Dhyana XF95
User Manual

V1.0.0

Tucsen Photonics Co.,Ltd.

Contents

1. Introduction

1.1. Disclaimer

To protect the legitimate rights and interests of users, please carefully read our accompanying instructions, disclaimers, and safety instructions before using our company's products. This camera user manual document contains basic information about the camera, installation instructions, product features, and maintenance, aiming to make it more convenient for users to use the TUCSEN's camera. This document is only disclosed for the above purposes. Please make sure to follow the instructions and safety instructions when operating this product.

Under no circumstances shall any content in this document constitute any express, implied, statutory or other form of warranty, including but not limited to any warranties of merchantability, non infringement or suitability for a specific purpose.

In any case, TUCSEN shall not be liable for any losses or damages arising from or related to the unauthorized use of the content of this document, whether direct, indirect, special, incidental, consequential or other reasons, whether caused by infringement or other reasons.

Product usage restrictions:

The product can only be used according to the instructions in the user manual, and unauthorized modifications, tampering, or reverse engineering are not allowed. Users are reminded that if they do not use the product according to the instructions in the user manual, resulting in product damage or malfunction, the responsibility shall be borne by the user. During the actual operation of the product, users should adjust and apply according to the content of the product manual, disclaimer, and safety instructions, combined with their own actual situation and needs. Our company does not assume any legal responsibility for any personal injury or property damage caused by users violating the product manual, disclaimer, safety instructions, or improper operation.

Quoting third-party content:

1) The user manual may contain content or links provided by third parties, which are for user reference and convenience only. TUCSEN only directly references the content or links of third parties and does not guarantee their authenticity, accuracy, and completeness, and does not assume any responsibility.
2) The publication of information in this document does not imply that TUCSEN Company or any third party automatically waives any patent or exclusive rights.
3) This document may contain technical or printing errors. Under no circumstances shall

TUCSEN be liable for any loss or damage caused by unauthorized use of the content of this document, whether direct, indirect, special, incidental, consequential or otherwise.

Trademark and Patent Information:

鑫图,TUCSEN, TUCSEN, TUCSEN, TUCSEN are trademarks of TUCSEN, and no one shall infringe upon the trademark rights of TUCSEN. All other trademarks are the property of their trademark owners, and TUCSEN is not responsible for any infringement by others.

Update of user manual:

TUCSEN does not promise to notify updates or maintain the information contained in this document at any time. If changes are made to the product, the relevant change information will be included in the new version of the manual. Without prior notice.

In summary, before using our company's products, please carefully read and understand the above disclaimer. Wishing you a pleasant use, thank you!

Tucsen Photonics Co., Ltd.

1.2. Safety and warning information

Operation and Use

Caution

- Do not drop, disassemble, repair or replace internal components on your own. Such action may damage the camera components or cause personal injury.
- In the event of spillage on the equipment, please disconnect the equipment and immediately contact the nearest dealer or manufacturer for technical assistance.
- Do not touch the device with wet hands, as it may cause electric shock.
- Do not let children touch the device without supervision.
- Ensure that the temperature of the camera is within the specified temperature range for use to avoid damage.

Installation and maintenance

Caution

- Please do not install it in dusty and dirty areas or near air conditioning or heaters to reduce the risk of camera damage.
- Avoid installation and operation in extreme environments such as vibration, high temperature, humidity, dust, strong magnetic fields, explosive/corrosive gases or gases.
- Do not apply excessive vibration and impact to the equipment. This may damage the equipment.
- Do not install equipment under unstable lighting conditions. Severe lighting changes can affect the quality of the images generated by the device.
- Do not use solvents or diluents to clean the surface of the equipment, as this will damage the surface of the casing.
- Please ensure that there is at least 10 cm of space around the device's ventilation openings to allow for proper airflow. Do not block the ventilation openings during use, as this may lead to excessive internal temperatures and damage the device.

Power

Caution	● Please use the original power adapter of the camera, as using an mismatched power source may damage the camera. ● If the voltage applied to the camera is greater than or less than the nominal voltage of the camera, the camera may be damaged or malfunction. ● Please refer to the specification table for the nominal voltage of the camera.

2. Product specifications

2.1. Packaging List

Standard Item Name	Specification	Quantity	Image
sCMOS scientific grade camera	Dhyana XF95	1	
Power adapter	12V/8A	1	
Control box AC power cord	Three core 250V/2.5A	1	
USB3.0 data cable	2 m	1	
USB flash drive	Software and Drivers	1	
Water pipes	2 m, OD: 6 mm, ID: 4 mm	2	
SMA trigger cable	3 m, SMA inner screw inner needle-SMA inner screw inner needle, wire RG178	4	

Optional Item Name	Specification	Quantity	Image
CameraLink frame grabber	Firebird	1	
Frame grabber cable	3 m	2	
Level conversion box	Standard	1	

2.2. Camera Introduction

The Dhyana XF95 is a professional soft X-ray sCMOS camera developed by Tucsen. It features a new generation of anti-reflective coated back-illuminated sCMOS sensor, which significantly enhances quantum efficiency in the 80-1000 eV photon energy range, with an overall efficiency exceeding 90% (see Figure 2-1). In certain bands, it achieves an exceptionally high level of nearly 100%. The camera offers advanced soft X-ray and extreme ultraviolet imaging capabilities and excellent radiation damage resistance, and has been successfully utilized in various synchrotron radiation research projects both domestically and internationally.

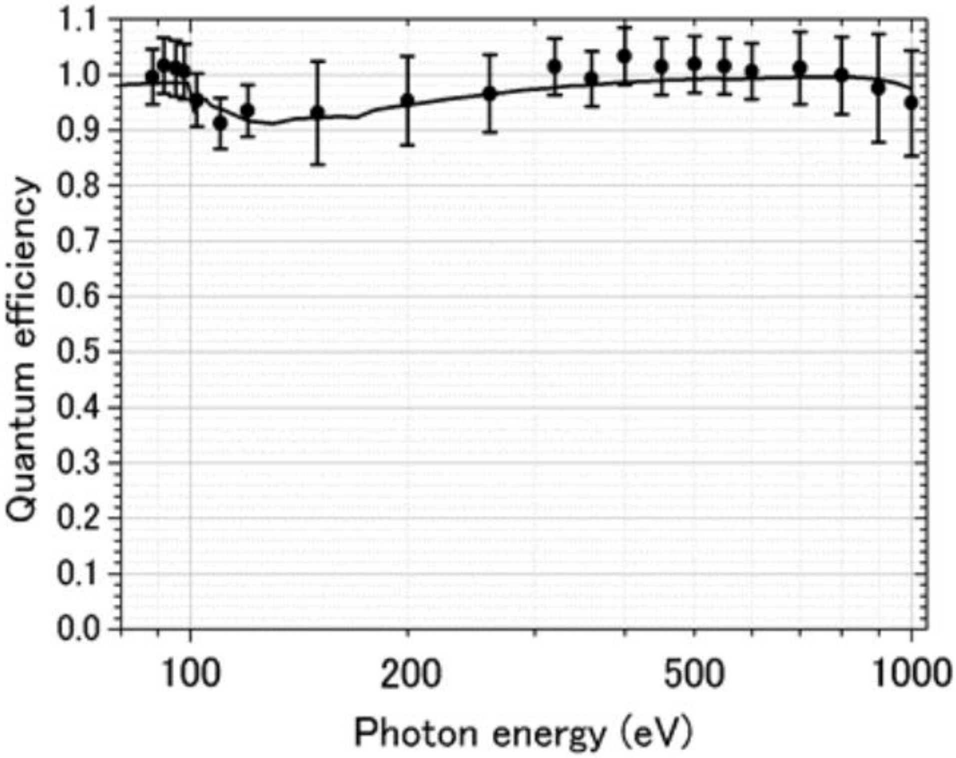


Figure 2-1 Quantum efficiency curve of Dhyana XF95

Vacuum compatibility up to 10^{-7} Pa

Utilizing Tucsen advanced cryogenic sealing technology, the Dhyana XF95 camera achieves an exceptionally high vacuum compatibility level of up to 10^{-7} Pa. With water cooling (20°C), it can reach a maximum cooling temperature of -50°C, significantly reducing dark current noise in the camera and extending the application time for long exposures.

