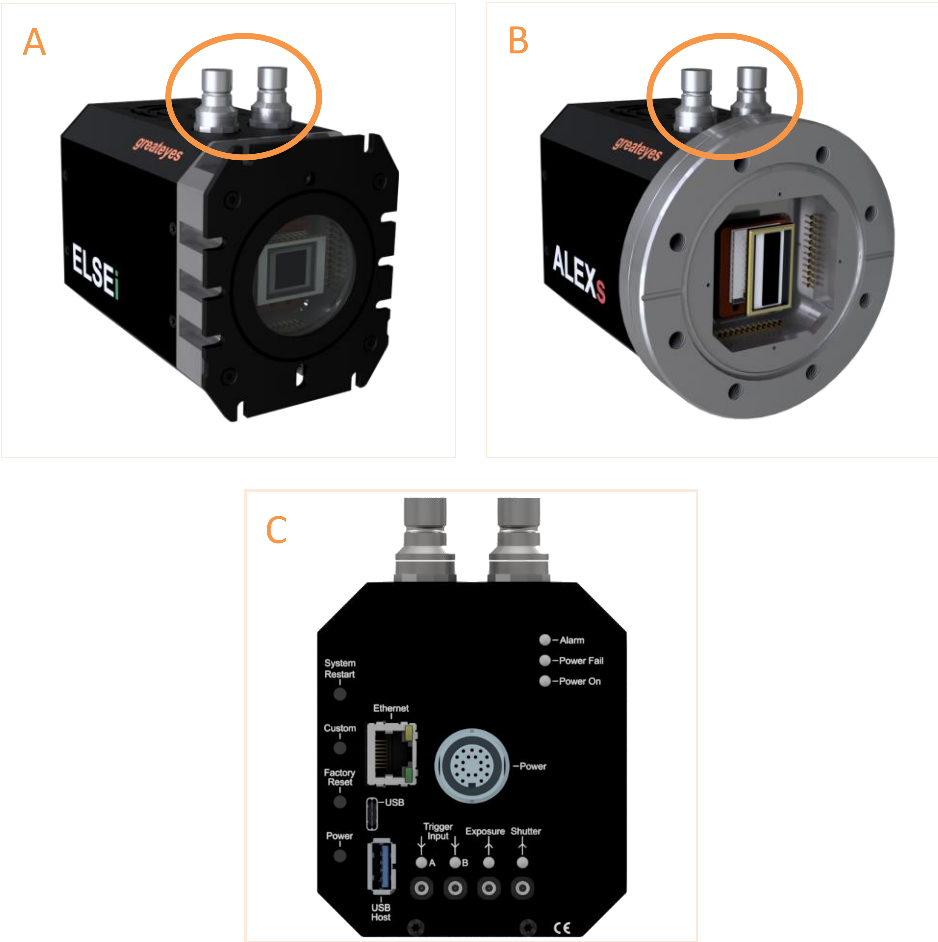



Fig. 1 Front and back sides of greateyes cameras (non 2k2k plus and non 4k4k formats). (A) front side of ELSE series; (B) front side of ALEX series; (C) back side of ELSE and ALEX series

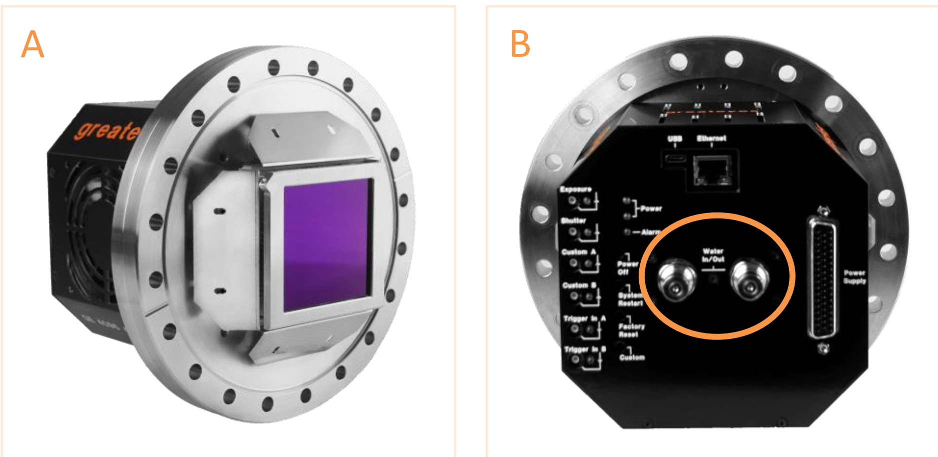



Fig. 2 Front and back sides of ALEX 4k4k cameras. (A)Front side; (B) Back side.

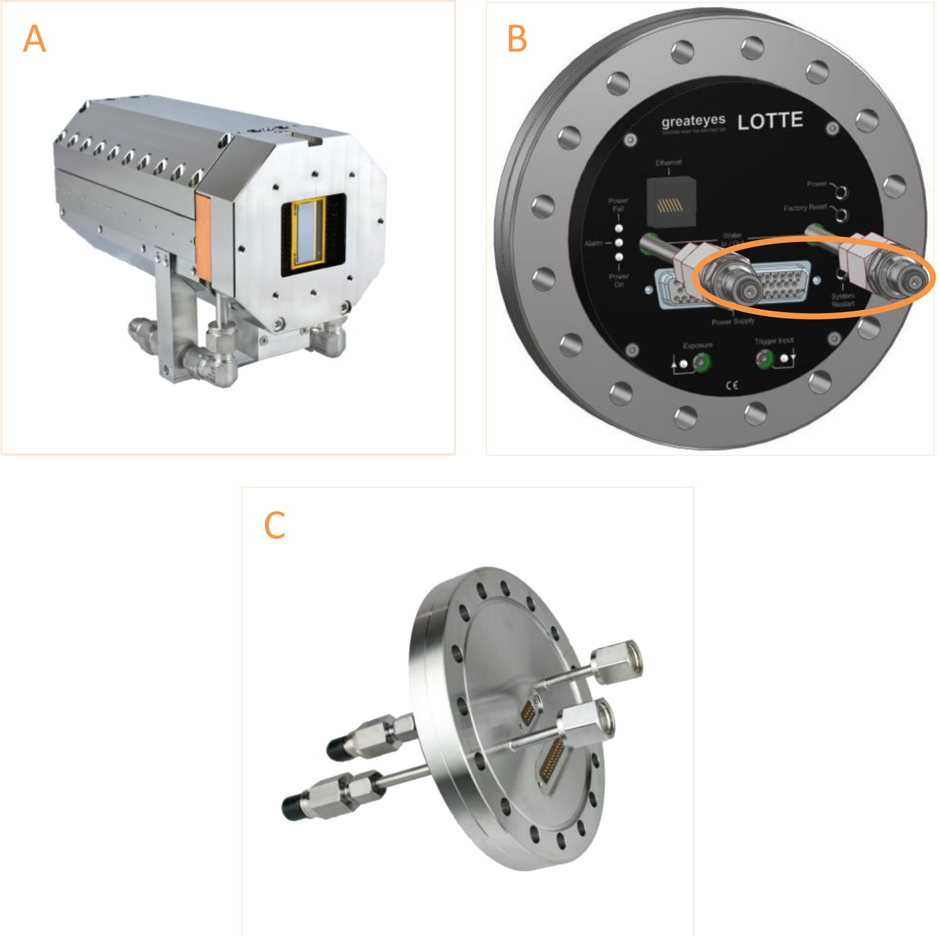



Fig. 3 (A) Front view of LOTTE camera; (B) Back view of feedthrough flange; (C) Side view of feedthrough flange

Some sockets are covered with protective caps for safety transportation and can be removed easily for installation. All sockets, buttons and lights on the back side of the cameras are listed here:

**Power** socket: connects the camera to the external power supply unit with the enclosed power cable (round 19POL for non 2k2k plus and non 4k4k formats, DSUB50 for 2k2k plus and 4k4k formats).

**USB** socket (not available for LOTTE): female USB 3.0 type C socket, connects the camera to a PC with enclosed type C to type A cable.

**USB Host** socket (not available for LOTTE): female USB 3.0 type A socket, external USB devices can be powered by the camera through this socket.

**Ethernet** socket: Ethernet socket, connect the camera to a PC, or to a switch/router of your network. Please see further instruction on Ethernet connection in Chapter 4.2.

**Trigger Input** socket: an input port receives external trigger signal with enclosed SMB to BNC cable. The user needs to activate the **ext. Trigger** in the software first to activate this port (see Chapter 4.4.5). Then the camera will be triggered to take an image whenever a 5V TTL signal is given. The input is loaded with a typical current of 5-10mA.

**Shutter** socket (not available for LOTTE): an output port to connect an external shutter (see Chapter 4.3.5). The maximum current applied to the Shutter output should not exceed 20 mA.

**Exposure** socket: an output port to connect and trigger external equipment. It provides a 5V TTL signal which is active during the exposure time of the camera only. The output may be loaded with a rated current of 20 mA max.

**System Restart** button: the button is used to reboot the camera electronics in case of any malfunction, or if the reboot upon firmware or configuration updates has failed.

**Custom** button: currently is not used by default and could be used for activities related to an output, when enabled, a user defined function can be implemented in a future firmware upgrade upon request.

**Factory Reset** button: the button is used to reset the entire camera configuration (including web interface password, network settings, etc.) to its factory defaults and the camera is rebooted to apply the changes immediately. Press the button for at least 10 seconds to perform this action.

**Power** button: the button is used to shut down the camera electronics in a safe manner. Press the button for at least 3 seconds to perform this action. When the camera is shutting down, all currently active status LEDs will start to blink, and the LEDs will be powered off when the camera shutdown process has completed.

Note: It may take up to 2 minutes until the camera shuts down in case the cooling system was running at high levels since the cooling control will perform a controlled ramp down of the cooling power to prevent any damage to the thermoelectric coolers and/or the sensor.

**Alarm** LED: the light turns on when at least one value within a set of critical operating condition limits has been exceeded. Among these are e.g. critical humidity conditions (condensation) within the camera, excessive temperatures as well as malfunctions within the camera electronics. If this LED is active, please power off the camera and contact greateyes for further advice.

**Power Fail** LED: indicates that the integrated monitoring circuitry has encountered a problem with the camera power (i.e. external power supply). If active, please power off the camera and contact greateyes for further advice.

**Power On** LED: indicates that the camera power is connected and active, and thus the camera is currently in operation.

## 2.2 THE INTERFACE OF POWER SUPPLIES

The power supply unit GE-POW01(Fig. 4A and43B) supports all camera series except ELSE-i 2k2k plus, ALEX-i 2k2k plus, LOTTE-i 2k2k plus, ELSE-i 4k4k, ALEX-i 4k4k, and LOTTE-i 4k4k, the last six series are supported by power supply GE-POW02 (Fig. 3D and 3E). Please see the detailed specifications of the power supplies in Chapter 6.3.

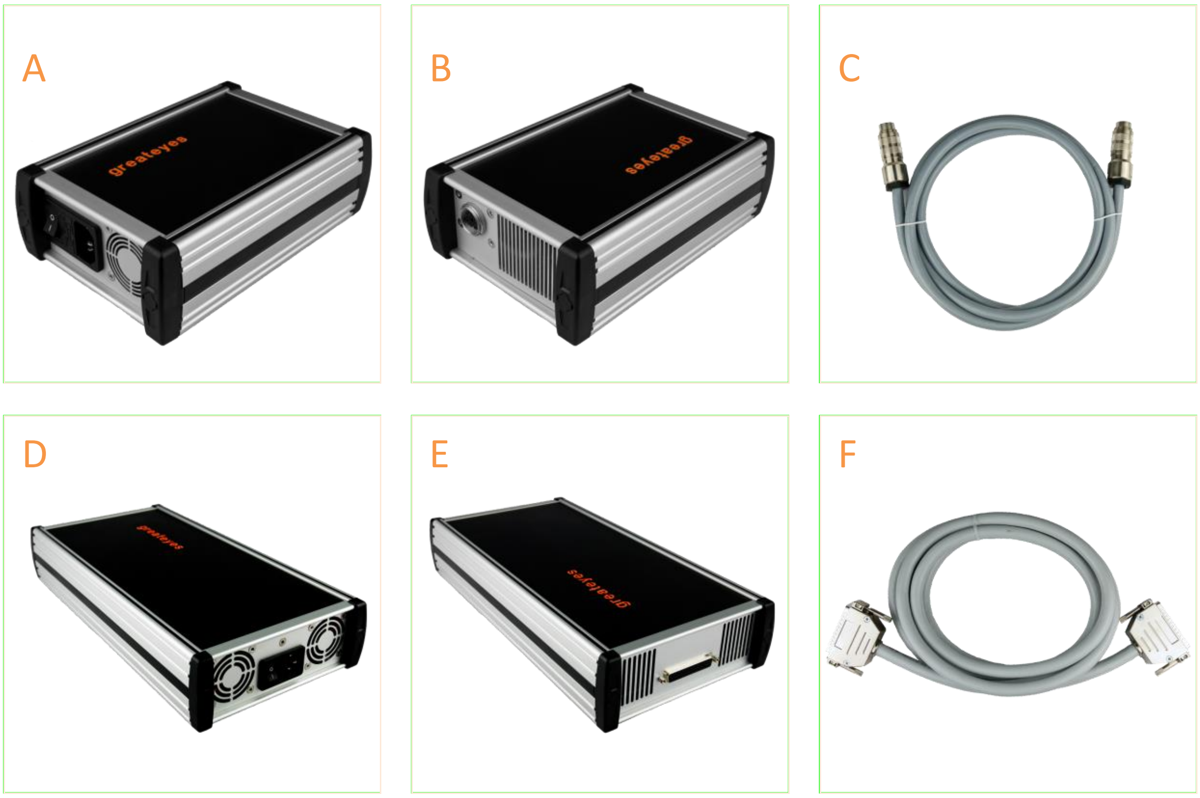



Fig. 4 Photos of power supply units. (A) Front side of GE-POW01, shows the power switch, input (AC Mains) connector, and forced-air cooling inlet; (B) Back side of GE-POW01 with output connector; (C) 19-pol cable for connecting the GE-POW01 and the cameras; (D) Front side of GE-POW02, shows the power switch, input (AC Mains) connector, and forced-air cooling inlets; (E) Back side of GE-POW02 with output connector; (F) 50-pin D-Sub cable for connecting the GE-POW02 and the cameras.

# 3 HARDWARE INSTALLATION

greateyes cameras support three different cooling options: air cooling, passive water cooling and active water cooling. For air cooling, there is already a fan installed inside the camera series of ELSE and ALEX, LOTTE series has no air cooling available. However, without external heat removal by using a liquid cooling system, only limited cooling performance can be achieved. Hence, we recommend attaching the liquid cooling unit.

## 3.1 INSTALLATION OF ALEX SERIES

All ALEX series cameras are equipped with a certain flange, which can be attached to a vacuum chamber. The flange type could be a standard knife-edge sealed CF flange or a standard KF flange of different sizes, or a customised flange. The user should inform themselves with different flange types and install the camera on the vacuum chamber correctly. Installation steps of ALEX series are as follows:

1. Take the camera out of package, lay it on the workbench carefully;

2. ALEX cameras are usually delivered with a cover on the flange to protect the sensor. Please hold the cover and remove screws which fix the cover on the flange, then remove the cover from the flange carefully.

**⚠ ATTENTION: For some customised cameras, the sensor could be protruding out of the flange surface of the camera, one has to pay attention to not touch the protruding parts while removing the cover, since the detector and wirings are very fragile!**

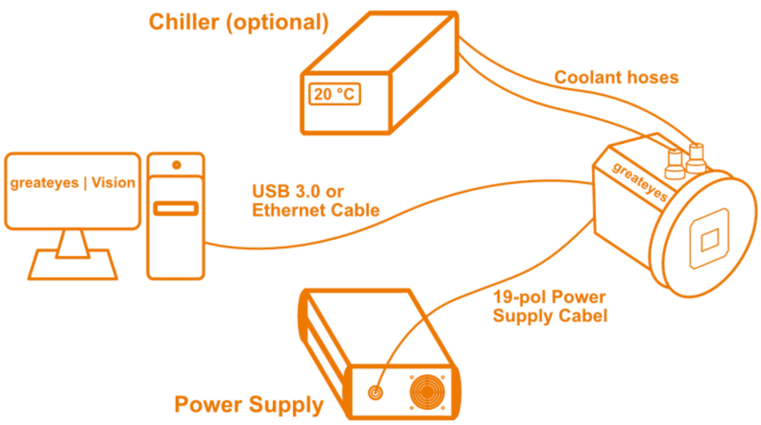
3. Please use the attached copper ring between the camera and the flange of the vacuum chamber. The copper ring can only be used once. Note: for cameras with protruding sensors, the copper ring may destroy the sensor if the copper ring dropped onto the protruding parts;

4. Aim the camera head to the flange on vacuum chamber carefully then combine flanges with screws or clamp;

5. When demounting the camera from the flange of vacuum chamber, please also pay great attention to the protruding part and the copper ring;

6. Do not turn on the camera and the cooling unit until the vacuum chamber is sufficiently evacuated. The minimum requirement of in-vacuum pressure for using camera with cooling is below $1*10^{-5}$ mbar;

7. After the camera is attached to the chamber, the cables and hoses can be connected as the following figure;




8. Only release the vacuum chamber after the CCD sensor has returned to room temperature, and after the power supply has been turned off. Otherwise contaminations could be condensed on the sensor. **Once contaminations on the sensor occurred, do not try to clean it by yourself and please ask greateyes for support.**

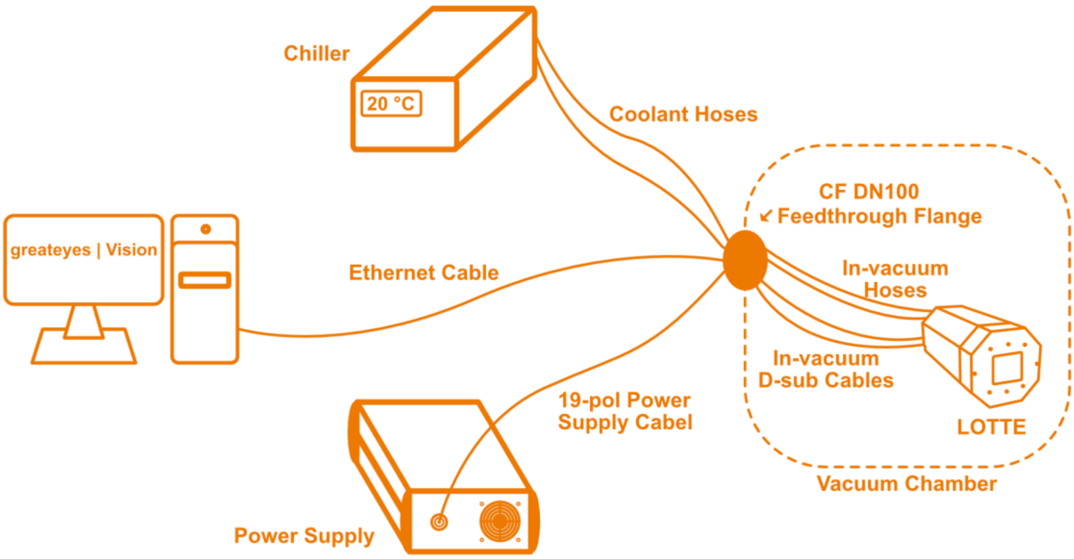
## 3.2 INSTALLATION OF ELSE SERIES

ELSE series cameras are also delivered with a cover on the front for protection. After the cover is removed, the camera is ready for use once they are connected to the power supply and PC, as the figure in the last chapter suggests. However the user should avoid getting ELSE exposed with room light when carrying out testing, as pixels on ELSE's sensor are very sensitive and can get over-saturated easily already with room light.