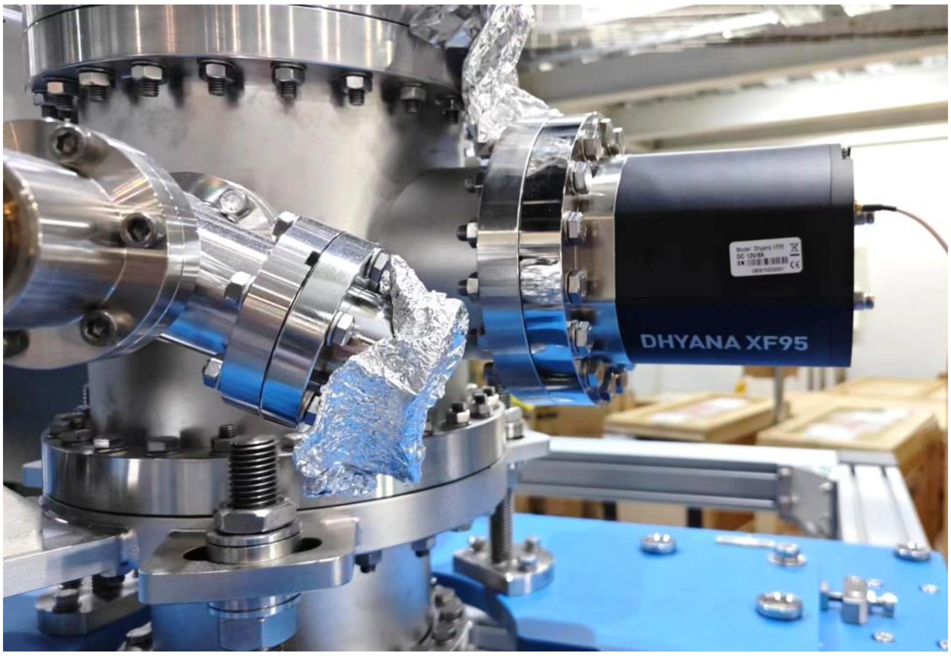


Figure 2-2 Schematic diagram of the camera outside the vacuum chamber

High-speed, high-dynamic imaging advantages

Back-illuminated sCMOS technology offers imaging speeds tens of times faster than CCD technology, coupled with a significantly higher overall dynamic range advantage. As shown in the figure, in the acquisition of soft X-ray diffraction patterns, it achieves a peak diffraction order of 6.

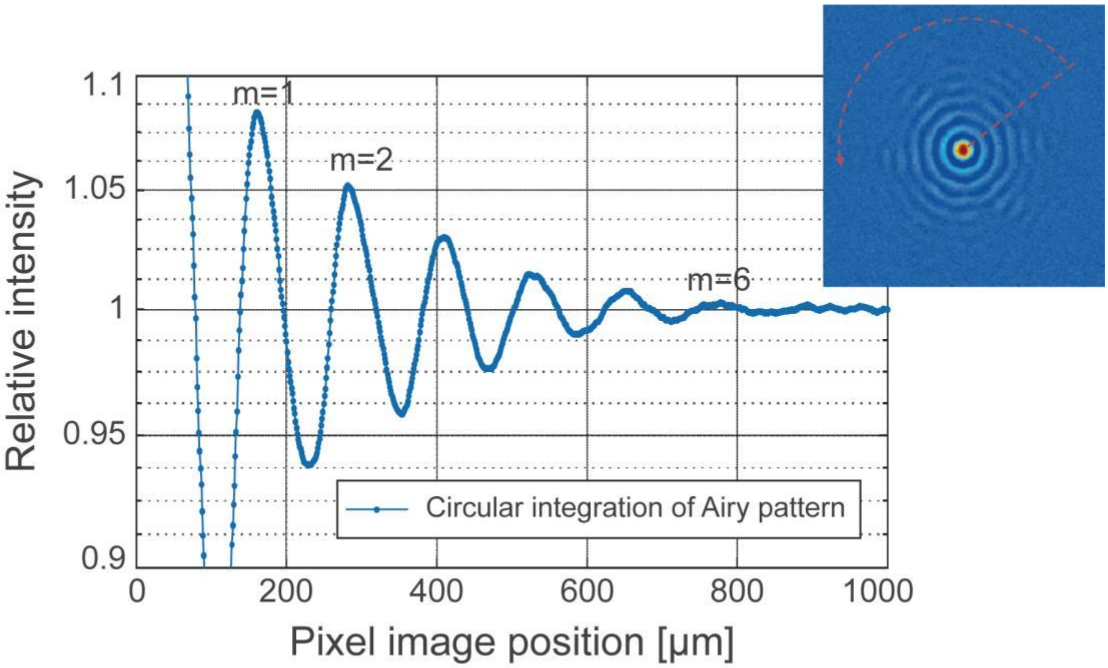


Figure 2-3 Soft X-ray diffraction pattern

2.3. Camera Power and Signal Connections

This section introduces the interfaces used during the camera installation process. Please ensure you have thoroughly understood the instructions in this section before proceeding with installation.

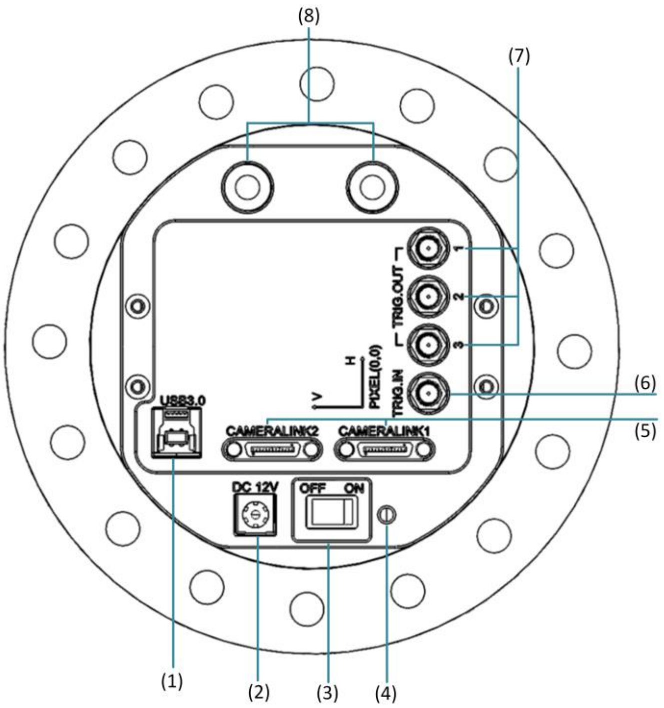


Figure 2-4 Camera interface diagram

No.	Name	Fuction
1	USB 3.0 interface	Camera data transfer
2	DC12V	Power interface
3	Switch	Control camera power
4	Indicator light	Indicate the camera status, press F2 to control the light on or off of the indicator light Red: Camera powered on Orange : Normal operation
5	CameraLink interface	Camera data transfer
6	TRIG.IN	External trigger input interface (SMA interface)
7	TRIG.OUT	Three external trigger output ports are available, with the default output signals as follows:

		TRIG OUT1: Readout end signal TRIG OUT2: Global exposure signal TRIG OUT3: Exposure start signal The above trigger output signal types support customer customization settings
8	Water cooling pipe joint	water cooling

Precautions for Camera Use Outside of Vacuum:

1) *For non-vacuum use, the fan must be turned on or a water cooling device must be connected, and the TEC must be turned off. For use in a vacuum, turn on the TEC only after the vacuum level has reached at least 1E-3 Pa;*

2) *For non-vacuum use, do not remove the camera's protective cover. Ensure that the surface of the camera is clean to avoid affecting its subsequent use in a vacuum;*

3) *If the software is already closed but the camera light is still orange, it indicates that the camera has not been fully released. You need to completely exit the camera thread or restart the camera to return the indicator light to red.*

3. Features and Functions

3.1. Structure and Operation of sCMOS

Scientific grade complimentary metal-oxide semiconductor (sCMOS) cameras are specialized cameras used for scientific research and high-performance imaging. They combine the advantages of CMOS and Charge coupled device (CCD) technologies, featuring high speed, low noise, and high sensitivity, and are widely used in scientific research, biomedical imaging, optical microscopy, and other fields.