## 3.3 INSTALLATION OF LOTTE SERIES

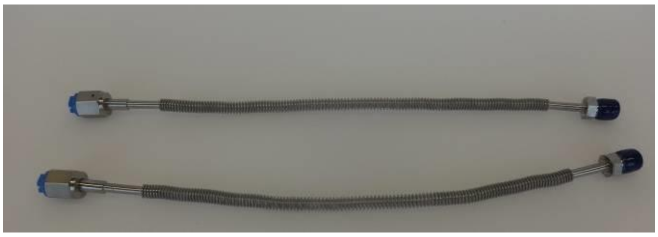
Similar to ALEX series, sensors of LOTTE series are also detecting photons directly. They are delivered with a cover on the front of the sensor as well. The difference is that LOTTE's camera body is not attached on the vacuum chamber but placed inside the vacuum chamber, the data and cooling connections are established through in-vacuum cables/hoses and a feedthrough flange on the vacuum chamber.

1. The sketch below shows connections between different parts;




2. Please wear lab gloves when handling LOTTE cameras;

3. Connect the In-vacuum hoses and the In-vacuum D-sub cables to the camera on the one hand and to the CF DN100 feedthrough flange on the other hand. The In-vacuum hoses are used for the water cooling within the vacuum. It is important to insert a new pair of sealing rings of silver plated stainless steel always when the bellows is screwed to the camera or to the Feedthrough Flange again:



To connect the In-vacuum hoses either to the camera or the interface flange, proceed as follows:

Insert a new sealing ring of silver plated stainless steel between all male and female connectors (4 sealing rings are needed for a complete initial installation).

Tighten all connections manually and make sure the sealing ring is still placed correctly. Use two wrenches and turn both connectors another 1/4 turn towards each other.

Please avoid bending the water pipes on the feedthrough flange during installation. A water pipe bent by force may cause a leakage.

The In-vacuum D-sub cables can be plugged in after the installation of the hoses. It is recommended to fix the screws of the D-sub connectors to the camera and to the Feedthrough flange;

4. LOTTE camera will be delivered with a cover at front, please remove the cover carefully, ⚠ **DO NOT touch the sensor surface with anything**;

5. Place the camera with hoses and cables carefully in your vacuum chamber and close it with the feedthrough flange. Please use the included copper ring between the feedthrough flange and the flange on vacuum chamber. The copper ring can only be used once;

6. ⚠ **DO NOT turn on the camera and the cooling unit until the vacuum chamber is sufficiently evacuated;**

7. ⚠ **DO NOT release the vacuum chamber until the CCD sensor has returned to room temperature.**

## 3.4 PASSIVE WATER COOLING UNIT


Fig. 5 Passive water cooling unit GE-CR01. (A) Front view, shows front control panel and the reservoir on top; (B) Back view of the cooling unit, power adaptor, and cables; (C) Hoses for connecting the camera and the passive cooling unit

Fig. 5 shows photos of passive water cooling unit, its product code is GE-CR01. This cooling unit circulates the coolant without cooling it down, hence its cooling ability is related with the ambient temperature. Before connecting the cooling unit to the camera, please make sure that the camera is turned off, and then follow the steps below:

1. First connect the camera to the passive cooling unit by using hoses in Fig. 5C. Connectors in the orange circle in Fig. 5C should be connected to the male connectors in orange circles in Fig. 1A, Fig. 1B, Fig. 2B. Fig. 3B. Then connectors in red circle in Fig. 5C should be connected to the Inlet / Outlet connectors in red circle in Fig. 5B. Each hose can either be connected to "In" or "Out";

2. Connect the cables and adaptor to the cooling unit in the order of ①→②→③→④ in Fig. 5B, then connect the cooling unit to an external power source;

3. Fill the reservoir on the top of the circulator with cooling liquid, one can open the circulator by removing the screws on the top of it. After filled in the cooling liquid, you can switch on the unit at the power adapter. To get the best cooling performance, please set the fan speed (F) and the pump speed (P) to 10 by using the buttons on the front control panel.

Note: 1. Check all connections for leaks before turn on the camera; 2.the water cooling unit should be placed above the camera in order to have a better distribution of the cooling liquid.

## 3.5 ACTIVE WATER COOLING UNIT

**Warning: If you want to use an active water cooling unit, please ensure that the liquid temperature is above the dew point (Fig. 6 D). We recommend a temperature of at least 2 °C above the dew point. Otherwise, the camera electronic could be damaged.**

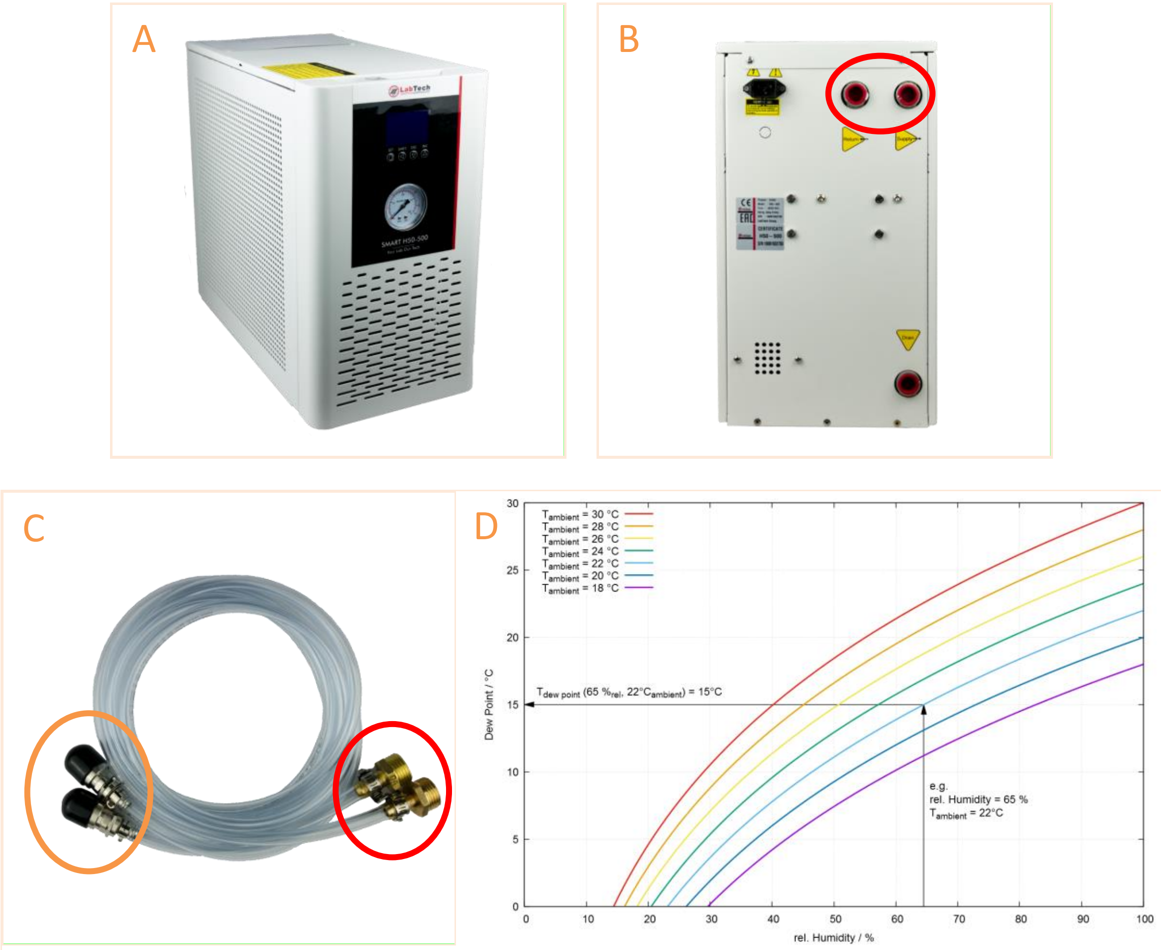



Fig. 6 Active water cooling unit GE-CR02. (A) Front view, shows front control panel and the reservoir on top; (B) Back view of the cooling unit; (C) Hoses for connecting the camera and the active cooling unit; (D) Dew point overview

Fig. 6 shows the photo of active water cooling unit, its product code is GE-CR02. This cooling unit will cool down the coolant to a temperature lower than the ambient temperature, then circulates the coolant. Hence, it can help the camera sensor to reach a lower cooling temperature than what GE-CR01 can achieve. Before connecting the cooling unit to the camera, please also make sure that the camera is turned off, then follow the steps below:

1. First connect the camera to the active cooling unit by using hoses in Fig. 6C. Connectors in the orange circle in Fig. 6C should be connected to the male connectors in orange circles in Fig. 1A, Fig. 1B, Fig. 2B. Fig. 3B. Then connectors in red circle in Fig. 6C should be connected to the Inlet / Outlet connectors in red circle in Fig. 6B. Each hose can either be connected to “In” or “Out”;

2. Fill the reservoir on the top of the circulator with cooling liquid, then connect the cooling unit to an external power source with the enclosed cable.

# 4 SOFTWARE OPERATION

This chapter is written to help users operate greateyes' Vision software. If you need support for other software or SDKs, such as C++, LabVIEW, EPCIS (when purchased), please find corresponding instructions in the USB drive attached in the package of the camera, or contact support@greateyes.de.

## 4.1 DRIVER AND SOFTWARE INSTALLATION

The greateyes Vision software is stored in the USB flash drive within the package of the camera. You can find the installation file (setupVision.exe), the testsheet of the camera (folder testsheet) and instruction files (folder documentation) after opening the USB drive on your PC.

For users who control the camera through USB connection, please first connect the camera to the PC with the enclosed USB cable from the package of the camera. Once the cable is connected properly, a virtual network adapter will be created in Windows or Linux system as a "Remote NDIS Compatible Device". The USB connection between the camera and the PC will also be established automatically. In case the USB connection fails, please check Chapter 5.1.

Once the virtual network adapter for the USB connection is established, one can also find the camera as a device in the Network tab of Windows Explorer. Here in the device you can also find other information such as the model name, serial number and IP address of the camera.

For users who control the camera through Ethernet connection, a network configuration needs to be set up, please see Chapter 4.2.

After the camera is connected to the PC, please start the "setupVision.exe" in the top-level of the USB drive to install the greateyes Vision software. After the installation is finished, users can start the Vision by clicking the icon on the desktop. Once the Vision software is started, please choose **USB** or **Ethernet** camera interface in the **Options** menu of the Vision software accordingly.

## 4.2 NETWORK CONFIGURATION

In addition to the instant USB 3.0 connection to PC, greateyes cameras also support a connection through Ethernet cable. It is recommended to connect the camera directly to the Ethernet port of your PC when proceeding this network configuration.

The network configuration of the camera can already be carried out prior to the shipping of camera. By default, they are preconfigured with the following TCP/IPv4 network settings:

IP address: 192.168.1.234

Subnet Mask: 255.255.255.0

Gateway: 192.168.1.1

Server Port: 12345 (TCP)

The software communicates with a server running on the camera's back-end electronics via TCP on port 12345 (customizable). Please make sure that the PC is part of the same IP subnet and that no firewall settings on the PC or within the network prevent TCP communication to/from the configured server port.

1. In order to change the network configuration please ensure that the PC has an IP address within the subgroup 192.168.1.xxx and a subnet mask of 255.255.255.0. The IP address of the PC can be changed within the network centre of your Windows control panel;

2. After the camera is connected to the PC via enclosed Ethernet cable, please open your web browser and enter the default camera **IP address 192.168.1.234** in the address bar. The IP address of the camera can be reset to default by pressing the **Factory Reset** button on the back of the camera for at least 10 seconds. Please note that it may take some minutes before the connection to the camera is established after changing the IP address;

3. The default login **User Name** is **admin**, the **Password** is **greateyes**. The user can change the password in later steps, and it can be reset to default by pressing the **Factory Reset** button on the back of the camera for at least 10 seconds.

After logged in, one can see four tabs on the left of the page: **Home**, **Network**, **System**, **Firmware** and **Log**.

In **Network** tab: **Current Network Status** shows the host name, IP address, Subnet Mask and the MAC address at present. **Network Settings** allows the user to change the IP configuration mode between **Dynamic (DHCP)** and **Static** IP address configurations. In DHCP mode, the IP address of the camera is set by a DHCP server within your network. In static mode, you may enter the IP address and subnet mask for the camera manually. Remember the IP address can be reset by pressing the **Factory Reset** button on the back of the camera for at least 10 seconds.

In **System** tab: **System Information** shows the type and Serial Number of the camera. **System Status** shows the present status of the camera server, the analogue front-end electronics (ADCs) power, the actual sensor power (including all clock, bias voltages), and SSH Access. In case of any malfunction the user can start, stop or restart the four status (the SSH Access is for service purposes only, it is not recommended activating the SSH Access). The user can change the login password in the **Change Login Settings**. Remember you can reset the system status and password to default ones by pressing the **Factory Reset** button on the back of the camera for at least 10 seconds. The system can also be reset by clicking the **Reset and Reboot** button in the **System Settings**. By clicking the **Reboot**, only the camera electronics will be rebooted, the IP configuration and the password will stay unchanged. Note: It may take up to 2 minutes until the camera reboots in case the cooling system was running at high levels since the cooling control will perform a controlled ramp down of the cooling power to prevent any damage to the thermoelectric coolers and/or the sensor.

In **Firmware** tab: **Firmware Information** shows the current the original firmware version of the camera. Firmware Update allows the user to update the firmware by selecting firmware update file. **Please do not turn off the camera power during the update process**. Once succeeded, the camera will reboot and the new firmware version string should appear under **Firmware Information** in the web interface. All configuration settings of the camera will stay unchanged during the update process. If an update fails or the new firmware causes inadvertent behaviour, the firmware can be reverted to the factory or any formerly installed firmware version under **Firmware Recovery**.

After the above settings, you can also choose to connect the camera to a switch or router in your network.

At last, enter the IP address of your camera in the **Camera Setup** tab in the **Camera Connection** area of the software. The Ethernet connection should be successfully built up by now. Please note that it may take seconds until the connection is established.

## 4.3 CAMERA SETUP BEFORE MEASUREMENTS

Fig. 7 shows the interface of greateyes Vision software. The input fields have been highlighted with turquoise colour. After given new inputs, the background colour in these fields will change from turquoise to yellow. New inputs can be confirmed by using the Enter key on your keyboard. **If a new input is valid, the yellow background will turn turquoise again, otherwise the new input is not valid and cannot be accepted by the software.**

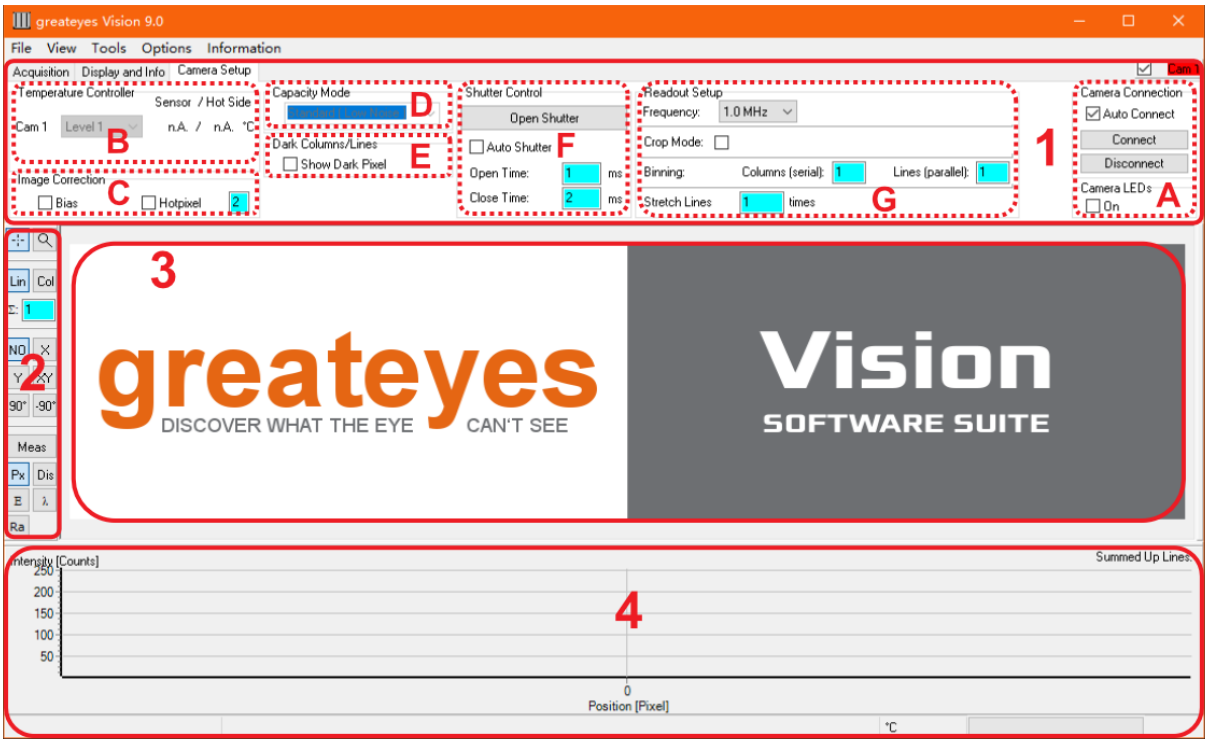



Fig. 7 The interface of greateyes Vision software (version 9.0 with USB connection). It includes four areas: (1) the operation area at the top; (2) the toolbar on the left; (3) the image display window; (4) the diagram display window, the diagram window can be opened or closed in the **View** menu or using **Ctrl + D**.

### 4.3.1 CAMERA CONNECTION IN THE SOFTWARE

After the hardware and the software installation, you can first turn on the water cooling unit (if purchased) and let it flow for 2 minutes. Then you can turn on the power supply unit of the camera and start the Vision software. Please **DO NOT** turn on the water cooling and power supply of the camera before the vacuum chamber is sufficiently evacuated (referring to ALEX and LOTTE series in this case).

Fig. 7A shows the **Camera Connection** options.

**If the camera is connected to the PC through a USB cable**, the functions are as follows. If the **Auto Connect** box is checked, the camera will be automatically connected to the software when the software starts. If not, please click **Connect** button to connect the camera to the software. If all cables are connected properly and the driver have been installed correctly, the **CAM 1** sign will turn green when the camera is connected. Otherwise the **CAM 1** sign will be red.

By clicking **Disconnect**, the camera will be disconnected from the software, **CAM 1** sign will turn red. Please note that the camera is still active after clicking **Disconnect**, the camera will be fully turned off only when the power supply unit is also switched off.

**If the camera is connected to the PC through an Ethernet cable**, the **Camera Connection** area shows the IP addresses of cameras, the user can connect cameras of different IP addresses by clicking the **Connect** after.

All **Camera LEDs** (including those of the Ethernet socket) can be turned off in the software to prevent any light contamination at long exposure times. Check or uncheck to turn on/off all camera indicator LEDs accordingly.

### 4.3.2 TEMPERATURE CONTROLLER

The greateyes cameras use thermoelectric coolers for the sensor cooling. When the cooling is activated, the dark noise of the sensor can be reduced, which in turn will increase the signal-to-noise ratio of the captured image.

Fig. 7B shows the **Temperature Controller**. From the drop-down menu in area B, the user can choose different temperatures ranging from 20 °C to -100 °C, or **No Control**. It may take several minutes to reach the target temperature once a new temperature is selected or the software is restarted. Please wait until the temperature becomes stable, and then start the measurement. If **No Control** is chosen, the camera won't active any cooling units and hence the detector will stay at room temperature.

Next to the drop-down menu, the actual temperature of both, the **Sensor** and the **Hot Side** of the thermoelectric cooling element, are indicated. Besides, the actual temperature of the sensor is also shown in the info line at the bottom of the software.

The dissipated heat from the sensor leads to a temperature increase of the hot side on the thermoelectric cooling element. If the cold side exceeds 50-60 °C, the **Alarm** LED light on the back of the camera will start to blink in order to warn the user. The efficiency of heat dissipation depends on the type of selected cooling, i.e. air cooling or liquid cooling. In order to achieve the maximum cooling performance, we recommend using the liquid cooling if purchased.

Please note that different camera models with different cooling units may have different cooling abilities, i.e. some cameras with certain types of cooling accessories cannot be cooled down to -90 °C or -100 °C even if you selected -90 °C or -100 °C in the drop-down menu. Please check the test sheet included in the camera's package to find out the lowest temperature that your camera can reach.

### 4.3.3 IMAGE CORRECTION

In the C area of Fig. 7 the user can proceed the **Image Correction**.

Due to its intrinsic property, the sensor may contain several pixels that are brighter than their neighbouring ones. The user can check the **Hotpixel** box to correct these failures. The input field next to **Hotpixel** affects one digit behind the decimal point of the correction factor. For example, if you enter value 2, the pixel which is 1.2 times brighter than the surrounding pixels, will be corrected to the mean intensity of its surrounding pixels.

Each camera sensor also contains several dark pixel columns or lines on the edges of the effective imaging area, these pixels will not be shifted during readout process and thus can be used as a reference to the dark noise in the effective imaging area. To show them on the image please check the **Show Dark Pixel** in the area E of Fig. 7. When camera is cooled at moderate temperature and when the readout speed is slow, the pixels at the top of the image continues to accumulate dark noises while reading out, as a result, it will lead to an gradually increased dark noises from the bottom line to the top line of the image, while the dark pixels mentioned above will have more homogeneous distribution of dark noise. By activating **Bias**, these dark pixels mentioned above can be used to correct the differences of dark noises between the lines.

## 4.3.4 CAPACITY MODE (GAIN SETTING)

greateyes Cameras with 2048 × 512, 2048 × 2048 and 4096 × 4096 pixel formats can change between two different pre-amplification modes (**Capacity Mode** in area D of Fig. 7). These two pre-amplification modes are directly set at the sensor of the camera. With **Extended (High Signal) Capacity Mode**, the gain value of the signal is lower (depends on different sensors, please see our camera testsheet), which is suitable for strong signals. With **Standard (Low Noise) Capacity Mode**, the gain value of the signal is higher, weak signals in this mode will be fully mapped onto the dynamic range of the AD converter. Please keep in mind that the noise gain is also different in these two modes.

## 4.3.5 SHUTTER CONTROL

ELSE and ALEX camera series can be connected to external shutters. In Fig. 7F, the user can change the settings of the shutter.

**Open Shutter:** click this button to open or close the shutter manually.

**Auto Shutter**: check this box to activate the auto shutter mode. The shutter will be open automatically before each exposure, and will be closed after the exposure time is finished.

**Open Time**: the period reserved to ensure the shutter is fully opened before the exposure time.

**Close Time:** the period reserved to ensure the shutter is fully closed before the readout process starts.

Note: after the camera sent output to the shutter, there will be a small delay until the shutter starts to open or close. The shutter will also take some time until it's fully open or fully closed. So the actual exposure time of the camera will be slightly more than the **Exp. Time** given in the software. Please check the timing of the camera with an automatic shutter in Chapter 6.4.5.

## 4.3.6 READOUT FREQUENCY AND OUTPUTS

In the area G of Fig. 7, the user can change the **Readout Setup**. The standard options in readout **Frequency** are 50 kHz, 100 kHz, 250 kHz, 500 kHz, 1 MHz, and 3 MHz. A lower frequency reduces the readout noise and increases the image quality.

Our ALEX, ELSE and LOTTE cameras support multiple readout options. In the drop-down menu of **Output**, one can decide how many amplifiers and readout registers will be used during the readout. Please note that greateyes cameras with 1024 × 128, 1024 × 256 and 2048 × 512 formats only support one readout register and one amplifier; while cameras with 1024 × 1024, and 2048 × 2048 formats support one readout register and two amplifiers; and 4096 × 4096 and 2k2k plus format supports two readout registers and four amplifiers. Fig. 8 shows names of the readout registers and amplifiers of 4096 × 4096 format cameras.

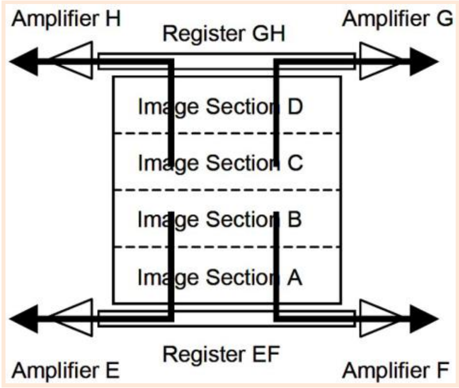



Fig. 8 Readout registers and amplifiers of 4096 × 4096 format cameras.

### 4.3.7 CROP MODE AND BINNING MODE

**Crop Mode:** In this mode only a part of the sensor will be read out, therefore the total readout time will be reduced. Once the **Crop Mode** is checked, you can specify a readout region by setting the numbers of column and line. The specified region will include columns and lines starting from the pixel (0, 0), an offset of the region from the pixel (0, 0) is not possible. Only cameras with formats of 2048 × 512, 1024 × 1024, 2048 × 2048, and 4096 × 4096 can crop both lines and columns. The formats of 1024 × 128, 1024 × 256 can only crop lines.

**Binning:** below the crop mode, the user can apply binning mode to measurements. Pixel binning is a very useful function to enhance the signal-to-noise ratio of an image. Columns and/or Lines can be binned in this mode. By giving input to the **Lines (parallel)**, electrons in several adjacent lines will be shifted into the readout register and combined as one before they are read out. By giving input to **Columns (serial)**, electrons in several adjacent pixels of the readout register will be shifted into the summing well before they are sent to the output amplifier. The binned image has fewer columns and/or lines but shows an enhanced signal-to-noise ratio, since multiple pixels are read out at once, the overall read noise is therefore reduced. Furthermore, by binning the lines one can achieve higher frame rate. Binning of lines can be applied in all camera formats, however, binning of columns is only available for the camera formats of 2048 × 512, 2048 × 2048, and 4096 × 4096.

Note: The total amount of pixels that can be binned and read-out as a single pixel is limited by the maximum charge storage capacity of the read-out register as well as the maximum charge capacity of the output node. If the sum of the electrons from the binned pixels exceed the capacity of the register pixel or output node, the register pixels or the output node.

## 4.4 DATA ACQUISITION

After the hardware installation and the software setup, now the user can take measurements in the **Acquisition** tab. Fig. 9 shows the interface of **Acquisition** tab.

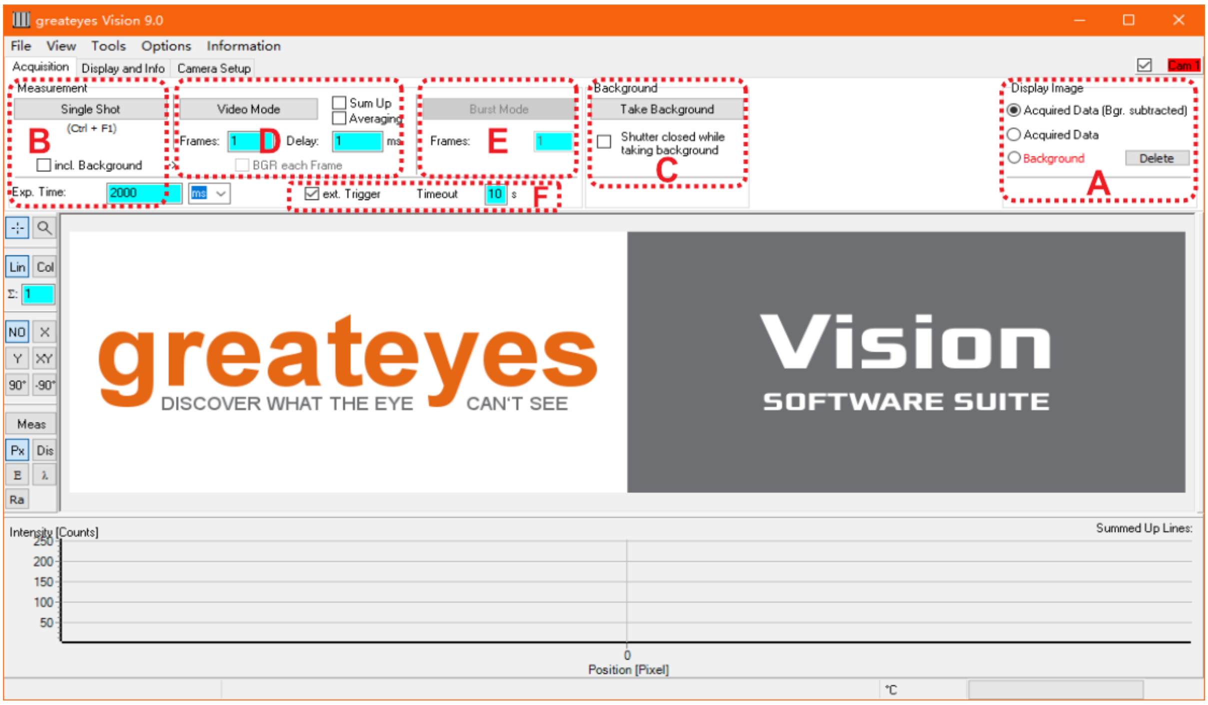



Fig. 9 The interface of Acquisition tab in GE Vision software

In the A area of **Acquisition** tab, the user can decide which data to be shown in image display window below:

**Acquired Data (Bgr. Subtracted)** : shows the final data with the background being subtracted;

**Acquired Data**: shows the final data only;

**Background**: shows the background signal only. Please note that the **Background** label will be marked red when no background was measured or loaded. The background can be removed by clicking **Delete**.

### 4.4.1 SINGLE MEASUREMENT

Before the measurements, the user would first need to define the exposure time by giving input to **Exp. Time** in the area B of Fig. 9. This input determines how long the sensor will be illuminated before the readout process starts. The time can be set between **1 ms** and **4,200 s**. You can switch the time unit between **ms** and **s** in the drop-down menu. Please note that if an automatic shutter is triggered to the measurements, the integration time will start after the **Open Time** of the shutter, and the readout process will start after the **Close Time** of the shutter (see Chapter 6.4.5).

The **incl. Background** option enables the camera to take two measurements at once, one is the background, and the other is a measurement with illumination. The background will be recorded first, then the camera will send a signal to the shutter through the **Shutter** output or to the light source through **Exposure** output, then the measurement with illumination will be taken.

After the setting, you can take one single shot by clicking the **Single Shot** button or using shortcut **Ctrl + 1**.

### 4.4.2 BACKGROUND ACQUISITION

In area C of Fig. 9, one can also choose to take the background manually. By clicking the **Take background** button, the camera will collect one background with the integration time set in Fig. 9B. Note: A new background (manual or automatic) will overwrite the last background.

If there is a shutter connected, by checking the **Shutter closed while taking background** box, the camera will keep the shutter closed when taking the background.

### 4.4.3 VIDEO MODE

In area D of Fig. 9, the user can take continuous shots by using **Video Mode**. Every shot will have the same integration time given in **Exp. Time**. However, only the latest shot will be shown in the display window below. If you wish to save all shots, please activate the AutoSave function in Chapter 4.6.

By giving input to **Frames**, the user can decide how many frames will be taken. The **Delay** decides the time gap between the starting points of two exposures. For example, if the Delay is 1000ms, then the camera will start a new acquisition every 1000ms. The Delay time should be larger than the exposure time plus readout time, otherwise it could happen that the camera will be triggered again in the last exposure or while reading out. Please check Chapter 6.4.2 to see the timing of the camera in Video Mode.

By checking **Sum Up**, the latest acquired image will be added onto the former one, so the image shown in the display window will be the accumulation of images with time. By checking Averaging, an average intensity of all frames will be shown in the display window.

If **incl. Background** is checked, one can choose to collect the background before each shot by checking the **BGR each Frame** box. Otherwise, the camera will only take one background before the series of shots.

### 4.4.4 BURST MODE

**Burst Mode**, the user can take a series of shots automatically as well. Different from the Video Mode, all shots in Burst mode will not be shown overlaid in one image, but will be patched together sequentially from top to bottom in one image. By giving input to the **Frames**, one can define how many shots will be taken and patched in one image. The number of frames in Burst Mode is limited by the RAM storage of the camera, which can only process about 180 million pixels in one image. If an external trigger is applied, each frame in Burst Mode needs to be triggered once. Please check Chapter 6.4.4 for the camera timing in Burst Mode with a trigger.

### 4.4.5 TRIGGER MODE

Fig. 9F shows the trigger mode. By checking **ext. Trigger**, the camera will activate trigger input. In this mode, the camera will be triggered by external devices to take one shot. This mode can be combined with **Single Shot**, **Video Mode**, **Burst Mode**, and **Take background**. But remember that every shot needs to be triggered once in **Video Mode** and **Burst Mode**. In trigger mode, the camera will start to take one shot whenever a 5V TTL signal on high level is applied to the trigger input of the camera. By giving value to **Timeout**, the camera will stay in trigger mode for a certain period, afterwards it will return to normal mode. The timeout can be set between 1s and 65s. Please check Chapter6.4.3 for the camera timing with a trigger.

## 4.5 DATA DISPLAY AND EVALUATION

Once the data acquisition is finished, the data can be shown with different modes in the display window. Furthermore, the user can use different tools to evaluate the data. Fig. 10 below shows the interface of **Display and Info** tab of the software.

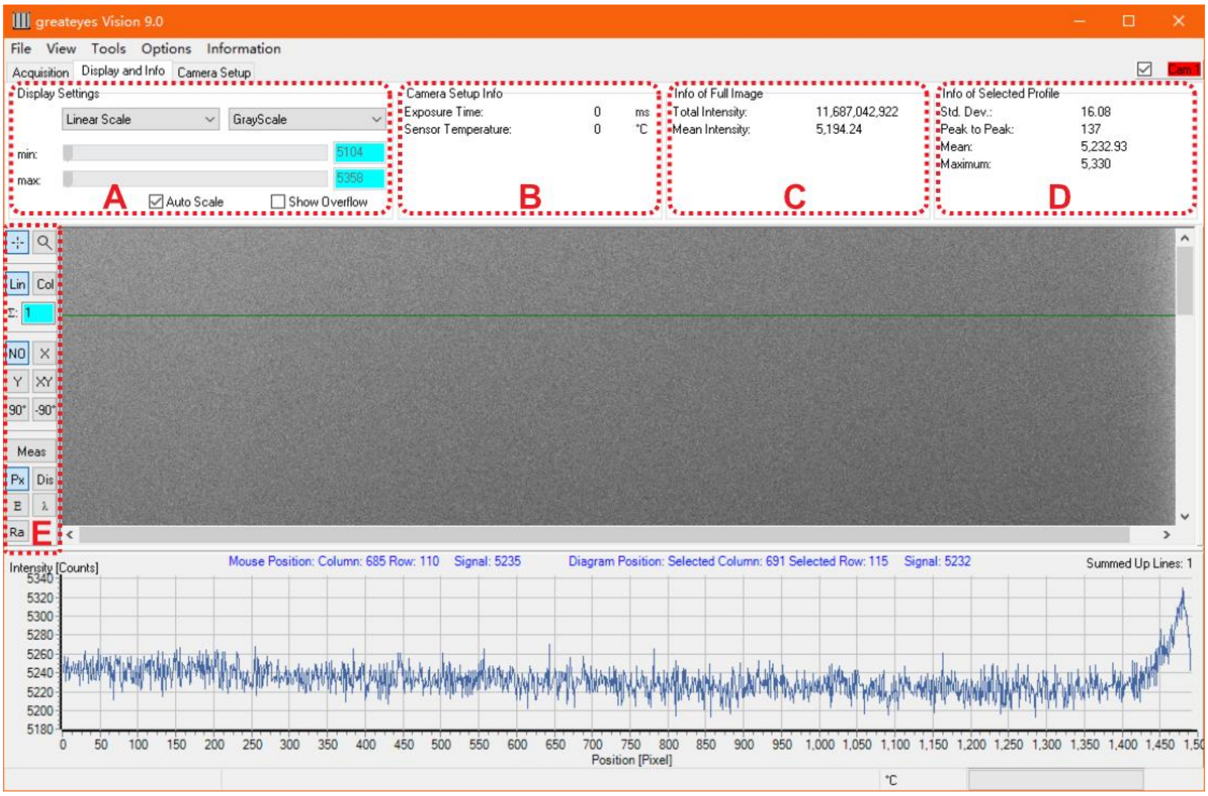



Fig. 10 the interface of **Display and Info** tab

### 4.5.1 DATA DISPLAY

In the area A of Fig. 10, the user can change the display settings. In the first drop down menu, one can choose **Linear Scale** or **Logarithmic Scale** to show the acquired data.