The structure of an sCMOS camera sensor typically includes the following components:

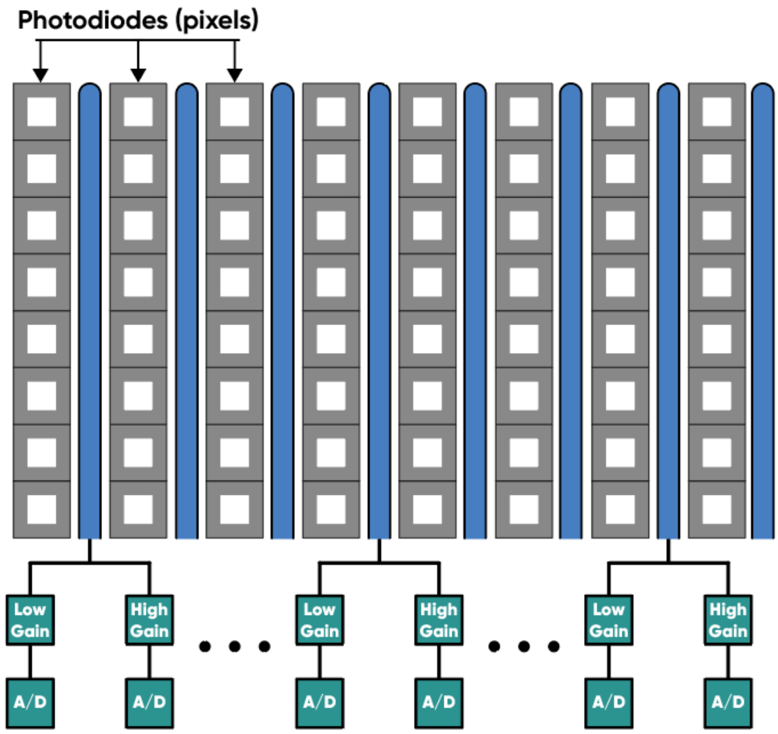


Figure 3-1 sCMOS camera sensor structure

1) Light-sensitive sensor array: sCMOS cameras use sCMOS sensor arrays (also known as image sensors) to capture light signals. These sensors consist of many photosensitive units that convert light into charge signals.

2) Gain amplifier: Each photosensitive unit in an sCMOS camera is equipped with an independent gain amplifier to amplify the charge signal and convert it into a voltage signal.

3) Analog-to-digital converter (ADC): The amplified analog signal is digitized through an analog-to-digital converter (ADC) inside the camera, converting it into a digital signal for further processing and storage.

sCMOS cameras typically also include an image processing unit for performing image enhancement, correction, and other image processing algorithms. The digitized image undergoes these processes to obtain higher-quality images.

The operation process of an sCMOS camera is as follows:

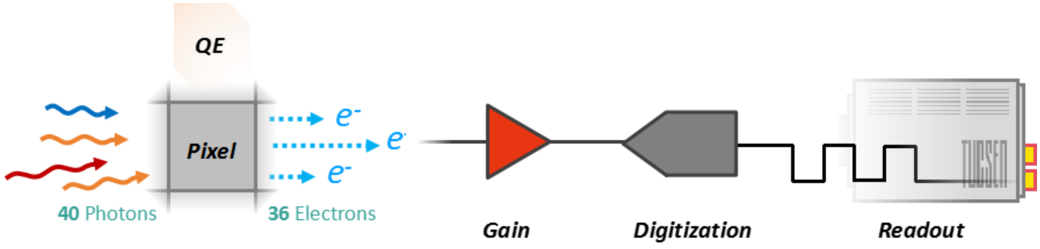


Figure 3-2 sCMOS operation process

1) Light signal capture: When photosensitive units are exposed to light, the light is converted into charge signals and stored in each unit.
2) Signal amplification: The charge signals from each photosensitive unit are amplified by corresponding gain amplifiers and converted into voltage signals.
3) Digitization: The amplified analog signals are converted into digital signals by an ADC for processing and storage.
4) Image processing: The digital signals undergo various algorithmic processes such as denoising, enhancement, and color correction through the image processing unit.
5) Data output: Processed image data can be transmitted to computers or other devices for display, analysis, and storage through various interfaces such as USB, Ethernet, etc.

3.2. Shutter Mode

The Dhyana XF95 camera uses a rolling shutter readout mode. In this mode, the camera reads out rows sequentially, with consistent exposure time for each row, but different starting exposure time point for different rows. The difference in exposure time points between adjacent rows is also known as the line time (T_{line}).

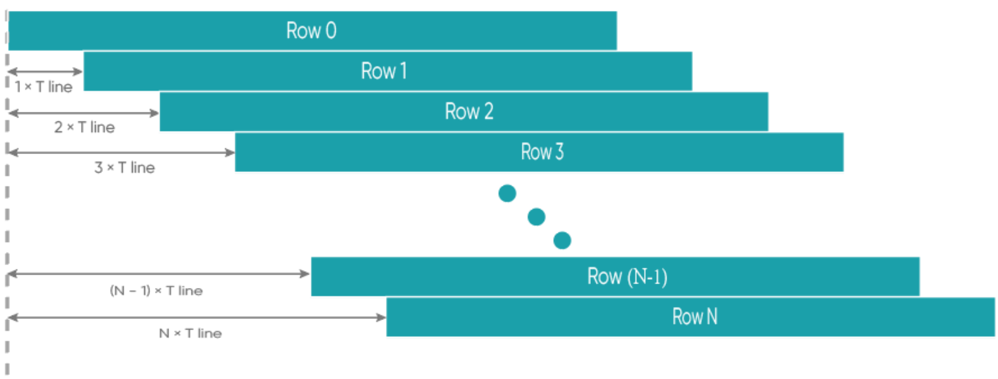


Figure 3-3 Rolling shutter diagram

In rolling shutter mode, if the camera is not synchronized with external light sources or if flickering light sources are present, it may result in striped images. This effect is especially noticeable with short exposure times(Please refer to the FAQs for solutions).

3.3. Front-Illuminated and Back-Illuminated sCMOS Technology

Cameras based upon sCMOS technology typically use two types of chips: front-illuminated (FSI) and back-illuminated (BSI). In front-illuminated cameras, light entering the pixels must pass through metal circuit structures before being detected. Due to the non-transparency of metal circuit structures, early cameras had only about 30-40% quantum efficiency (QE). Later, with the introduction of microlenses, light was focused through the conductors onto the photosensitive silicon, increasing QE to around 70%. Some advanced front-illuminated cameras can even achieve a peak QE of around 84%.

Back-illuminated cameras reverse this sensor design by placing the metal circuitry behind the photosensitive silicon layer, allowing incident photons to directly strike the thin photosensitive silicon layer. This process innovation significantly increases the peak QE of back-illuminated cameras and improves imaging quality in low-light environments. Due to the thin photosensitive silicon layer of back-illuminated pixels, there are higher process requirements and production difficulties compared to front-illuminated ones.

The Dhyana XF95 camera uses an anti-reflection coated back-illuminated sensor, with peak QE reaching approximately 100% in certain spectral bands.