In the second drop down menu, the user can choose three different colour schemes: **Greyscale**, **Rainbow**, or **RedTemp** to display the data.

greateyes' ELSE, ALEX and LOTTE camera series support 18-bit AD converter, which means the data can have maximal 262,144 levels of greyscale. However, the image shown on the computer monitors has much lower greyscale (usually 256 levels depending on the quality of the monitor). The 18-bit measured data will be mapped onto the 256 greyscale of the image. By adjusting the two scale bars **min** and **max**, the user can change the lower and upper constraints of the data in order to change the contrast of the image.

If **Auto Scale** is checked**,** the values of **min** and **max** will be chosen automatically, which are the minimal and maximal intensities of the measured data.

When the signal is too strong, pixels could be saturated. If **Show Overflow** is checked, all saturated pixels will be shown in black colour.

In area B of Fig. 10, it shows the **Exposure Time** and the **Sensor Temperature** when the data was acquired. Please note that only raw data can store the both information. All the other formats, such as TIFF and so on, do not include the information of exposure time and sensor temperature.

In Fig. 10C, it shows the **Info of Full Image**. **Total Intensity** is the total intensity of all pixels in the image; **Mean Intensity** is the mean intensity of all pixels in the image.

In Fig. 10D, it shows the following information from the diagram window (selected line or column):

**Std. Dev.**: shows the standard deviation of the chosen profile's the intensity;

**Peak to Peak**: shows the difference between the min. and the max. intensity of the profile;

**Mean**: the mean intensity of the chosen profile;

**Maximum**: the maximal intensity of the chosen profile.

Area E of Fig. 10 shows the **Toolbar**. When combined with the mouse, the user can achieve the following actions to transform the picture.

- **Cross sign ✜** + **Lin** + **single click left mouse button**: select a line in the image;
- **Cross sign ✜** + **Col** + **single click left mouse button**: select a column in the image;

  The intensity of the chosen line or column is shown in the diagram window below the image. The diagram window can be opened or closed in the **View** menu or using **Ctrl + D**.

  If an input has been given to ∑, multiple lines or columns will be selected, the intensity shown in the diagram window will be the sum of the chosen lines or columns.
- **Cross sign ✜** + **drag with left mouse button**: enlarge a certain rectangle area in the image;
- **Single click right mouse button**: cancel the above actions;
- **Double click left mouse button**: the image will be shown in a separate window. After the separate window is opened, the image can be enlarged and shrunk with left-click and right-click;
- **Magnifier sign + left click**: zoom in
- **Magnifier sign + right click**: zoom out

In the middle part of area E, one can also apply the following transformation of the image:

- **NO**: no rotation of the image;
- **X**: flip the image in the horizontal direction;
- **Y**: flip the image in the vertical direction;
- **XY**: flip the image first in the horizontal direction, then in the vertical direction;
- **90°**: rotate the image 90° clockwise;
- **-90°**: rotate the image 90° counter-clockwise;

In the lower part of Fig. 10E, one can change the units of the coordination. The coordination of the mouse cursor with respect to the origin, which is at the left upper corner of the image, is shown in the information bar below the image. The unit of the coordination can be changed between **Px** (pixel number), **Dis** (distance), ***E*** (energy), **λ** (wavelength), and **Ra** (Raman shift). Please note that the unit of **Dis** is meaningful only when the distance calibration has been processed (see Chapter 4.5.2). The units of ***E***, **λ**, and **Ra** are meaningful only when the wavelength calibration has been processed (see Chapter 4.5.3).

## 4.5.2 DISTANCE CALIBRATION

When greateyes cameras are used for imaging purpose, the user can use the **Distance Calibration** in the **Tools** menu to measure the real distance on the object with the measured image. Fig. 11 shows the window of **Distance Calibration** tool.


Fig. 11 The **Distance Calibration** tool

The **Distance Calibration** tool window can be opened in the **Tools** menu. The method is to calibrate two known distances of the object in horizontal and vertical directions on the image, and then the geometry of the whole image is calibrated. After the window of Distance Calibration appears, please follow the steps below:

1. Check **Distance Calibration** box and choose **Cross sign** ✜ in the toolbar;
2. Choose **Select Points** button, and select a **Zero Point** on the image (see Fig. 11);
3. Choose a second point **P1(X)** which is in the lateral direction of the Zero Point. Then choose a third point **P2(Y)** which is in the vertical direction of the Zero Point (see Fig. 11). The actual distances from P1(X) and P2(Y) to the Zero Point should be known already;
4. Choose the **Unit** of distance in the drop-down menu at the top of the window;
5. Give the two known distances to the **Distance to ZeroPoint**, then Enter;
6. Click **OK**.

Besides, the user can set the geometrical resolution manually. Choose option **Set resolution** and enter the values in the fields below.

Now the geometry of the image has been calibrated. By choosing **Meas** and **Dis** button in the toolbar, or choosing **Dis** and **Ctrl + M**, the user can select two points on the image and get the distance in between.

## 4.5.3 WAVELENGTH CALIBRATION

When greateyes cameras are used for spectroscopy purpose, the wavelength or photon energy of measured spectrum can also be calibrated. Fig. 12 shows the window of **Wavelength Calibration** tool.

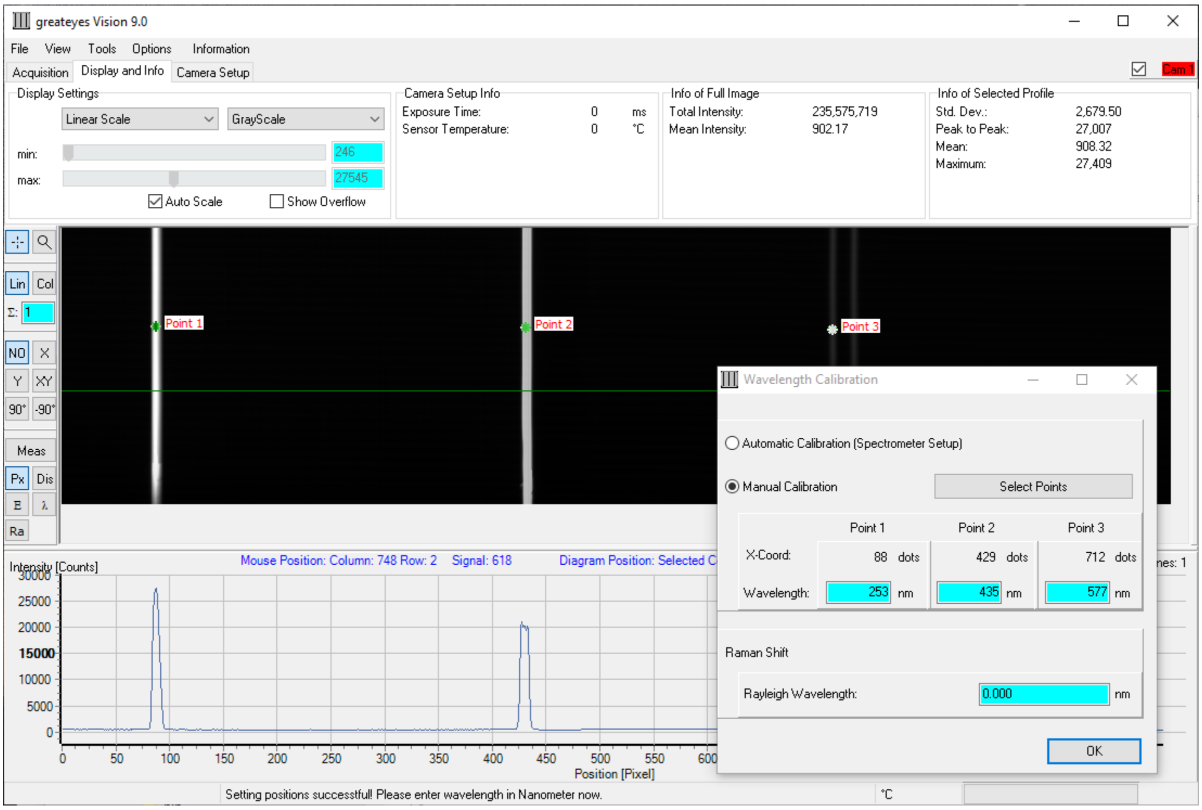



Fig. 12 The window of **Wavelength Calibration** tool

The Wavelength Calibration window can be opened in the **Tools** menu. The calibration can be done automatically according to the setup of the spectrometer by choosing **Automatic Calibration**. Or the user can do it manually by choosing **Manual Calibration**. The method of manual calibration is to mark three points where the wavelengths or photon energies are known, and then the whole spectrum can be calibrated. For Wavelength Calibration please follow the steps below:

1. Select the **Cross Sign** ✜ in the toolbar and the **Manual Calibration** in the Wavelength Calibration window;
2. Click **Select Points** and select three points on the measured image;
3. Give input to the **Wavelength**;
4. Click **OK**.

Now if the user moves the mouse cursor on the measured image, the corresponding wavelength or photon energy of the pointed pixel will be shown in the information bar below the image. The user can change the unit between nm and eV by clicking **λ** or ***E*** in the toolbar.

If the user assigns the Rayleigh Wavelength of the light in the **Wavelength Calibration** tool, one can also choose **Ra** in the toolbar, then the unit of the pointed pixel will be the Raman shift of this point ($cm^{-1}$).

### 4.5.4 OTHER TOOLS

In the **Tools** menu the user can find additional tools described as below:

**Adjust ZeroPoint**: temporarily places the Zero Point from Distance calibration in the upper left corner of the image.

**Measure Distance**: by choosing this tool or using **Ctrl + M**, the user can select two points on the image, the distance in between will be measured if the Distance Calibration is done in Chapter 4.5.2.

**Histogram:** shows the histogram of measured image in the diagram window. It shows the probability distribution of measured values from 0 to the maximal value. Note: you can zoom in certain area of the diagram by dragging with left mouse button.

**Boolean Histogram:** shows the Boolean histogram of measured intensities of all pixels. Value between 0 - 262144 (18 bit) and acquire in the image will be shown as positive in the upper half. Value between 0 and 262144 (18 bit) but were not acquired in the image will be shown as negative in the lower half.

**Total Intensity Profile**: **Horizontal** shows the sum of pixel intensities in each line, **Vertical** shows the sum of pixel intensities in each column.

**Label BMP/JPG:** with this function the user can insert any lettering in an appended area below the actual image area when the data is saved as .bmp or .jpg format.

## 4.6 DATA EXPORT AND IMPORT

The greateyes Vision software supports three ways to export the data: save manually, quick-save, and auto-save.

In the **File** menu on the top of Vision software, one can use the **Save as** options to save the data manually by defining the format, path and file name.

The measured image can be saved as formats of JPEG (.jpg), BMP (.bmp), and TIFF (.tif), or saved as raw data (.dat).

By saving as JPEG or BMP files, the measured information may lose partially during the saving, since both formats will compress the data and only have 8 bit greyscale. However, both formats take less storage space and can be opened in most image display software.

The TIFF files include the entire data but can only be opened in certain software (e.g. IrfanView or ImageJ).

The raw data (.dat) files include the entire data as well as additional information such as the exposure time, sensor temperature and so on. In the **View** menu, the user can check the information of the raw data, or simply use **Ctrl + I**. However, the raw data can only be opened again with Vision software.

Besides, all information from the image and the diagram window can be exported as TXT file (.txt) as well.

The quick-save and auto-save function can also be applied after the saving options are set up. The saving options window can be opened in the **Options** menu. Fig. 13 shows the **Options** window.

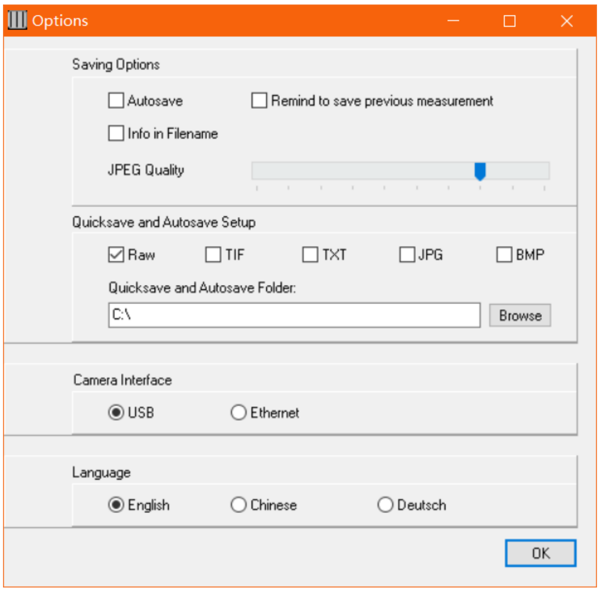



Fig. 13 The **Options** window

**Autosave**: the measured image will be automatically saved in selected formats once the acquisition is finished.

**Remind to save previous measurement**: the software will remind the user to save the current data before the next measurement, in case the data is not saved yet.

**Info in Filename**: without checking this option, the name of quick-saved or auto-saved data will have an appendix of the system time in the following format: YYMMDD_ AM (PM) HHMMSS_MS. For example, a raw data saved on 14. April 2020 at 11h: 15m: 44s: 164ms in the morning, the name will be: **200414_AM111544_164.dat**. The software will also automatically create sub-folders for data measured on each day, for example the data mentioned above will be saved in “Autosave Folder\200414” or “Quicksave Folder\200414”, depending on whether it’s auto-saved or quick-saved. If **Info in Filename** option is checked, a new window will pop up to ask the user to fill in more information of the measurement, each time when it’s auto-saved or quick-saved (see Fig. 14). This window includes the **Example ID**, **Short Mark**, and **Project**, which can be defined by the user according to their experiments. The name of the above mentioned data will then be auto-saved or quick-saved as **Project_ShortMark_ExampleID**. If **Add Date/Time** is also checked, then the name of the above mentioned data will be **200414_Project_ShortMark_ExampleID_AM111544_164.dat**.

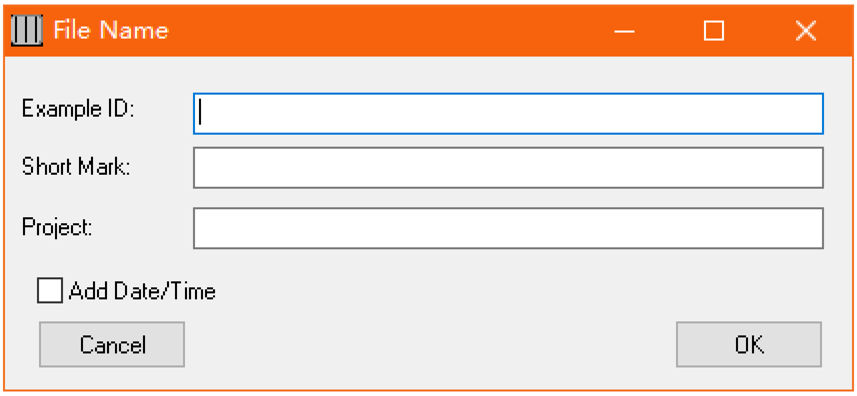



Fig. 14 **Info in Filename** window

**JPEG Quality:** by sliding this bar in Fig. 13 the user can define the quality of the image when it’s saved as a JPEG file.

Then the user can decide in which formats the data should be quick-saved or auto-saved, the options include **Raw**, **TIF**, **TXT**, **JPG**, and **BMP**.

By giving input to **Quicksave and Autosave folder**, the user can define where the data should be quick-saved or auto-saved.

After all the saving options have been defined, the user can quick-save the data by clicking the button in **File** menu or using **Ctrl + S**. Or active the **Autosave**, then data will be saved automatically with the above setup.

At last, the user can also define the data connection of the camera and the language of the software in the **Options** window.

# 5 TROUBLESHOOTING

Users are always welcome to contact us through email support@greateyes.de or by telephone +49 (0)30 912075 259 when having troubles using greateyes cameras. When contacting us for the first time, it will be very helpful to send us the camera information (**Software Version** and **Camera Info** in the **Information** menu of Vision software), as well as some raw data files which exhibit problems. We could use the information to analyse the problems first then give out a preliminary answer. In the following chapters, we have summarized several typical support cases.

## 5.1 THE CAM 1 SIGN IS RED

It means the camera is not connected to the PC properly. The reasons could either be the cables were not connected correctly or the driver of the camera was not installed successfully.

Please close the software and reconnect all cables, then make sure that your computer supports USB 2.0 or USB 3.0 connection and the USB or Ethernet connection was successfully established.

To ensure whether your PC supports USB 3.0, you can check it on your PC through **Start → Control Panel → Hardware tab → Device Manager → USB Controller**. Here you should find the **greateyes USB Camera** and an **Intel(R) USB 3.0 eXtensible Host Controller Driver.**

If the installation of the USB device driver fails, manually select the matching driver by a right click on **Computer** and selecting **Manage**. From **System Tools**, select **Device Manager** to show a list of devices currently connected with the PC. In the list, greateyes camera can be seen with an exclamation mark implying that driver has not been installed yet. Right click on it and select **Update Driver Software**. When prompted to choose how to search for device driver software, choose **Browse my computer for driver software**. On the shown pup-up window select **Let me pick from a list of device drivers on my computer**. A window will come up asking to select the device type. Select Network adapters, and from there, select Microsoft Corporation from the **Manufacturer** list. Under the list of Network Adapter: select Remote NDIS compatible device and click the **Next** Button. Then please make sure the **USB** interface option in **Option** menu of the Vision software has been choosen.

Please also check your network setting and make sure the server IP of the camera is reachable on the configured TCP port from your PC or via your local area network. Go to **Control Panel → Network and Internet → Network Connections**, here you can find the virtual network device of the camera. Right click on the virtual network device and select Properties, check the IP address of the camera in TCP/IPv4, the IP address of this virtual network device should be 192.168.1.x, and x shouldn't be 234.

## 5.2 ONLY BLACK IMAGE AFTER TAKING A SINGLE SHOT

It could be two reasons. The first is that your computer does not support USB 2.0 or 3.0 connection. In this case the data from the camera cannot be transferred correctly to the PC (although the **CAM 1** sign in the software is green).

The other reason could be that the camera did not receive any light signal (the picture should be black but noisy, means it has small amount of intensity in the image). Check the light source and make sure that the objective is open (both cap and aperture).

## 5.3 RECEIVED SIGNAL EVEN WITHOUT LIGHT SOURCE

There could be several reasons for the acquired intensities when there is no direct light source.

The first cause is the dark current. Dark current, given in e-/s/px, is the random distribution of electrons that are thermally generated within each pixel of the sensor. It is an intrinsic property of the sensor material and irrelevant to the incoming photons. The dark current presents a Poisson distribution and the statistical variation of the distribution is called dark noise, which is calculated as square root(dark current * exposure time). One can see that the dark current accumulates as the exposure time increases even without external signals. Besides, the dark current also depends on the temperature. By cooling down the sensor, the dark current can be significantly reduced.

Sometimes when the temperature of your sensor is not cooled down enough and/or with long integration time, the dark current can be easily distinguished when there is no external signal. It usually increases from the bottom to the top of your image. This is because the readout process takes time, and the camera reads out pixels from the bottom to the top of your image. So the pixels at the top, which were read out later, accumulated more dark noises.

However, even when the camera is cooled down at a very low temperature and the integration time is very short, for example -60 °C with 1 ms, we can still see "noises" on the image even without external light sources. This is because we have set offset to the sensor, so that the counts on the image is above zero for all possible settings.

The second cause could be that there is a leak in your experimental setup. Please shut down all possible external light sources then take a measurement and compare it to your image with leak. The leak could be at the shutter, vacuum chamber or other devices.

If none of above scenarios apply to your problem, please take several measurements without external light source under different integration time and readout speed, and contact support@greateyes.de.

## 5.4 CONTAMINATION ON THE SENSOR

Very few users can see strange patterns on their images which are independent from the shape and intensity of their light source, and/or irrelevant to the exposure time. With naked eye, one may also see residues on the detector surface. At this point, one should shut off the power supply of the camera and stop using the camera under this circumstance any longer, since the contamination could cause serious damages to the sensor. This kind of contamination could come from two resources.

The first resource could be the frost from frozen water, which should disappear once the CCD sensor returned to room temperature. The frost or ice shouldn't occur on the CCD surface when the camera is operating under high vacuum environment (~1e-6 mbar). When it occurs, it means there could be a major leak close to the CCD sensor.

For ALEX and LOTTE camera series, the second cause could be organic residues or other contamination from the vacuum pump or other instrument. The contamination could still stay on the surface even when the CCD camera returned to room temperature. The user should open the vacuum chamber only after the camera was shut off and returned to room temperature, and the pressure of the vacuum chamber has returned to room pressure, since contamination tend to condense on the cold surface.

Under both situations, users should **NEVER** clean the CCD sensor surface by themselves! The CCD sensors possess very delicate wires on the surface, any minor cleaning movement could lead to total damage of the sensor. Once the sensor is damaged, the cost of repair could take up to two thirds of the original price of the camera. Please contact greateyes by support@greateyes.de once there were such contamination occurred on sensor.

## 5.5 "GHOST SIGNALS" ABOVE OR UNDER THE MAIN SIGNAL (HOW CCD READS OUT)

Some users reported "ghost signals" when they are using cameras. The "ghost signals" are usually parallel to the main signal. To understand how "ghost signals" occur, one needs to know how full frame CCD sensor reads out.

The full frame CCD sensor consists of pixel matrix which is a light sensitive area. Below the light sensitive area, there is one extra row of pixels which is called readout register. Once the readout starts when the exposure time ends, the electrons in the whole light sensitive area, for example 1024 columns × 256 lines, will be shifted downwards into the readout register vertically (in reality the bottom of the sensor is on the left side of the camera if you look at the camera from front, so pixels are actually shifted towards left of the camera).

The first line of pixels at the bottom of the sensor will be shifted into the readout register first, and then the shifted electrons in the readout register will be transferred one pixel after another into output node to get read out. Then the next line of electrons will repeat until all electrons in 256 lines are read out.

If the incoming light was not blocked or turned off when the electrons are shifting downwards, the pixels may continue to receive signals while reading out. The shifting time of each line varies from sensor to sensor. If your light source is continuous, you could see a wide smearing effect on the upper half of your data. If your light source is pulsed, it may leave bands with intervals on the upper half. The intensity of the smearing effect or the width of the "ghost signals" depends on the intensity of your light source, your readout speed, the pulse frequency of your light source and so on. Once the readout frequency is changed, the pattern of the "ghost signals" will change too.

If the light source is cut off or the sensor is blocked out before and after the exposure period of the camera, this problem should be solved. greateyes offer several solutions, such as a shutter in front of the camera or a cable for the synchronisation between the light source and the camera. If you need our support, please contact support@greateyes.de.

# 6 APPENDIX

## 6.1 GLOSSARY

**AD-Converter:** It converts an analogue signal into digital values. In digital cameras the AD-converter is an electronic device in which the voltage signal for each pixel of the sensor is transformed into discrete numbers. The values for every pixel form the digital representation of the detected image. Scientific cameras typically use precise AD converters having a resolution of 16-bit (65536 gray scales) or above.

**Advanced inverted mode operation (AIMO):** AIMO sensors have a modified gate structure which reduces the dark current at the silicon-silicon dioxide interface. The full-well capacity is improved compared with the IMO sensors.

**Anti-reflection coating**: The surface of the sensor is coated with a layer of transparent dielectric material with a refractive index between that of sensor material and the air in order to reduce the loss of light due to reflection. The coating is adapted to a certain wavelength range. Sensors with different coatings are available.

**Back-illuminated:** In order to improve the overall quantum efficiency, especially for blue and UV-light, back-illuminated sensor has been developed. The silicon wafer gets flipped during manufacturing and thinned by mechanical grinding and chemical etching. The incoming light is directed onto the backside of the sensor. Therefore, the absorption and reflection loss, which occur on the front side due to the gate structure, are eliminated. Hence, back-illuminated sensors have an enhanced quantum efficiency compared with front-illuminated sensors. Photons with wavelength in the blue and UV ranges have short absorption depth. The benefit of thinning the silicon is that the light can enter directly into the photosensitive region without passing through a thick layer of silicon. Furthermore, deep depletion back-illuminated sensors increase the light sensitivity in the near infrared and x-ray ranges up to 20keV for direct detection. Anti-reflection coatings and special surface passivation can improve the quantum efficiency in the visible, UV or EUV ranges.

**Binning:** Pixel binning is the summation of signal charge from adjacent pixels. Binning can be performed for pixels of the same column or of the same row. The advantages are less readout noise at the same frame rate and higher frame rate compared with the same readout frequency without binning. The disadvantage is the reduced spatial resolution of the detected image.

**Blooming:** When the CCD is overexposed, the amount of generated electrons in the pixels exceed their full-well capacity. The overflow of generated excess electrons into adjacent pixels is called blooming.

**Broadband coating**: An anti-reflection coating optimized for a broad wavelength range in the visible spectrum.

**Burst mode:** In burst-mode the camera takes a number of image frames under predefined parameters like binning or crop mode at fixed delay or trigger events. The frames are streamed to the PC based on a single request. Burst mode allows precise and fast time-sequenced measurements.

**CCD Sensor:** A charged coupled device (CCD) is an image sensor in which the generated and accumulated charge is shifted pixel by pixel by applying an electric potential to insulated electrodes on the surface of the sensor. The charge is transferred to an output node on the chip. Due to their low noise and high sensitivity, CCDs are ideal for spectroscopy and optical imaging applications of low light signals and enable measurements with a high dynamic range.

**Crop mode:** Crop mode is a specialized readout mode for achieving fast frame rates. In this mode the user defines a number of lines above the readout register. The camera is directed to read out only defined lines. The smaller the defined array size, the faster the frame rate achievable. The crop mode is ideal for applications which demand fast temporal resolution. The rest of the sensor area must be shielded against incoming light.

**Dark noise:** Thermal excitation of charge carriers in the sensor due to defects in the silicon causes a dark current. The dark noise is the standard derivation of the dark current in the device. Dark noise can be reduced by cooling the sensor. The dark noise varies among different sensor architectures. In case of CCDs, non-inverted mode sensors (NIMO) have a higher dark noise in comparison with advanced inverted mode (AIMO) sensors.

**Deep depletion:** The quantum efficiency for near-infrared light and for direct detection of X-ray photons up to 20keV can be improved by a deeper depletion region which is realized through different doping of the sensor material. Photons in the above mentioned spectral region penetrate deeper into the silicon and are collected more efficiently by deep depletion sensors compared with conventional CCDs.

**Depletion region:** A space in the silicon in which an electrostatic field forces electrons to drift in the potential well. The width of the depletion region depends also on the doping of the silicon.

**Dynamic range:** The dynamic range is the ratio of the maximum to the minimum signal distinguishable from the noise. The maximum dynamic range of image sensors is the ratio of full well capacity to read noise.

**Electro-mechanical shutter**: Used to block the incoming light from the sensor during readout to prevent image smearing. It consists typically of an iris diaphragm which can be opened and closed by using an electromagnetic coil. This mechanism can be controlled by the camera, for example in such a way that the shutter is open during the exposure time and closed during readout.

**Enhanced process**: Surface passivation (enhanced process) of the backside of the sensor reduces light reflection and therefore improves the quantum efficiency especially in the UV and deep UV regions.

**Etaloning**: NIR rays that enter a back-illuminated sensor are reflected at the interface between the silicon region and the gate at the back of the sensor due to a refraction index mismatch. Further reflections occur within the silicon making it act like an etalon. These reflections lead to a distorted output image seen as fringes of constructive and destructive interference. This can be reduced through fringe suppression techniques.

**Full-frame CCD image sensor:** In a full-frame image sensor, the entire pixel area is light sensitive. During exposure time, charges are generated and accumulated in the pixels. Afterwards the electrons in each pixel are shifted towards the readout register. When photons hit the light sensitive area during readout time, image smearing may occur. This effect can be suppressed if the light source is synchronized with the camera or in case of low light intensities where the exposure time is much longer than the readout time. Alternatively an electro-mechanical shutter can be employed to block the incoming light during readout. As the whole pixel area of the full frame CCD sensor is light sensitive, full-frame cameras are ideal for the detection of low light signals.

**Full-well capacity:** The full-well capacity is the number of electrons that can be stored in one pixel. The capacity depends on the CCD architecture and pixel size. A high full-well capacity is fundamental for achieving high dynamic range. Therefore, scientific CCD sensors have larger pixel sizes which can store a higher number of electrons leading to increased full-well capacity and dynamic range.

**Frame rate:** The amount of frames that are read out per second. The frame rate mainly depends on the exposure or integration time and the pixel readout frequency. It can be improved by pixel binning.

**Frame-transfer CCD image sensor**: The frame-transfer image sensor is divided into two areas. One half of the sensor is used for image acquisition and the other half is used for temporary storage. When the sensor is illuminated, an image is acquired in one half of the sensor. After the integration or exposure time the image is shifted to the storage area of the sensor. The storage area is opaque in order to prevent additional charge generation. During the next integration time, the stored image is shifted to the readout register. Since the image acquisition and the readout happen simultaneously, the frame rate can be higher than that of a full-frame image sensor. The chip size must be larger to accommodate the storage region in comparison to a full-frame CCD.

**Front-illuminated:** In front-illuminated sensors the incoming light enters the sensor through poly-silicon gates. This electrode structure absorbs and reflects part of the light, reducing the overall quantum efficiency. Especially blue and UV light is absorbed by the gate structures. Open electrode structure or Lumogen coating of the sensor can improve the quantum efficiency. An alternative with higher sensitivity is back-illuminated sensors.

**Image sensor**: An image sensor is an array of light sensitive pixels in which photons are converted into electric charge. Currently used types are Charged Coupled Devices (CCD) or CMOS based image sensors.

**Integration time**: The integration time (also exposure time) is the time interval in which the sensor is accumulating electrons in each pixel depending on the incoming light intensity. After the integration time, the image is transferred to a storage region or directly read out.

**Interline-transfer CCD image sensor:** Next to every pixel is a light insensitive area which is used for the storage of electric charge. After the exposure time, the generated electrons in the pixels are shifted into these areas where they are transferred into the readout register. This prevents image smearing during the readout. Since the transfer of charges into the storage registers is fast, pixels can be exposed to light continuously and smearing is prevented. As only part of the pixels is light sensitive, interline transfer cameras have a reduced full-well-capacity and dynamic range compared with full-frame sensors of the same chip size.

**Inverted mode operation (IMO):** IMO sensors have a modified gate structure which reduces the dark current. In comparison to the standard mode devices, these multi-phase pinned devices have a lower full well capacity. Therefore, they have a smaller dynamic range compared to non-inverted mode (NIMO) sensors.

**Lumogen coating:** Lumogen phosphor is a coating for front-illuminated CCD sensors to achieve significant UV sensitivity. UV light is absorbed by the readout gate structures on the surface of front-illuminated CCDs. The Lumogen coating converts UV photons into visible light which can penetrate the poly-silicon gates. This type of coating is a cost-effective approach in comparison with back-illuminated CCDs. On the other hand back-illuminated sensors achieve much higher UV sensitivity.

**Mid-band coating:** An anti-reflection coating optimized for wavelength ranging from circa 500 nm to 800 nm.

**Near-infrared coating**: An anti-reflection coating optimized for wavelength ranging from 750 nm to 950 nm.

**Non inverted mode operation (NIMO):** During charge transfer the input clock signals for the poly-silicon electrodes of one pixel are timed such that the voltage applied to at least one electrode is low. This ensures that the electrons don't mix with electrons from adjacent pixels. Due to defects at the silicon-silicon oxide interface, NIMO sensors have a high dark current which can be reduced by cooling. NIMO sensors have a larger full-well-capacity compared to AIMO sensors.

**Open electrode**: Front-illuminated sensors can have patterned electrodes such that part of the pixels are uncovered from the poly-silicon gate structure and therefore open for direct light exposure. Therefore, light absorption by the poly-silicon electrodes is reduced. Image sensors with open electrodes have enhanced quantum efficiency in the UV range.

**Output node**: An on-chip circuit into which the charge is shifted from the readout register. The output node converts the collected electrons in each pixel into a voltage and amplifies the signal.

**Pixel**: Pixels are the smallest elements in the light sensitive area of a sensor. They are arranged in rows and columns on an image sensor. The smaller the pixel size, the higher the spatial resolution of the sensor. In larger pixels more electrons can be stored typically, which results in a higher dynamic range.

**Pixel readout frequency:** The frequency with which the charges in the readout register are transferred pixel by pixel towards the output node.

**Poly-silicon electrodes**: Gate electrodes are placed on the surface of the image sensor. They control the storage and transfer of charges from pixel to pixel. For charge transport each of the poly-silicon gate electrodes in one pixel receives individual input clock signals. The signals are timed such that the charge is shifted pixel by pixel.

**Potential well:** A region in the pixels of the CCD sensor where the generated electrons are stored before they are shifted to the readout register. The depth of this region is controlled by altering voltages to the gate electrodes or by special doping of the silicon material.

**Quantum efficiency:** The quantum efficiency is the proportion of incoming photons per generated electrons in the sensor. The value lies between 0 and 1 and is crucial for low intensity measurements. A quantum efficiency of one is the ideal case, where every photon that hits the sensor surface is converted into an electron. In practice, it is reduced due to the absorption of light caused by the poly-silicon electrodes in case of front-illuminated sensors, especially in the blue and ultraviolet ranges. There are different approaches to enhance the quantum efficiency. Back-illuminated sensors eliminate absorption by the poly-silicon electrodes through back-side illumination. Front-illuminated sensors with Lumogen coating or with open electrodes increase the sensitivity of light in the blue and UV ranges. Anti-reflection sensor coatings lead to the increase of quantum efficiency in certain spectral regions like the UV, VIS or NIR ranges. Deep-depletion sensors display increased near-infrared sensitivity and slightly extended sensitivity range for direct detection of hard x-rays.

**Sensitivity:** The sensitivity of scientific cameras is typically given in counts per electron. When photons hit the CCD sensor, there is an accumulation of electrons in the respective pixel. The camera translates the number of stored electrons into a digital representation of the signal.

**Shot noise:** Due to fluctuation in the emission of every light source, the number of photons that hit the sensor pixels in time may vary. The standard derivation of the statistic distribution of the photon flux is the shot noise.

**UV anti-reflection coating**: An anti-reflection coating optimized for a wavelength range in the UV-range.

**Video mode:** In video mode the camera takes image frames continuously. Each image is requested by the software separately.

## 6.2 CAMERA SPECIFICATIONS

Table 1 The specifications of **ELSE-s** series cameras

| ELSE-s Series | ELSE-s 1k128 | ELSE-s 1k256 | ELSE-s 2k256 | ELSE-s 2k512 |
|---|---|---|---|---|
| Enhanced UV sensitivity | | **OE UV**<br>**BI UV2, BI UV3** | | **FI UV**<br>**BI UV2, BI UV3** |
| Enhanced VIS sensitivity | **BI MID** | **FI**<br>**BI MID** | **FI** | **FI**<br>**BI MID** |
| Enhanced NIR sensitivity | **DD NIR** | **FI DD**<br>**DD NIR**<br>**DD MU2** | **DD NIR** | |
| Nominal pixel format | 1024 × 127 | 1024 × 255 | 2048 × 264 | 2048 × 515 |
| Image area | 26.6 mm × 3.3 mm | 26.6 mm × 6.7 mm | 30.7 mm × 3.9 mm | 27.6 mm × 6.9 mm |
| Pixel size | 26 µm × 26 µm | | 15 µm × 15 µm | 13.5 µm × 13.5 µm |
| Full well capacity | 300 ke$^-$(OE UV) / 500 ke$^-$ / 700 ke$^-$ (DD) | | 75 ke$^-$ | 100 ke$^-$ |
| Register well capacity | 1 000 ke$^-$ / 1 400 ke$^-$ (DD) | | 650 ke$^-$ | 400 ke$^-$ |
| Typ. read noise (e$^-$) | BI / DD | FI BI DD | | FI / BI |
| @ 50 kHz | 5.5 | 4.2 6.0 5.4 | 3.7 | 3.5 |
| @ 1 MHz | 12.5 | 12.0 13.1 12.3 | 7.0 | 6.8 |
| @ 3 MHz | 26.0 | 25.0 26.0 25.0 | 12.1 | 10.7 |
| Dark current @ -100 °C | 0.0004 e$^-$/pixel/s<br>0.005 e$^-$/pixel/s (DD) | | 0.0006 e$^-$/pixel/s | 0.00025 e$^-$/pixel/s |
| Gain (counts/e$^-$) | | | | |
| Standard mode | 0.4 | | 1.5 | 1 |
| High capacity mode | - | | - | 0.34 |
| CCD sensor type | Front-illuminated (FI), back-illuminated (BI), deep depletion fringe suppression (DD), open-electrode (OE) | | | |
| Anti-reflective coating | UV (UV2, UV3), mid-band (MID), multiband (MU2), near-infrared (NIR) | | | |
| Blemish specifications | Grade 0 or grade 1 (standard) as specified by sensor manufacturer. For more information, please see: [https://www.greateyes.de/en/glossar.html](https://www.greateyes.de/en/glossar.html) | | | |
| Pixel readout frequency | 50 kHz, 100 KHz, 250 kHz, 500kHz, 1 MHz, 3 MHz<br>(can be customised from 25 kHz - 5 MHz; 5 MHz for preview mode) | | | |
| AD converter resolution | 18-bit | | | |
| Linearity | Better than 99% | | | |
| Window material | $MgF_2$ or UVFS for UV sensitive models, otherwise BK7 | | | |
| CCD sensor cooling | -100 °C to 20 °C, forced air or liquid cooling | | | |
| Temperature monitoring | Two thermistors at CCD sensor and thermoelectric cooler (hot side) | | | |
| Data link | Gigabit Ethernet, USB 3.0 | | | |
| Software | greateyes Vision software for Windows 7 / 10 | | | |
| SDK and drivers | DLL for Windows; LabVIEW, EPICS, Linux, Python, Tango driver (optional) | | | |
| TTL interface signals | Exposure out, shutter out, 2 external trigger in | | | |
| Operating conditions | Temperature: 0 °C - 35 °C ambient, relative humidity <80% (non-condensing) | | | |
| Weight | 1 800 g | | | |