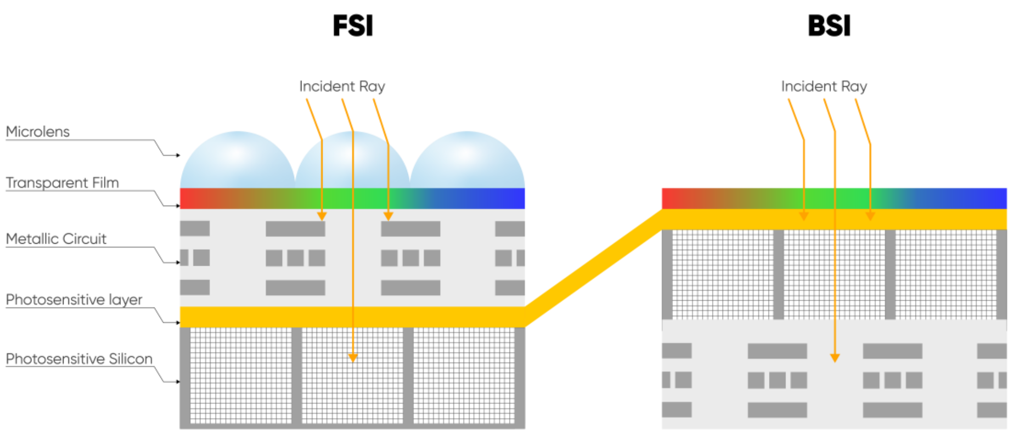


Figure 3-4 Front-Illuminated and Back-Illuminated diagram

3.4. Readout Noise

Noise is a description of the uncertainty of a signal. The noise introduced by the circuit when reading the signal is called readout noise. Readout noise dominates in low signal level imaging, and excessive readout noise can limit the applications of imaging under weak light conditions.

In CCD cameras, since all pixels share the same readout circuit, the standard deviation (σ) of each pixel is relatively uniform, so a unified value can be used to represent the overall level of readout noise. In sCMOS cameras, each pixel has its own readout circuit, and the statistical distribution of readout noise for all pixels can be obtained as shown in the graph below. The camera's readout noise is typically represented by the median and root mean square (RMS). The median represents the median of the standard deviations of all pixels, while the root mean square reflects the overall noise situation, with the RMS value usually higher than the median value.

To accurately measure readout noise, it is usually evaluated by acquiring multiple dark frame images under no light signal and the shortest exposure condition, and calculating the time-domain standard deviation of each pixel to assess its readout noise level.

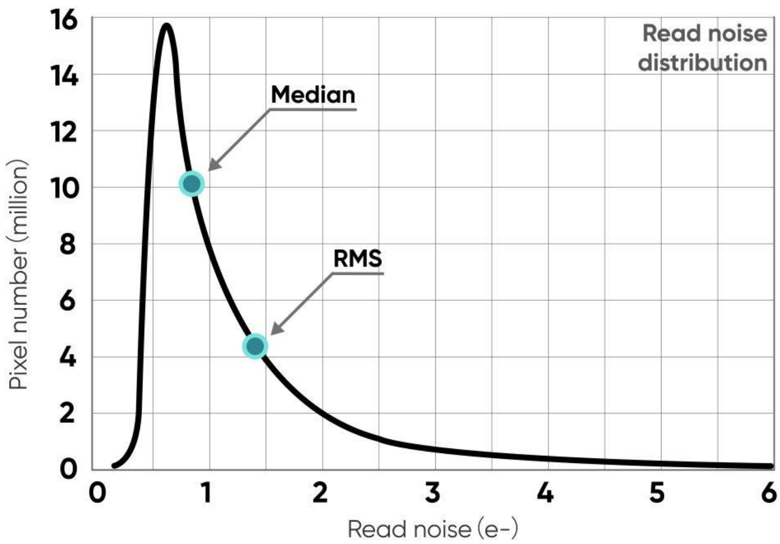


Figure 3-5 Readout noise distribution of an typical sCMOS camera

3.5. Defective Pixel Correction (DPC)

There are always a few abnormal values on the sCMOS camera chip. Through the camera's Defective Pixel Correction (DPC) function, these abnormal points can be corrected, removing defective pixels from the image. However, this may cause flickering pixels in some single-molecule imaging applications. It is not recommended to use the DPC function for these applications or to use only the weakest correction level.

The Dhyana XF95 adopts dynamic defective pixel correction, correcting using a 3x3 matrix of pixels. Currently, four correction levels are available, each corresponding to different thresholds, thereby controlling the intensity of defective pixel correction.

3.6. Dark Signal Non-Uniformity (DSNU)

When the camera captures images in complete darkness, ideally, all pixel grayscale values should be close to zero and equal. However, in reality, when the camera captures images in darkness, subtle differences in the performance of each pixel in the sensor will cause some variations in the pixel grayscale values outputted from the camera.

In practical applications, when there are no photons incident on the camera, the obtained image usually does not show a grayscale value of 0 (DN). This is because manufacturers typically set a offset value, such as 100 grayscale values, to account for the influence of noise on measurements based on this baseline in the absence of light. However, without careful calibration and correction, this fixed offset may also vary between different pixels. This variation is called "fixed pattern noise" and can be measured by DSNU (Dark Signal Non-Uniformity). It represents the standard deviation of pixel bias, measured in charge units.

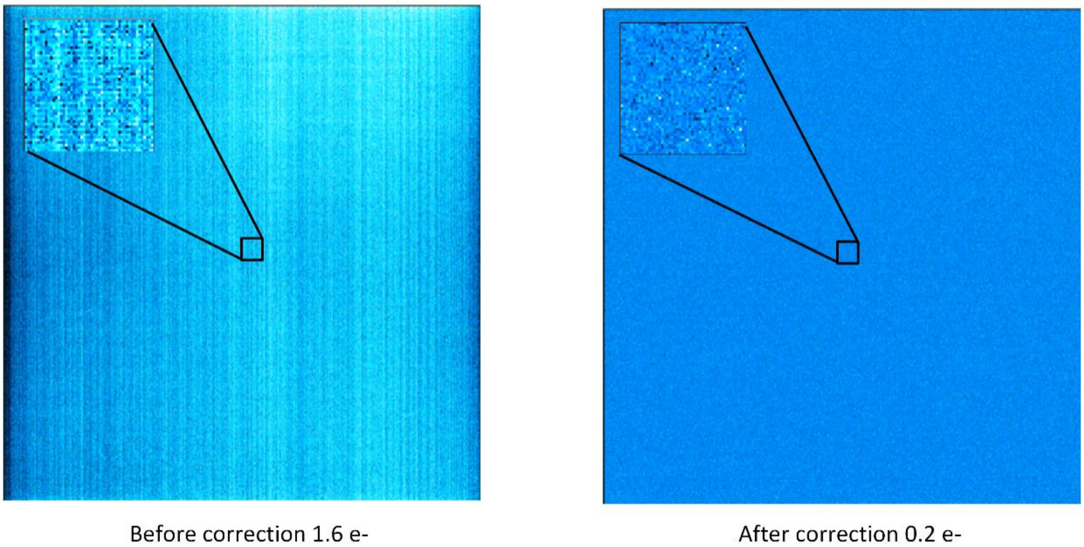


Figure 3-6 DSNU correction comparison before(left) and after(right)