Table 2 Specifications of **ELSE-i** series cameras

| **ELSE-i Series** | **ELSE-i 1k1k** | | **ELSE-i 2k2k** | | **ELSE-i 2k2k plus** | **ELSE-i 4k4k** | |
|---|---|---|---|---|---|---|---|
| Enhanced UV sensitivity | **BI UV3** | | | **BI UV3** | | | **BI UV2**<br>**BI UV4** |
| Enhanced VIS sensitivity | **FI**<br>**BI BR**<br>**BI MID** | | **FI**<br>**BI MID** | | **BI MID** | **FI**<br>**BI BR**<br>**BI MID** | |
| Enhanced NIR sensitivity | | **DD NIR**<br>**DD MU2** | | **DD NIR**<br>**DD MU2** | | | **DD MU2** |
| Nominal pixel format | 1024 × 1024 (FI)<br>1056 × 1027 | | 2048 × 2052 | | 2048 × 2064 | 4096 × 4112 | |
| Image area | 13.3 mm × 13.3 mm | | 27.6 mm × 27.6 mm | | 30.7 mm × 30.7 mm | 61.4 mm × 61.4 mm | |
| Pixel size | 13 µm × 13 µm | | 13.5 µm × 13.5 µm | | 15 µm × 15 µm | 15 µm × 15 µm | |
| CCD sensor cooling | -100 °C to 20 °C | | -80 °C to 20 °C | | -90 °C to 20 °C | -90 °C to 20 °C | |
| Full well capacity | 100 ke$^-$ | 120 ke$^-$ | 100 ke$^-$ | 150 ke$^-$ | 150 ke$^-$ | 150 ke$^-$ | 350 ke$^-$ |
| Register well / Output node | 400 ke$^-$ / - | | 400 ke$^-$ / - | 600 ke$^-$ / - | 850 ke$^-$ / 900 ke$^-$ | - / 900 ke$^-$ | - / 600 ke$^-$ |
| Typ. read noise (e$^-$)<br>@ 50 kHz<br>@ 1 MHz<br>@ 3 MHz | <br>2.8<br>6.4<br>10.9 | | <br>3.4<br>7.0<br>13.6 | | <br>4.6<br>8.5<br>17.0 | <br>4.6<br>8.5<br>17.0 | <br>2.8<br>5.8<br>10.4 |
| Dark current (e$^-$/pixel/s) | @ -100 °C<br>0.00015 | 0.0005 | @ -80 °C<br>0.0003 | 0.01 | @ -90 °C<br>0.00008 | @ -90 °C<br>0.00008 | 0.0006 |
| Gain (counts/e$^-$)<br>Standard mode<br>High capacity mode | <br>1<br>- | | <br>1<br>0.34 | | <br>0.6<br>0.2 | <br>0.6<br>0.2 | <br>1<br>0.34 |
| CCD sensor type | Front-illuminated (FI), back-illuminated (BI), deep depletion fringe suppression (DD) | | | | | | |
| Anti-reflective coating | UV (UV3), broadband (BR), mid-band (MID), near-infrared (NIR), multiband (MU2), astro broadband (UV2), astro midband (UV4) | | | | | | |
| Blemish specifications | Grade 0 or grade 1 (standard) as specified by sensor manufacturer. For more information, please see: https://www.greateyes.de/en/glossar.html | | | | | | |
| Pixel readout frequency | 50 kHz, 100 KHz, 250 kHz, 500kHz, 1 MHz, 3 MHz<br>(can be customised from 25 kHz - 5 MHz; 5 MHz for preview mode) | | | | | | |
| Readout modes | 2 output nodes for 1k1k & 2k2k cameras, 4 output nodes for 2k2k plus & 4k4k cameras | | | | | | |
| AD converter resolution | 18-bit | | | | | | |
| Linearity | Better than 99% | | | | | | |
| Window material | $MgF_2$ or UVFS for UV sensitive models, otherwise BK7 | | | | | | |
| Temperature monitoring | Two thermistors at CCD sensor and thermoelectric cooler (hot side) | | | | | | |
| Data link | Gigabit Ethernet, USB 3.0 | | | | | | |
| Software | greateyes Vision software for Windows 7 / 10 | | | | | | |
| SDK and drivers | DLL for Windows; LabVIEW, EPICS, Linux, Python, Tango driver (optional) | | | | | | |
| TTL interface signals | Exposure out, shutter out, 2 external trigger in | | | | | | |
| Operating conditions | Temperature: 0 °C – 35 °C ambient, relative humidity <80% (non-condensing) | | | | | | |
| Weight | 2.2 kg (1k1k & 2k2k), 5.4 kg (2k2k plus & 4k4k) | | | | | | |

Table 3 Specifications of **ALEX-s** series cameras

| **ALEX-s Series** | **ALEX-s 1k256** | **ALEX-s 2k512** |
|---|---|---|
| Sensor code | **FI**<br>**FI DD**<br>**BI UV1** | **FI**<br>**BI**<br>**BI UV1** |
| Nominal pixel format | 1024 × 255 | 2048 × 515 |
| Image area | 26.6 mm × 6.7 mm | 27.6 mm × 6.9 mm |
| Pixel size | 26 µm × 26 µm | 13.5 µm × 13.5 µm |
| Full well capacity | 500 ke$^-$ / 700 ke$^-$ (DD) | 100 ke$^-$ |
| Register well capacity | 1 000 ke$^-$ / 1 400 ke$^-$ (DD) | 400 ke$^-$ |
| Typ. read noise (e$^-$)<br>@ 50 kHz<br>@ 1 MHz<br>@ 3 MHz | FI BI DD<br>4.2 6.0 5.4<br>12.0 13.1 12.3<br>25.0 26.0 25.0 | FI / BI<br>3.5<br>6.8<br>10.7 |
| Dark current @ -100 °C | 0.0004 e$^-$/pixel/s<br>0.005 e$^-$/pixel/s (DD) | 0.00025 e$^-$/pixel/s |
| Gain (counts/e$^-$)<br>Standard mode<br>High capacity mode | <br>0.4<br>- | <br>1<br>0.34 |
| CCD sensor type | Front-illuminated (FI), back-illuminated (BI), deep depletion fringe suppression (DD), enhanced back-illuminated (BI UV1) | |
| Blemish specifications | Grade 0 or grade 1 (standard) as specified by sensor manufacturer. For more information, please see: https://www.greateyes.de/en/glossar.html | |
| Pixel readout frequency | 50 kHz, 100 KHz, 250 kHz, 500kHz, 1 MHz, 3 MHz<br>(can be customised from 25 kHz - 5 MHz; 5 MHz for preview mode) | |
| Readout modes | 1 output nodes | |
| AD converter resolution | 18-bit | |
| Linearity | Better than 99% | |
| CCD epitaxial thickness | 15 µm standard, 40 µm for deep depletion (DD) models | |
| Flange types | ISO-F DN63, knife-edge sealed CF DN63, CF DN100, CF DN160 | |
| Vacuum compatibility | With CF flange: $10^{-10}$ mbar (UHV capability) | |
| Bake out temperature | Max. +80 °C | |
| CCD sensor cooling | -100 °C to 20 °C, forced air or liquid cooling | |
| Temperature monitoring | Two thermistors at CCD sensor and thermoelectric cooler (hot side) | |
| Data link | Gigabit Ethernet, USB 3.0 | |
| Software | greateyes Vision software for Windows 7 / 10 | |
| SDK and drivers | DLL for Windows; LabVIEW, EPICS, Linux, Python, Tango driver (optional) | |
| TTL interface signals | Sync out, shutter out, 2 external trigger in | |
| Operating conditions | Temperature: 0 °C – 35 °C ambient, relative humidity <80% (non-condensing) | |
| Weight | 2.9 Kg (with CF DN63 flange) | |

Table 4 Specifications of **ALEX-i** series cameras

| **ALEX-i Series** | **ALEX-i 1k1k** | | **ALEX-i 2k2k** | | **ALEX-i 2k2k plus** | **ALEX-i 4k4k** | |
|---|---|---|---|---|---|---|---|
| Sensor code | **FI**<br>**BI**<br>**BI UV1** | **BI DD** | **FI**<br>**BI** | **BI DD**<br>**BI UV1** | **BI** | **BI** | **BI DD**<br>**BI UV1** |
| Nominal pixel format | 1024 × 1024 (FI)<br>1056 × 1027 | | 2048 × 2052 | | 2048 × 2064 | 4096 × 4112 | |
| Image area | 13.3 mm × 13.3 mm | | 27.6 mm × 27.6 mm | | 30.7 mm × 30.7 mm | 61.4 mm × 61.4 mm | |
| Pixel size | 13 µm × 13 µm | | 13.5 µm × 13.5 µm | | 15 µm × 15 µm | 15 µm × 15 µm | |
| CCD sensor cooling | -100 °C to 20 °C | | -80 °C to 20 °C | | -90 °C to 20 °C | -90 °C to 20 °C | |
| Full well capacity | 100 ke$^-$ | 120 ke$^-$ | 150 ke$^-$ | 150 ke$^-$ | 150 ke$^-$ | 150 ke$^-$ | 350 ke$^-$ |
| Register well / Output node | 400 ke$^-$ / - | | 400 ke$^-$ / - | | 850 ke$^-$ / 900 ke$^-$ | - / 900 ke$^-$ | - / 600 ke$^-$ |
| Typ. read noise (e$^-$)<br>@ 50 kHz<br>@ 1 MHz<br>@ 3 MHz | <br>2.8<br>6.4<br>10.9 | | <br>3.4<br>7.0<br>13.6 | | <br>4.6<br>8.5<br>17.0 | <br>4.6<br>8.5<br>17.0 | <br>2.8<br>5.8<br>10.4 |
| Dark current (e$^-$/pixel/s) | @ -100 °C<br>0.00015 | <br>0.0005 | @ -90 °C<br>0.0001 | <br>0.01 | @ -90 °C<br>0.00008 | @ -90 °C<br>0.00008 | <br>0.0006 |
| Gain (counts/e$^-$)<br>Standard mode<br>High capacity mode | <br>1<br>- | | <br>1<br>0.34 | | <br>0.6<br>0.2 | <br>0.6<br>0.2 | <br>1<br>0.34 |
| CCD sensor type | Front-illuminated (FI), back-illuminated (BI), deep depletion fringe suppression (DD), enhanced back-illuminated (BI UV1) | | | | | | |
| Blemish specifications | Grade 0 or grade 1 (standard) as specified by sensor manufacturer. For more information, please see: [https://www.greateyes.de/en/glossar.html](https://www.greateyes.de/en/glossar.html) | | | | | | |
| Pixel readout frequency | 50 kHz, 100 KHz, 250 kHz, 500kHz, 1 MHz, 3 MHz<br>(can be customised from 25 kHz - 5 MHz; 5 MHz for preview mode) | | | | | | |
| Readout modes | 2 output nodes for 1 Mpx and 4 Mpx camera, 4 output nodes for 16 Mpx camera | | | | | | |
| AD converter resolution | 18-bit | | | | | | |
| Linearity | Better than 99% | | | | | | |
| CCD epitaxial thickness | 15 µm standard, 40 µm for deep depletion (DD) models | | | | | | |
| Flange types | ISO-F DN63, knife-edge sealed CF DN63, CF DN100, CF DN160 | | | | | | |
| Vacuum compatibility | With CF flange: $10^{-10}$ mbar (UHV capability) | | | | | | |
| Bake out temperature | Max. +80 °C | | | | | | |
| Temperature monitoring | Two thermistors at CCD sensor and thermoelectric cooler (hot side) | | | | | | |
| Data link | Gigabit Ethernet, USB 3.0 | | | | | | |
| Software | greateyes Vision software for Windows 7 / 10 | | | | | | |
| SDK and drivers | DLL for Windows; LabVIEW, EPICS, Linux, Python, Tango driver (optional) | | | | | | |
| TTL interface signals | Sync out, shutter out, 2 external trigger in | | | | | | |
| Operating conditions | Temperature: 0 °C to 35 °C ambient, relative humidity <80% (non-condensing) | | | | | | |
| Weight | 2.9 kg (1k1k & 2k2k, CF DN63) / 4.3 kg (1k1k & 2k2k, CF DN 100) / 12.5 kg (2k2k plus & 4k4k, CF DN160) | | | | | | |

Table 5 Specifications of **LOTTE-s** series cameras

| **LOTTE-s Series** | **LOTTE-s 1k256** | **LOTTE-s 2k512** |
|---|---|---|
| Sensor code | **FI**<br>**FI DD**<br>**BI UV1** | **FI**<br>**BI**<br>**BI UV1** |
| Nominal pixel format | 1024 × 255 | 2048 × 515 |
| Image area | 26.6 mm × 6.7 mm | 27.6 mm × 6.9 mm |
| Pixel size | 26 µm × 26 µm | 13.5 µm × 13.5 µm |
| Full well capacity | 500 ke⁻ / 700 ke⁻ (DD) | 100 ke⁻ |
| Register well capacity | 1 000 ke⁻ / 1 400 ke⁻ (DD) | 400 ke⁻ |
| Typ. read noise (e⁻)<br>@ 50 kHz<br>@ 1 MHz<br>@ 3 MHz | FI BI DD<br>4.2 6.0 5.4<br>12.0 13.1 12.3<br>25.0 26.0 25.0 | FI / BI<br>3.5<br>6.8<br>10.7 |
| Dark current @ -100 °C | 0.0004 e⁻/pixel/s<br>0.005 e⁻/pixel/s (DD) | 0.00025 e⁻/pixel/s |
| Gain (counts/e⁻)<br>Standard mode<br>High capacity mode | <br>0.4<br>- | <br>1<br>0.34 |
| CCD sensor type | Front-illuminated (FI), back-illuminated (BI), deep depletion fringe suppression (DD), enhanced back-illuminated (BI UV1) | |
| Blemish specifications | Grade 0 or grade 1 (standard) as specified by sensor manufacturer. For more information, please see: https://www.greateyes.de/en/glossar.html | |
| Pixel readout frequency | 50 kHz, 100 KHz, 250 kHz, 500kHz, 1 MHz, 3 MHz<br>(can be customised from 25 kHz - 5 MHz; 5 MHz for preview mode) | |
| Readout modes | 1 output nodes | |
| AD converter resolution | 18-bit | |
| Linearity | Better than 99% | |
| CCD epitaxial thickness | 15 µm standard, 40 µm for deep depletion (DD) models | |
| Feedthrough Flange | CF DN100 flange with D-sub electrical feedthrough connectors and 6 mm liquid feedthrough tubes (airside: G 1/4 fitting female, vacuum side: VCR 1/4 fitting female) | |
| Vacuum compatibility | With CF flange: $10^{-9}$ mbar (UHV capability) | |
| Bake out temperature | Max. +80 °C | |
| CCD sensor cooling | -100 °C to 20 °C, forced air or liquid cooling | |
| Temperature monitoring | Two thermistors at CCD sensor and thermoelectric cooler (hot side) | |
| Data link | Gigabit Ethernet | |
| Software | greateyes Vision software for Windows 7 / 10 | |
| SDK and drivers | DLL for Windows; LabVIEW, EPICS, Linux, Python, Tango driver (optional) | |
| TTL interface signals | 1 Exposure out, 1 Trigger in | |
| Operating conditions | Temperature: 0 °C – 35 °C ambient, relative humidity <80% (non-condensing) | |
| Weight | 5.0 kg | |

Table 6 Specifications of **LOTTE-i** series cameras

| **LOTTE-i Series** | **LOTTE-i 1k1k** | | **LOTTE-i 2k2k** | | **LOTTE-i 2k2k plus** | **LOTTE-i 4k4k** | |
|---|---|---|---|---|---|---|---|
| Sensor code | **FI**<br>**BI**<br>**BI UV1** | **BI DD** | **FI**<br>**BI** | **BI DD**<br>**BI UV1** | **BI** | **BI** | **BI DD**<br>**BI UV1** |
| Nominal pixel format | 1024 × 1024 (FI)<br>1056 × 1027 | | 2048 × 2052 | | 2048 × 2064 | 4096 × 4112 | |
| Image area | 13.3 mm × 13.3 mm | | 27.6 mm × 27.6 mm | | 30.7 mm × 30.7 mm | 61.4 mm × 61.4 mm | |
| Pixel size | 13 µm × 13 µm | | 13.5 µm × 13.5 µm | | 15 µm × 15 µm | 15 µm × 15 µm | |
| CCD sensor cooling | -100 °C to 20 °C | | -80 °C to 20 °C | | -80 °C to 20 °C | -80 °C to 20 °C | |
| Full well capacity | 100 ke$^-$ | 120 ke$^-$ | 150 ke$^-$ | 150 ke$^-$ | 150 ke$^-$ | 150 ke$^-$ | 350 ke$^-$ |
| Register well / Output node | 400 ke$^-$ / - | | 400 ke$^-$/ - | 600 ke$^-$/ - | 850 ke$^-$ / 900 ke$^-$ | - / 900 ke$^-$ | - / 600 ke$^-$ |
| Typ. read noise (e$^-$)<br>@ 50 kHz<br>@ 1 MHz<br>@ 3 MHz | <br>2.8<br>6.4<br>10.9 | | <br>3.4<br>7.0<br>13.6 | | <br>4.6<br>8.5<br>17.0 | <br>4.6<br>8.5<br>17.0 | <br>2.8<br>5.8<br>10.4 |
| Dark current (e$^-$/pixel/s) | @ -100 °C<br>0.00015 | <br>0.0005 | @ -80 °C<br>0.0003 | <br>0.015 | @ -80 °C<br>0.0001 | @ -80 °C<br>0.0001 | <br>0.006 |
| Gain (counts/e$^-$)<br>Standard mode<br>High capacity mode | <br>1<br>- | | <br>1<br>0.34 | | <br>0.6<br>0.2 | <br>0.6<br>0.2 | <br>1<br>0.34 |
| CCD sensor type | Front-illuminated (FI), back-illuminated (BI), deep depletion fringe suppression (DD), enhanced back-illuminated (BI UV1) | | | | | | |
| Blemish specifications | Grade 0 or grade 1 (standard) as specified by sensor manufacturer. For more information, please see: https://www.greateyes.de/en/glossar.html | | | | | | |
| Pixel readout frequency | 50 kHz, 100 KHz, 250 kHz, 500kHz, 1 MHz, 3 MHz<br>(can be customised from 25 kHz - 5 MHz; 5 MHz for preview mode) | | | | | | |
| Readout modes | 2 output nodes for 1k1k & 2k2k cameras, 4 output nodes for 2k2k plus & 4k4k cameras | | | | | | |
| AD converter resolution | 18-bit | | | | | | |
| Linearity | Better than 99% | | | | | | |
| CCD epitaxial thickness | 15 µm standard, 40 µm for deep depletion (DD) models | | | | | | |
| Feedthrough Flange | CF DN100 flange with D-sub electrical feedthrough connectors and 6 mm liquid feedthrough tubes (airside: G 1/4 fitting female, vacuum side: VCR 1/4 fitting female) | | | | | | |
| Vacuum compatibility | With CF flange: $10^{-9}$ mbar (UHV capability) | | | | | | |
| Bake out temperature | Max. +80 °C | | | | | | |
| Temperature monitoring | Two thermistors at CCD sensor and thermoelectric cooler (hot side) | | | | | | |
| Data link | Gigabit Ethernet | | | | | | |
| Software | greateyes Vision software for Windows 7 / 10 | | | | | | |
| SDK and drivers | DLL for Windows; LabVIEW, EPICS, Linux, Python, Tango driver (optional) | | | | | | |
| TTL interface signals | 1 Exposure out, 1 Trigger in | | | | | | |
| Operating conditions | Temperature: 0 °C to 35 °C ambient, relative humidity <80% (non-condensing) | | | | | | |
| Weight | 5.0 kg | | | | | | |