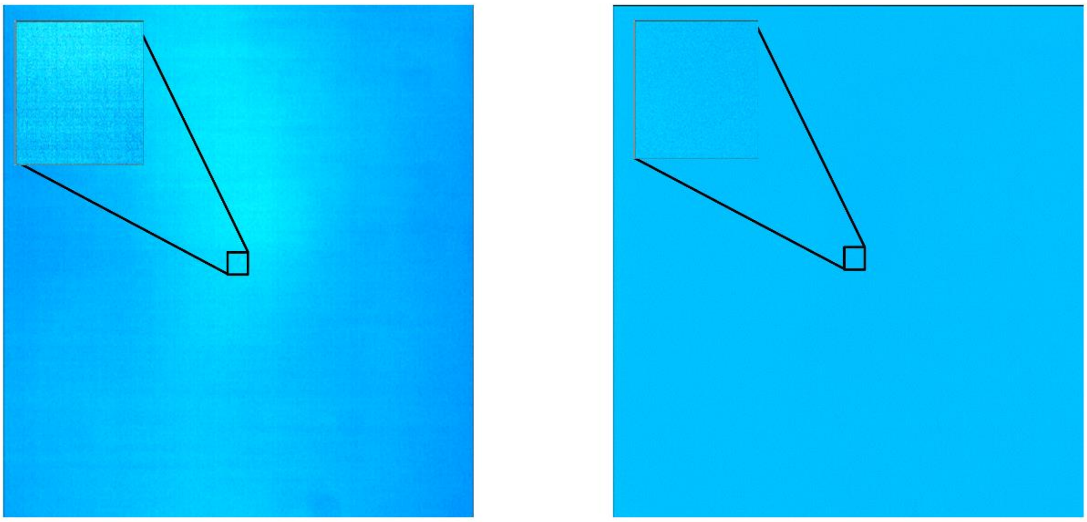
For many low-light imaging cameras, DSNU is typically less than 0.5 e-. This means that in medium or high light level applications (where each pixel can typically capture hundreds or thousands of photons), the influence of this noise can be completely negligible. Moreover, even for low-light applications, if DSNU is lower than the camera's readout noise (typically 1-3 e-), this fixed pattern noise is unlikely to affect image quality.

3.7. Photo Response Non-Uniformity (PRNU)

When a camera captures uniformly illuminated light targets under bright light conditions, ideally, all pixel grayscale values should be close to the maximum grayscale value and equal. However, in reality, there are subtle differences in the performance of camera pixels, causing changes in pixel grayscale values outputted from the camera due to variations in lenses or illumination.

When the camera detects light signals, the number of photoelectrons captured by each pixel during the exposure process is measured and transmitted as digital grayscale values (DN) to the computer. The conversion from electrons to DN follows a certain proportion, called the system gain (K) or conversion gain, plus a fixed offset (usually 100 DN). These values are determined by both the analog-to-digital converters and amplifiers used for conversion. sCMOS cameras use parallel transmission, with one or more analog-to-digital converters per column of the camera and one amplifier per pixel, resulting in slight variations in pixel gain and offset.

Under dark field or low light conditions, differences in offset can be measured by DSNU as mentioned in Section 3.6. In bright environments, the influence of gain also needs to be considered. Differences in gain and offset changes are measured by Photo Response Non-Uniformity (PRNU), which is the ratio of detected electrons to displayed DN. Given that the intensity values produced will vary depending on the signal size, PRNU is expressed as a percentage.



Before correction 1.6% After correction 0.3%

Figure 3-7 PRNU correction comparison before(left) and after(right)

Typical PRNU values are < 1%. For all low-light and medium-intensity light source imaging (signals of 1000 e- or less), this variation is negligible compared to readout noise and other sources of noise. Similarly, when imaging at high light levels, this variation is not significant compared to other noise sources in the image (such as photon shot noise). However, in high light level imaging applications requiring very high measurement accuracy, especially those using frame averaging or frame summation, PRNU values < 1% are highly necessary.

3.8. Gain Mode

The XF95 camera has follwing gain modes: High Dynamic Range (HDR) mode, High Gain (HG) / Low Gain (LG) in HDR mode, and High Gain High-Speed (HG_HS) / Low Gain High-Speed (LG_HS). Each mode has differences in synthesis principles, line times, gain values, and readout noise. Selecting the appropriate mode based on the actual scenario is essential to obtain high-quality imaging results.

Table 3-1 Typical gain mode parameter table*

Mode	HDR（16bit）	High Gain（12bit）	Low Gain（12bit）
System gain (DN/e-)	0.75	1.98	0.043
Full-Well Capacity (e-)	80000	1900	85000
Readout noise (e-)	2.4 (Median) 2.5 (RMS)	1.6 (Median) 1.7 (RMS)	45 (Median) 50 (RMS)

***Note:**

The values in this table are typical and may vary between different cameras. Please refer to the factory photoelectric report for specific details.

3.8.1. High Dynamic Range

High Dynamic Range (HDR) mode synthesizes images with different analog gains but the same exposure time. It includes Low Gain (LG) mode with high full well capacity and high noise suitable for imaging strong signals, and High Gain (HG) mode with low full well capacity and low readout noise suitable for imaging weaker signals. Combining high and low gain images through algorithms generates an HDR image. This mode is suitable for applications with large variations in signal strength.

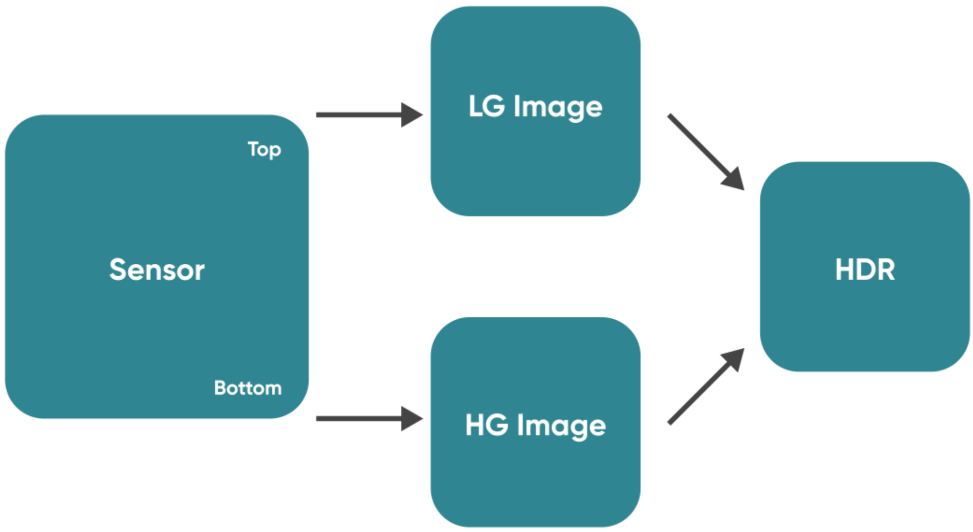


Figure 3-8 Schematic diagram of HDR mode

3.8.2. High Gain

The High Gain (HG) mode has lower readout noise and is suitable for imaging scenarios with weaker signals.

3.8.3. Low Gain

The Low Gain (LG) mode has a higher full well capacity, making it suitable for imaging scenarios with strong signals.

3.8.4. High Speed

In High speed mode (HS), unlike the normal rolling shutter readout method, both the High Gain (HG) and Low Gain (LG) channels are set with identical parameters, allowing for simultaneous readout of odd and even rows of data. This configuration doubles the readout speed.

High-Speed mode can be configured in two gain settings: "High Gain High-Speed (HG_HS)" and "Low Gain High-Speed (LG_HS)." The "High Gain High-Speed" setting is optimized for readout noise, while the "Low Gain High-Speed" setting is optimized for saturation capacity.

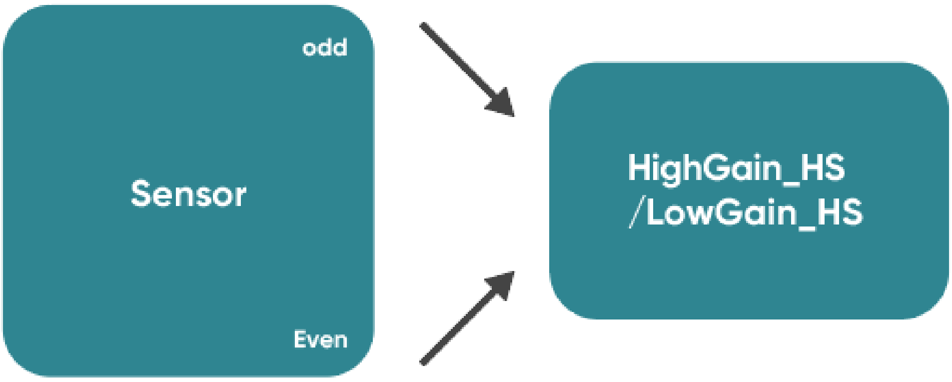


Figure 3-9 Schematic diagram of High speed mode

Note:

The high-speed mode is also known as the STD mode.

3.9. Region of Interest Readout

In imaging applications, ROI (Region of Interest) defines a subregion of interest within the camera sensor's resolution range, and selecting an ROI allows only the images within this subregion to be read out. Rolling shutter cameras can increase the camera's readout speed by reducing the number of rows. The software sets preset subregions and also supports manual settings, where the row window must be a multiple of 4, and the column window must be a multiple of 8.

The typical ROI frame rates for different camera interfaces can be referenced as following:

Table 3-2 Typical ROI frame rates (fps) for the Dhyana XF95 camera under USB 3.0 & CameraLink can be found in the following table*

Column (Pixel)	Row (Pixel)	HDR&HG&LG	HighGain_HS/LowGain_HS
2048	2048	23.88	47.53
2048	1024	47.53	94.58
2048	512	94.58	187.99
2048	256	188.18	369.46
2048	128	372.41	717.24
2048	64	728.08	1354.68
2048	32	1393.10	2439.41
2048	16	2565.95	4066.01
2048	8	4433.50	6084.81
48	8	4433.50	6091.54

***Note:**

1) The minimum supported ROI for Dhyana XF95 on Mosaic V3 is 48 (columns) × 8 (rows).

2) Frame rates are affected by computer system configuration, and it is recommended to use a computer with an i5 processor or above and a 64-bit system.

3) For high-speed image acquisition, it is recommended to uncheck automatic levels and turn off the Image Adjustment module.

4) The frame rates in the above table are the measured maximum values under the shortest exposure time.

3.10. Binning Readout

Binning is a readout mode that recombines camera pixels, which can improve sensitivity but may also reduce resolution. For example, 2 x 2 binning combines every 4 pixels (2 rows 2 columns) into one "large pixel", and the camera outputs one pixel intensity value.

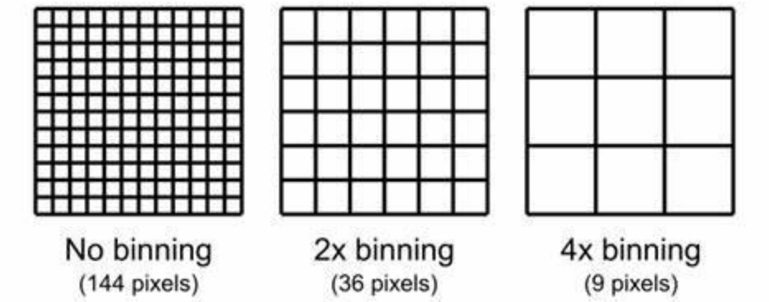


Figure 3-10 Schematic diagram of Binning

Binning can be performed by the camera's FPGA or by the camera operating software. Combining signals in this way can improve the signal-to-noise ratio, enabling the detection of weaker signals, improving image quality, or shortening exposure times. However, the effective pixel size of the camera also increases, which may reduce the camera's resolution of target details.

Binning data processing can be divided into Sum Binning and Average Binning. In 2 x 2 Binning, for example, Sum Binning adds the grayscale values of four pixels, while Average Binning adds the grayscale values of four pixels and then divides by 4 to obtain the average grayscale value.

The software Binning seclection on Mosaic V3 is shown below:

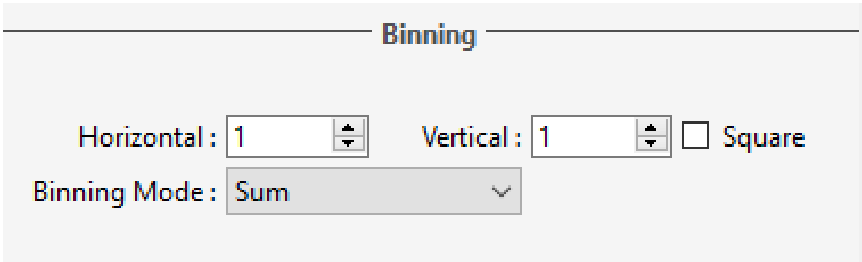


Figure 3-11 Software Binning

The FPGA Binning seclection on Mosaic V3 is shown below:

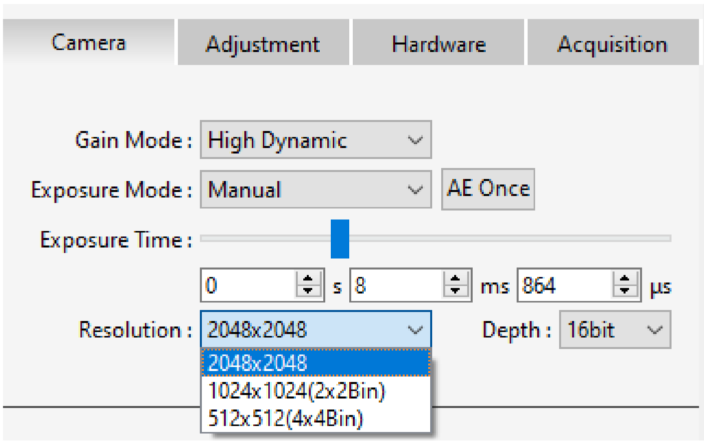


Figure 3-12 FPGA Binning

3.11. Timestamp

The camera accurately reads the start time of each frame with a time precision of 1 µs. In Mosaic V3 software, images are saved in .sen format, and timestamp information is displayed in the image information, supporting the export of image information to .csv format files.

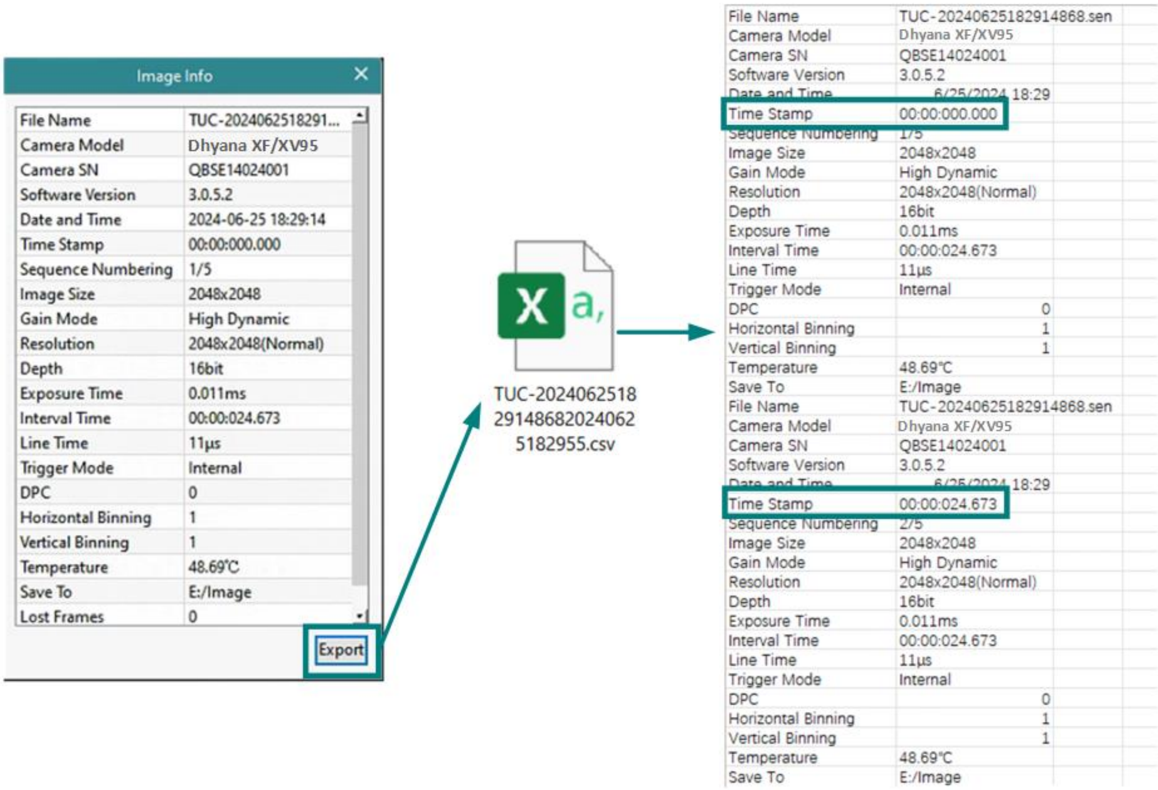


Figure 3-13 Illustration of the timestamp function in Mosaic V3 software

Note:

Applications requiring timestamp functionality generally have high time precision requirements, and it is recommended to use the To RAM image storage mode.