## 6.3 POWER SUPPLY SPECIFICATIONS

### 6.3.1 POWER SUPPLY GE-POW01 (FOR NON 2K2K PLUS & 4K4K CAMERAS)

| Input Characteristics | |
|---|---|
| **Input Voltage Range** | 80-264 VAC (115/230V typical) |
| **Input Frequency Range** | 47-63 Hz (50/60 Hz typical) |
| **Power Factor** | EN61000-3-2, class A |
| **Input Current (at full load)** | 1.1A (230 VAC) / 1.9A (115VAC) |
| **Inrush Current (Typ. / max.)** | 40A (230 VAC; cold start at 25 °C) |
| **Input Protection** | F2.50 A/250 V external fuse in phase line<br>F3.15 A/250 V internal fuse in both lines |

| Output Characteristics | |
|---|---|
| **Output voltage** | +0.0…+15.0 VDC (adjustable)<br>+36.0 VDC<br>+12.0 VDC<br>±13.0 VDC |
| **Output current (max.)** | +7.0A at +0.0…+15.0 VDC (cooling power)<br>+2.0A at +36.0 VDC<br>+2.9A at +12.0 VDC<br>±2.9A at ±13.0 VDC |
| **Start Up Delay / Hold Time** | 1s typical / 18ms typical |
| **Output Protection** | Over-voltage, Overload, Short Circuit, Over-temperature |

| General Specifications | |
|---|---|
| **Approbation** | CE |
| **Protection class** | Class I |
| **Isolation** | Input to Output: 4000 VAC (2×MOPP)<br>Input to Ground: 1500 VAC (1×MOPP) |
| **Connectors** | Input: IEC C14 (with integrated fuse holder & switch)<br>Output: 19-Pin connector (Binder 09 0336 90 19) |
| **Materials (housing)** | Aluminium, Plastic |
| **Weight** | 0.65 kg |
| **Dimensions (L×W×H)** | 188.5 mm × 159 mm × 62 mm |

| Environmental | |
|---|---|
| **Operating Temperature** | 0 °C – +40 °C |
| **Storage Temperature** | -40 °C – +85 °C |
| **Operating Humidity** | 20 – 85 % RH (non-condensing) |
| **Storage Humidity** | 5 – 95 % RH (non-condensing) |
| **Cooling** | Forced-air cooled (5-7 CFM) |

| Mechanical Details | |
|---|---|
| **Units** | mm |

### 6.3.2 POWER SUPPLY GE-POW02 (FOR 2K2K PLUS & 4K4K CAMERAS)

| **Input Characteristics** | |
|---|---|
| **Input Voltage Range** | 85-264 VAC (115/230V typical) |
| **Input Frequency Range** | 47-63 Hz (50/60 Hz typical) |
| **Power Factor** | >0.95 (230 VAC; at full load) |
| **Input Current (at full load)** | 1.9A (230 VAC) / 3.8A (115VAC) |
| **Inrush Current (typ. / max.)** | 35A/60A (230 VAC; cold start at 25 °C) |
| **Input Protection** | F3.15 A/250 V external fuse in phase line (230VAC)<br>F6.30 A/250 V external fuse in phase line (115VAC)<br>F10.0 A/250 V internal fuse in both lines |

| **Output Characteristics** | |
|---|---|
| **Output voltage** | 4× +0.0…+15.0 VDC (adjustable)<br>+36.0 VDC<br>+12.0 VDC<br>±13.0 VDC |
| **Output current (max.)** | 4× +7.0A at +0.0…+15.0 VDC (cooling power)<br>+2.0A at +36.0 VDC<br>+2.9A at +12.0 VDC<br>±2.9A at ±13.0 VDC |
| **Start Up Delay / Hold Time** | 1.5s typ. (2.0s max.) / 30ms typ. |
| **Output Protection** | Over-voltage, Overload, Short Circuit, Over-temperature |

| **General Specifications** | |
|---|---|
| **Approbation** | CE |
| **Protection class** | Class I |
| **Isolation** | Input to Output: 4000 VAC (2×MOPP)<br>Input to Ground: 1500 VAC (1×MOPP) |
| **Connectors** | Input: IEC C14 (with integrated fuse holder & switch)<br>Output: D-Sub 50 |
| **Materials (housing)** | Aluminium, Plastic |
| **Weight** | 3.00 kg |
| **Dimensions (L×W×H)** | 370 mm × 190 mm × 72 mm |

| **Environmental** | |
|---|---|
| **Operating Temperature** | 0 °C – +40 °C |
| **Storage Temperature** | -20 °C – +85 °C |
| **Operating Humidity** | 20 – 85 % (non-condensing) |
| **Storage Humidity** | 5 – 95 % (non-condensing) |
| **Cooling** | Forced-air cooled (redundant, 30-40 CFM) |

| **Mechanical Details** | |
|---|---|
| **Units** | mm |

## 6.4 CAMERA TIMING

### 6.4.1 SINGLE SHOT

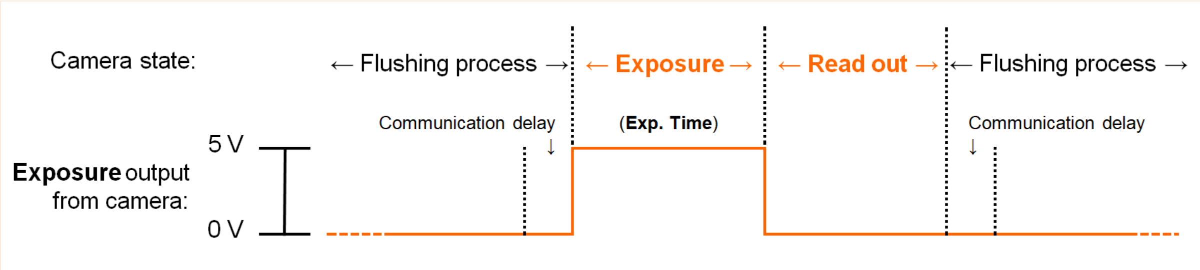



Fig. 14 the camera state under Single Shot mode

When the user clicks **Single Shot** in the software, there is a small communication delay before the camera actually executes the order. This communication delay depends on the PC and connections, it could last about tens of milliseconds. Then the **Exposure** output on the camera will be at high level during the **Exp. Time** given in the software (Fig. 8B). Afterwards the camera will start to read out. Once the last pixel is read out, there is also a period for the camera to transfer the data to the PC, to display the data on the software, and to save the data on the PC.

### 6.4.2 VIDEO MODE WITHOUT TRIGGER AND SHUTTER

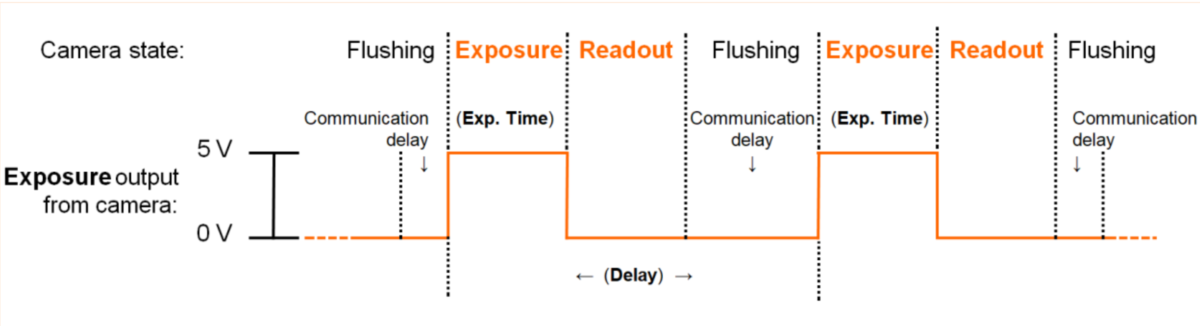



Fig. 15 camera state under Video Mode (only two frames are shown)

In the Video Mode, a series of shots will be taken and displayed. Similar to Single Shot, there is a small communication delay before the exposure and another one after the readout. The parameters in the brackets can be defined in the Vision software. The **Delay** time in Vision (Fig. 9D) means the time gap between the starting points of two exposures, please make sure it is larger than the total amount of Exp. Time and readout time, otherwise, the new exposure could be overlapped with the last exposure or readout process.

### 6.4.3 BURST MODE WITHOUT TRIGGER AND SHUTTER

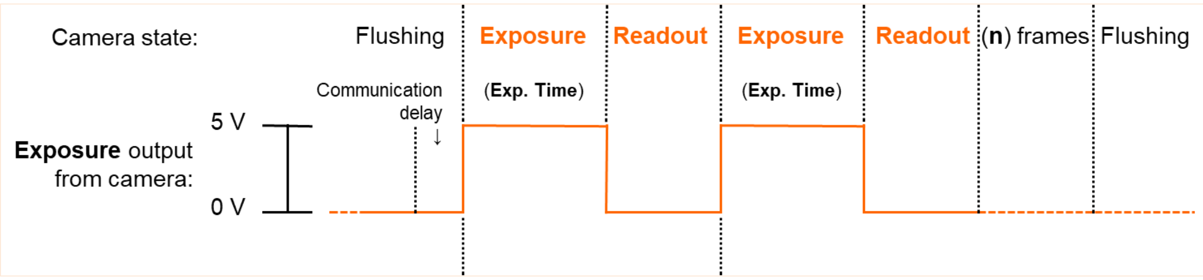



Fig. 16 camera state under Burst Mode

In the Burst Mode, a series of shots will also be taken. Different from the Video Mode, every picture will be saved on the built-in memory of the camera first, and all frames will be stacked into one picture, only this final picture will be saved on the PC. Thus there is no communication delay between the frames. The parameters Exp. Time and the number of frames (n) can be defined in the Vision software.

### 6.4.4 SINGLE SHOT WITH TRIGGER

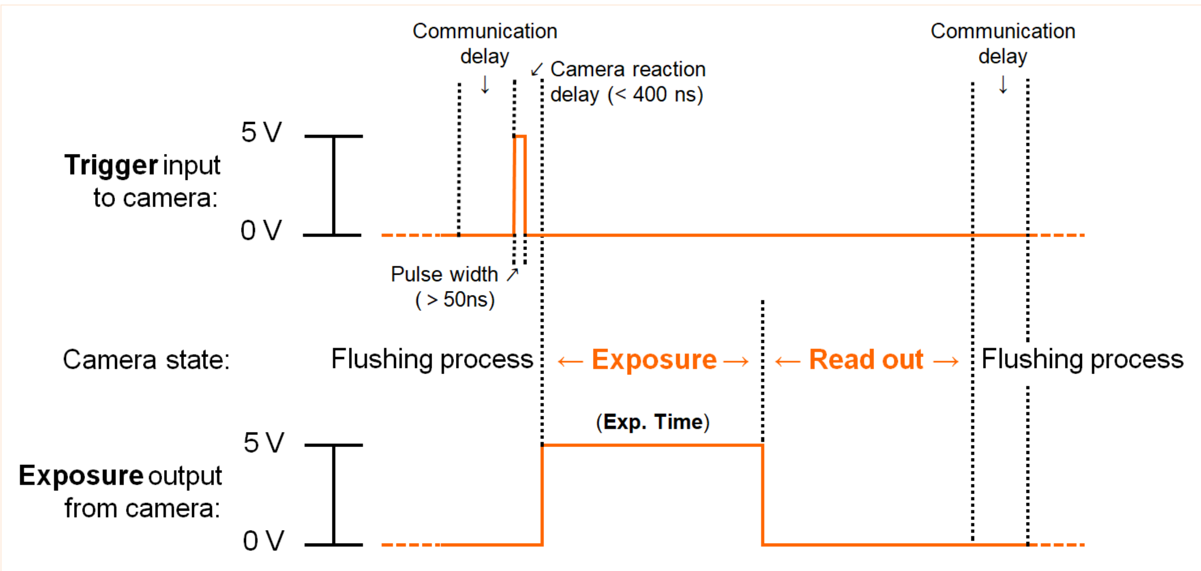



Fig. 17 Camera state with an external trigger

In this mode, the camera will first experience a communication delay once Single Shot is clicked in the Vision software, then it will be triggered by the first input from the trigger. The trigger input should last longer than 50 ns. A small camera reaction delay will occur before the exposure starts.

## 6.4.5 VIDEO MODE WITH TRIGGER

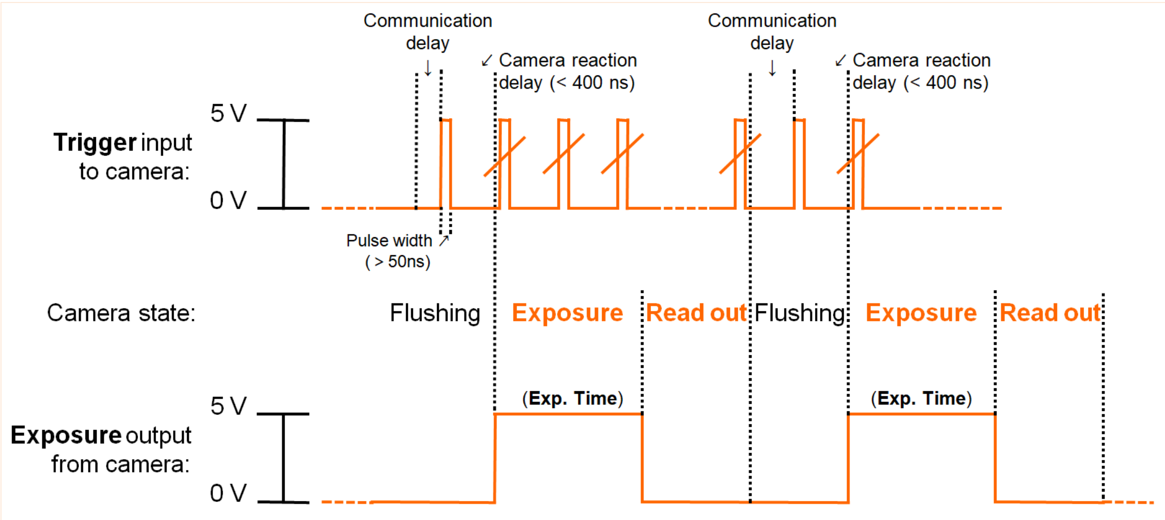



Fig. 18 Camera state with Video Mode and trigger

In Video Mode, each shot needs to be triggered once. The trigger input during the exposure and readout time will be ignored. Once a readout is finished, the camera will wait until the next trigger input and then start the next shot. If Trigger input is still at high level when a readout is finished, the camera will start to take a shot immediately. In Burst Mode with a trigger, each shot needs to triggered once as well.

## 6.4.6 SINGLE SHOT WITH SHUTTER

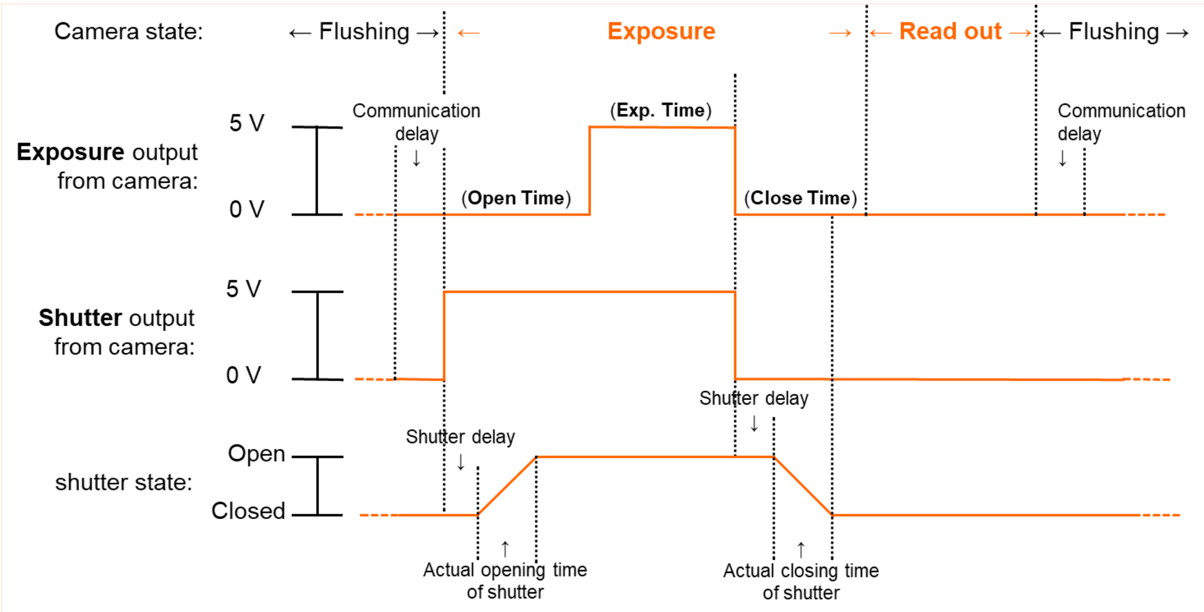
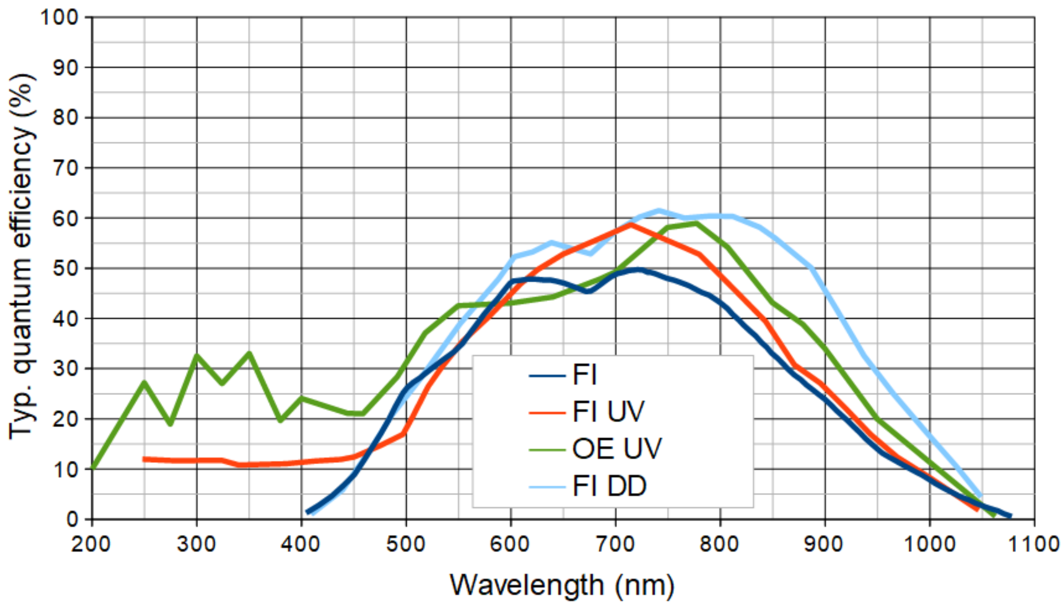