3.12. Frame Rate Calculation

The frame rate of the camera is influenced by the readout time and exposure time, and the final frame rate is also limited by the transmission bandwidth. The theoretical frame rate can be calculated with reference to Table 3-4.

Table 3-3 Calculation of Line time and Theoretical Minimum Full-Frame Readout Time for Each Mode of the Dhyana XF95.

Gain mode	Line time T_{line}	Readout Time $T_{readout}$
HDR/HG/LG	20.52 µs	2048*20. 52 µs=42.02496 ms
HighGain_HS/LowGain_HS	20.52 µs	2048/2*20.52 µs=21.01248 ms

Typical frame rate calculations for USB 3.0 & CameraLink

Hn: The number of rows selected horizontally

Vn: The number of rows selected vertically

T_{line}: The line time;

T_{exp}: The set exposure time;

Table 3-4 Frame Rate Calculation

Gain mode	Calculation formula	Horizontal (Hn)	Vertiacal (Vn)	Frame rate (fps)	Gain mode
HDR/HG/LG	20.52 µs	1/(Vn*T_{line})	2048	2048	23.8
				1024	47.6
				512	95.2
				256	190.4
				128	380.7
				64	761.4
HighGain_HS /LowGain_HS	20.52 µs	1/(Vn/2*T_{line})	2048	2048	47.6
				1024	95.2
				512	190.4
				256	380.7
				128	761.4
				64	1522.9

Note:

1) The frame rate is affected by the actual transmission bandwidth and computer system configuration, and to prevent frame loss, the actual transmission will increase the interval time in units of line time, and the readout time will increase accordingly, resulting in part of the calculated frame rate may be greater than the actual frame rate;

2)The frame rate table values are calculated based on the minimum exposure time. When the user-set exposure time (T_{exp}) is greater than the frame transfer time, the frame rate is calculated as 1/T_{exp} (s).

3.13. Incident Photon Calculation

Scientific camera imaging involves the conversion of photons, electrons, voltage, and grayscale values. Therefore, it is possible to reverse calculate the incident number of photons from the grayscale values. The calculation formula* is as follows:

$$P = \frac{(DN\text{-}Offset)/K}{Q(\lambda)}$$

Where:P represents the incident number of photons.DN is the grayscale value of the light signal. K is the system gain (refer to Table 3-1) in (DN/e-). Q(λ) corresponds to the quantum efficiency at the wavelength.Offset s the camera's background value in DN.

***Note:**

1) For high-energy lasers, a single excitation may involve multiple photons. If precise photon counts are needed, appropriate coefficients should be applied to obtain accurate photon values.

2) The camera should not be exposed to light intensity exceeding 3/4 of the saturation grayscale value. Prolonged exposure to high-intensity light may damage the sensor.

3.14. Acquisition Mode

3.14.1. Live mode

Live mode is suitable for real-time preview, providing data stream output. Images are continuously output like a flowing stream. In this mode, users can freely modify settings such as exposure time, gain mode, region of interest, etc., for real-time preview and image capture operations.

After successfully installing the Mosaic V3 software and drivers, the hardware trigger mode defaults to "internal trigger" (live mode), the user can click Preview/Stop to control the opening and closing of the camera live mode, and click Capture to obtain the image.

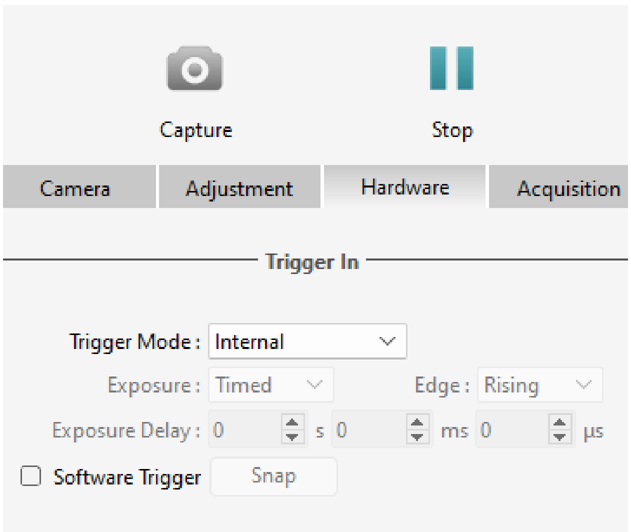


Figure 3-14

Users can set the exposure time, gain mode and other camera parameters, and preview them in real time through the preview window to get a suitable image.

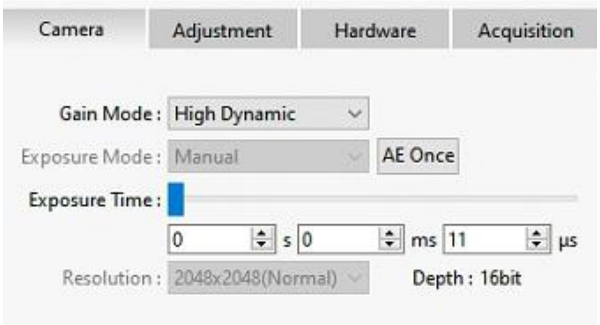


Figure 3-15

In the acquisition module, users can set the save path, file name, total number of frames and other information, and the image can be taken after the setting is completed.

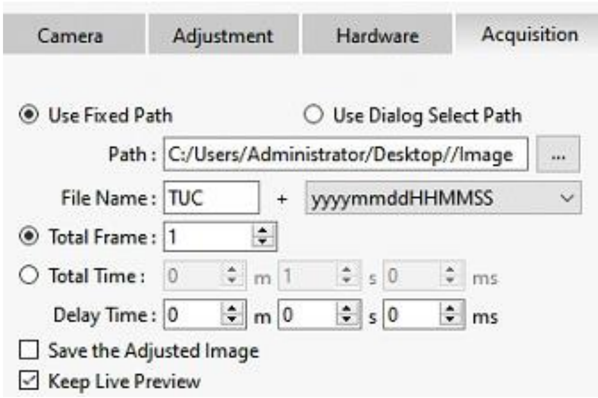


Figure 3-16

3.14.2. Software Trigger Mode

When the camera is in Software trigger mode, the software gives the camera a command to take a picture, and when the camera receives the signal, it starts the exposure and outputs the image.

To use the software trigger mode in Mosaic V3, check the software trigger, click Capture to enter the waiting trigger state, and then click the **Snap** to execute the image capture command, and only output one image at a time.

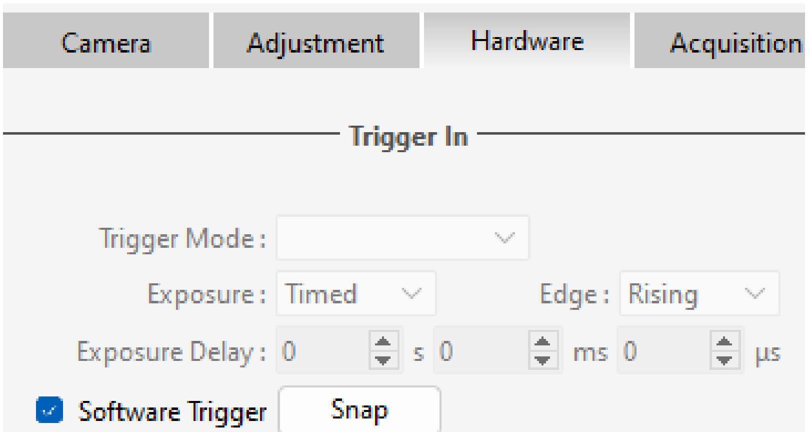


Figure 3-17

3.14.3. Hardware Trigger Mode

Hardware trigger mode waits for an external level trigger signal command to capture an image.