Fig. 19 Camera state with a shutter and under single shot mode

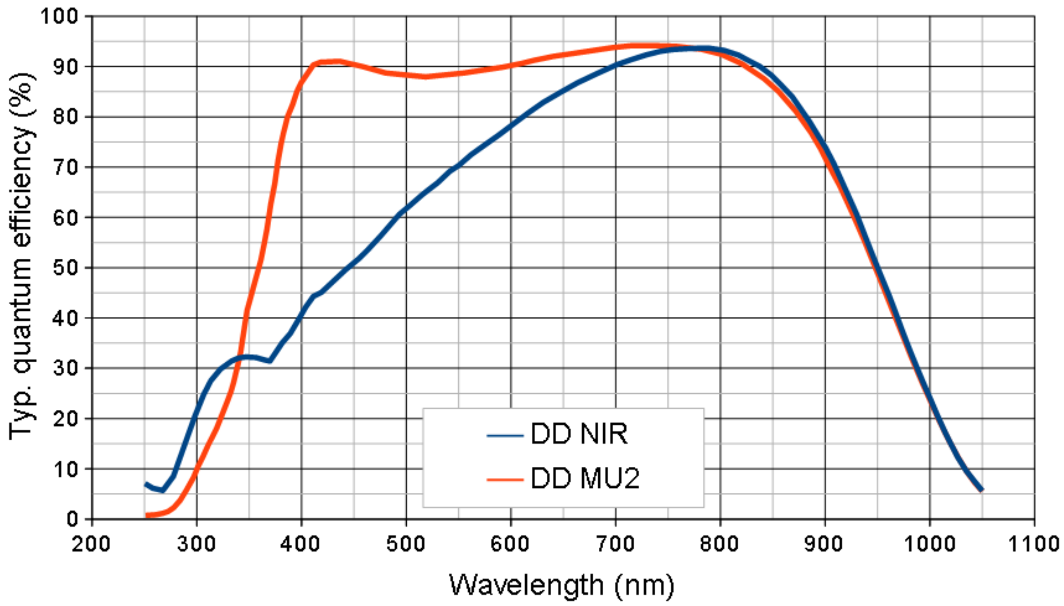
Since the shutter needs a certain period to get fully opened or fully closed, the value of "**Open Time**" and "**Close Time**" in the software can be given to ensure the shutter is fully opened during **Exp. Time** and is fully closed during the readout process. However, this will make the actual exposure time of the camera slightly more than the **Exp. Time** given in the software. The extra exposure time will depend on the delay of the shutter and the actual opening and closing time of the shutter. If a trigger and shutter are both used, the trigger will trigger the Open Time instead of Exp. Time.

## 6.5 QUANTUM EFFICIENCY CURVES

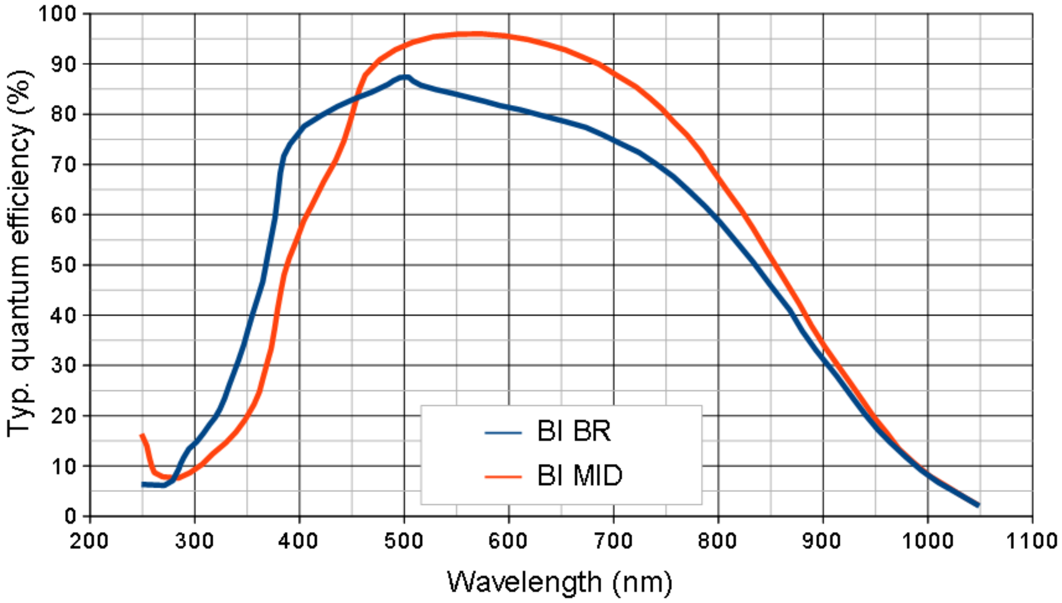
### 6.5.1 FRONT ILLUMINATED (FI) CCD SENSORS



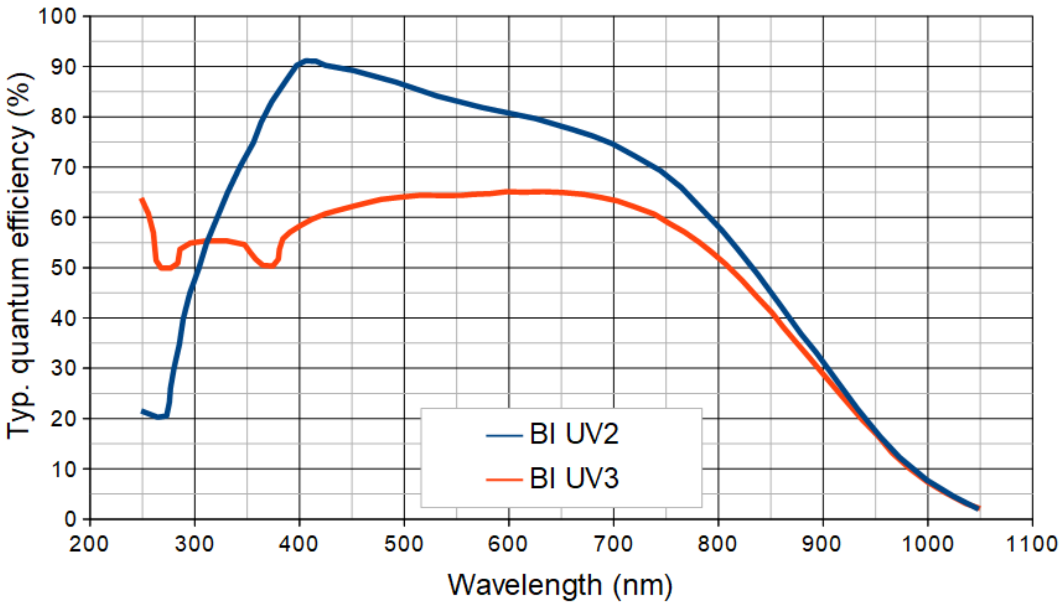

### 6.5.2 BACK ILLUMINATED (BI) CCD SENSORS IN NIR RANGE



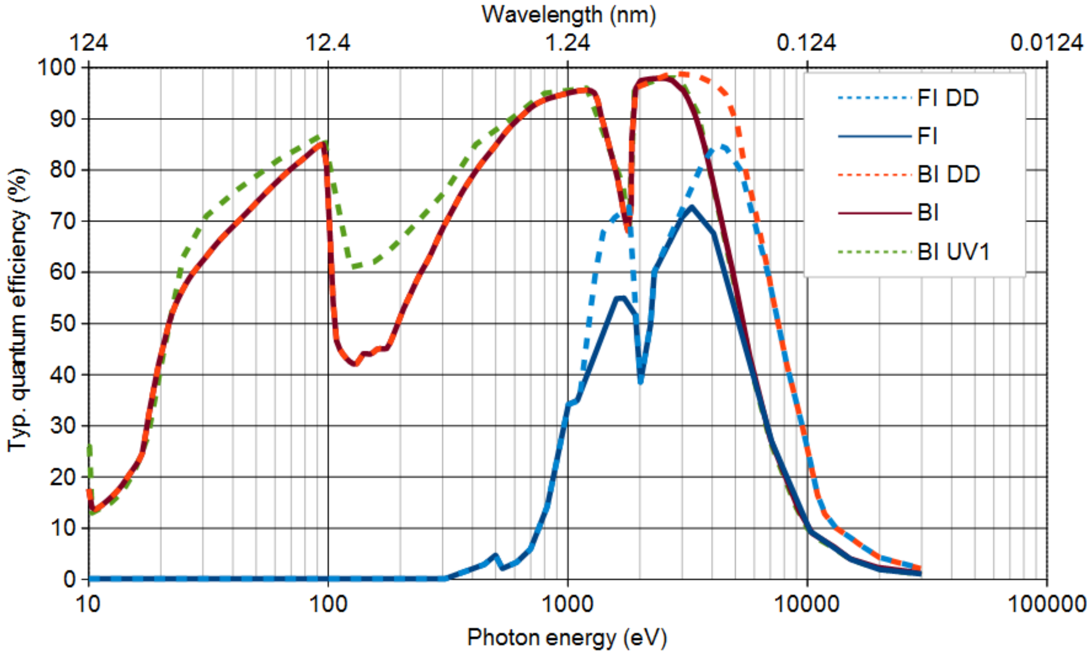
### 6.5.3 BACK ILLUMINATED (BI) CCD SENSORS IN VISIBLE RANGE




### 6.5.4 BACK ILLUMINATED (BI) CCD SENSORS IN UV RANGE

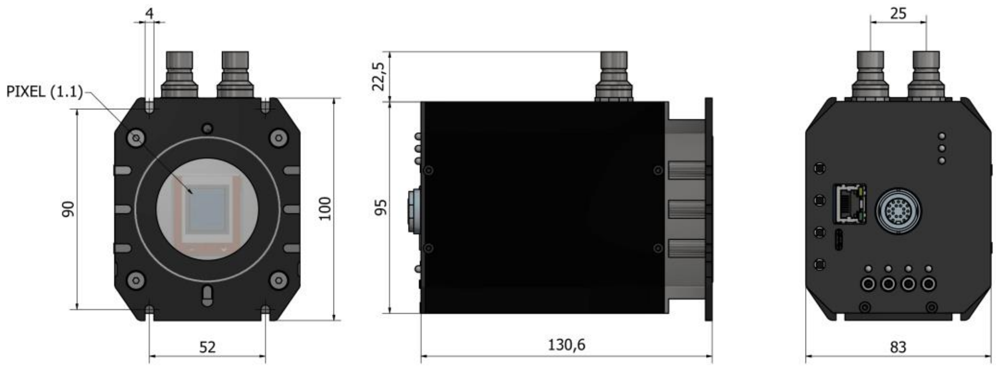


### 6.5.5 CCD SENSORS IN VUV EUV X-RAY RANGE

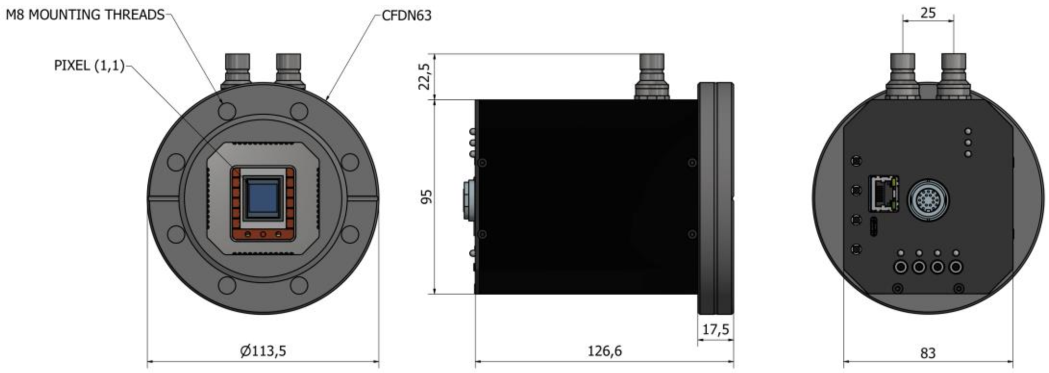


## 6.6 TECHNICAL DRAWINGS

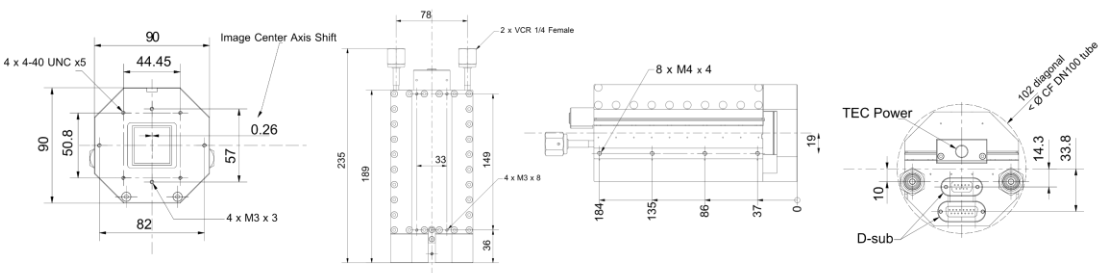
### ELSE-I 2K2K




### ALEX-I 1K1K




### LOTTE-I 2K2K




For the technical drawing of other models, please contact support@greateyes.de.

## 6.7 COPYRIGHT INFORMATION



The greateyes Vision Software uses the LibTIFF Library.

LibTIFF: Copyright (c) 1988-1997 Sam Leffler

LibTIFF: Copyright (c) 1991-1997 Silicon Graphics, Inc.

For detailed licence information please have a look into "licence_LibTiff.txt" on the USB device.

## 6.8 DECLARATION OF CONFORMITY

**EC Declaration of Conformity**
**EG-Konformitätserklärung**
**Déclaration de Conformité CE**
**greateyes**

| | |
|---|---|
| Document number: | 2017-09-CE-CCD |
| Manufacturer / Representative: | greateyes GmbH |
| Address: | Justus-von-Liebig-Str. 2, DE 12489 Berlin |
| Phone / E-Mail: | +49 (0)30 912075 250 / info@greateyes.de |
| Equipment name / type number: | ELSE 1k128 series / ALEX 1k128 series / LOTTE 1k128 series<br>ELSE 1k256 series / ALEX 1k256 series / LOTTE 1k1256 series<br>ELSE 2k512 series / ALEX 2k512 series / LOTTE 2k512 series<br>ELSE 1k1k series / ALEX 1k1k series / LOTTE 1k1k series<br>ELSE 2k2k (+) series / ALEX 2k2k (+) series / LOTTE 2k2k (+) series<br>ELSE 4k4k series / ALEX 4k4k series / LOTTE 4k4k series<br>GE CCD camera power supply (PS/PSK versions) |

Product description: Cooled Full-Frame CCD cameras, In-Vacuum CCD cameras and respective Super Resolution CCD camera models for imaging and spectroscopy and respective associated CCD camera power supplies

greateyes GmbH hereby declares under its sole responsibility that the product(s) specified above is (are) in conformity with the following EEC directives and harmonized standards:

**2014/35/EU** **Low Voltage Directive (LVD)** - Council of 26 February 2014 on the harmonization of the laws of the Member States relating to the making available on the market of electrical equipment designed for use within certain voltage limits

The following harmonized standards and technical specifications have been applied:

**EN 61010-1:2010** Safety requirements for electrical equipment for measurement, control, and laboratory use – Part 1: General requirements

**EN 61204:1995** Low-voltage power supply devices, d.c. output - Performance characteristics

**EN 61204-7:2006 +A11:2010** Low voltage power supplies, d.c. output - Part 7: Safety requirements

**2014/30/EU** **Electromagnetic Compatibility (EMC) Directive** - Directive 2014/30/EU of the European Parliament and of the Council of 26 February 2014 on the harmonization of the laws of the Member States relating to electromagnetic compatibility (recast)

The following harmonized standards and technical specifications have been applied:

**EN 61326-1:2013** Electrical equipment for measurement, control and laboratory use — EMC requirements – Part 1: General requirements

**EN61000-3-2:2014** Electromagnetic compatibility (EMC) — Part 3-2: Limits — Limits for harmonic current emissions (equipment input current ≤ 16 A per phase)

**EN61000-3-3:2013** Electromagnetic compatibility (EMC) — Part 3-3: Limits — Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment with rated current <= 16 A per phase and not subject to conditional connection

**EN 55011:2009 +A1:2010** Industrial, scientific and medical equipment – Radio frequency disturbance characteristics – Limits and methods of measurement

**EN 61204-3:2001** Low voltage power supplies, d.c. output. Electromagnetic compatibility (EMC)

CE Mark first applied to this product in the year 2010.

| Berlin / 2017/09/11 | Roman Kemmler / Managing Director | |
|---|---|---|
| **Place / Date of issue** | **Name / Position** | **Signature** |

## 6.9 WARRANTY CARD

# Warranty Card

| | |
|---|---|
| Model: | |
| Name of owner: | |
| Address: | |
| Telephone: | |
| E-Mail: | |
| Date of purchase: | |
| 1. Date and description of defects: | |
| 2. Date and description of defects: | |
| 3. Date and description of defects: | |

**Terms of guarantee:**

The period of guarantee starts on the date of delivery (see delivery note or packing list in package).

In case the camera is defect, please contact us first before further actions. You can reach us through the phone number +49 (0)30 912075 259 or the email address support@greateyes.de. It's possible that the camera needs to be de-mounted under instruction of a greateyes engineer, and sent back to greateyes for repair. In this case, please attach this paper in the package or make a copy of it.