It includes two modes: Standard and Synchronization.

The Mosaic V3 software provides configurations such as trigger mode, exposure, edge, exposure delay, etc.

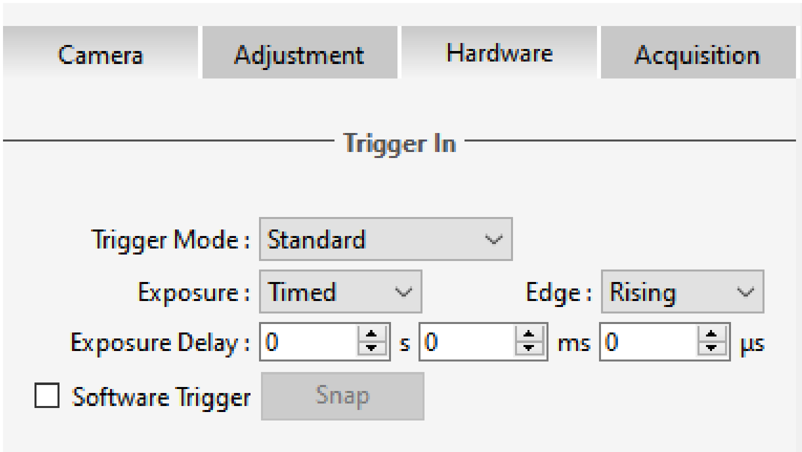


Figure 3-18

3.14.3.1. Hardware Trigger input circuit

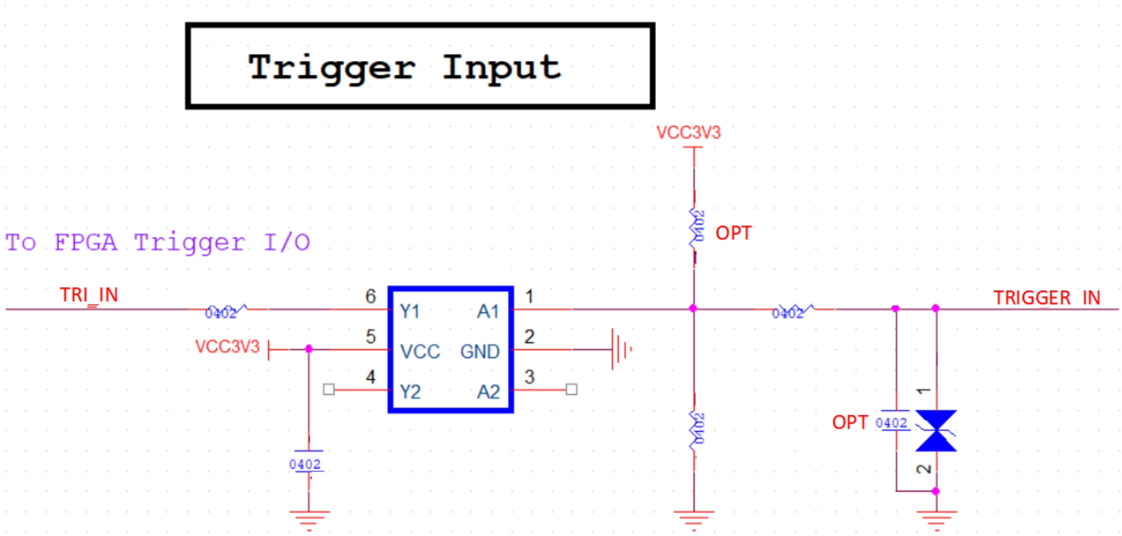


Figure 3-19 Hardware trigger input circuit

Note:

1) The valid external trigger signal recognized by the imager must be a level signal of 3.3 to 5 V. Exceeding the maximum voltage limit may cause permanent damage;

2) The pulse width of the recognized level signal must be greater than 1 µs.

3.14.3.2. Trigger Delay and Jitter

The trigger delay and jitter for the HDR, High Gain/Low Gain and High Speed modes are shown below, When the external trigger signal arrives, there is a nanosecond-level delay T_{iso}. through the hardware circuitry. After the delay through the hardware circuitry, the level signal input to the camera's internal undergoes conversion, resulting in some jitter T_{logic}, ranging from 0-1 minimum exposure unit T_{line}. Therefore, the total delay time from external trigger input to exposure start is $T_{idelay}=T_{iso} + T_{logic}$, within the range of one line time.

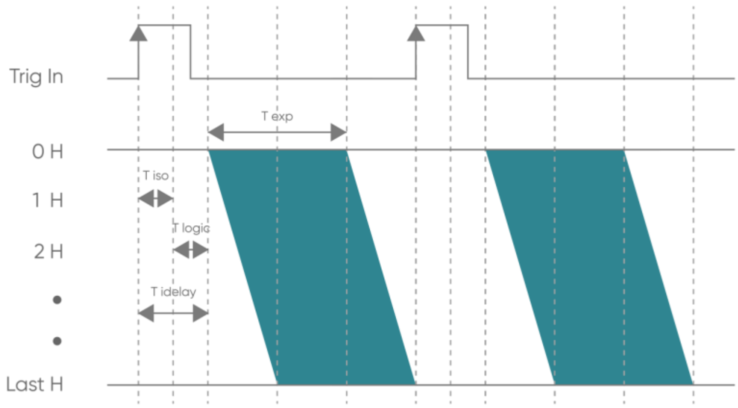


Figure 3-20 Schematic of trigger delay

T_{exp}: exposure time; T_{iso}: hardware circuit delay; T_{logic}: trigger jitter; T_{idelay}: total delay time;1H: one T_{line}

3.14.3.3. Standard Trigger Mode

In standard trigger mode, when the camera is in live mode, it can respond to the trigger signal immediately after the exposure of the first row of the image ends.

This mode supports two types of triggering: level triggering and edge triggering. In level triggering mode, exposure start and end are controlled by the rising or falling edge of an external trigger signal, with the duration of exposure determined by the duration of the level. Level triggering mode is not continuous shooting; it is commonly used for capturing stationary or slow-moving objects.

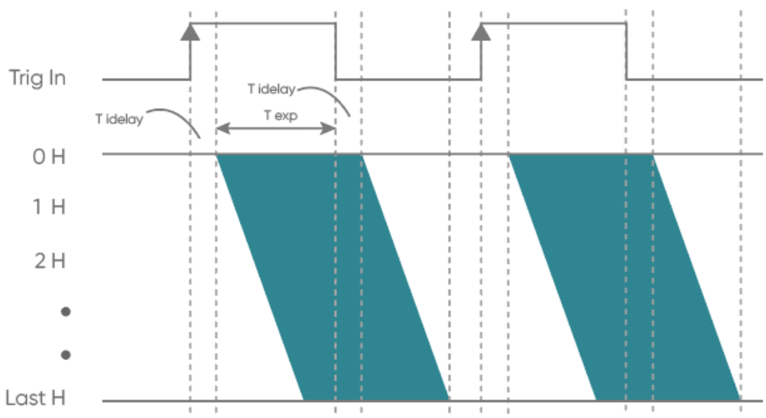


Figure 3-21 Level Triggering Mode

In contrast, in edge triggering mode, exposure duration is directly set in the software interface. When using this mode, it's crucial to ensure that the duration of each pulse cycle of the trigger signal (pulse width + pulse interval) is greater than or equal to the total time required for each frame image output (i.e., the reciprocal of the frame rate, including delay time, exposure time, and readout time). This ensures that each frame image is complete and error-free.

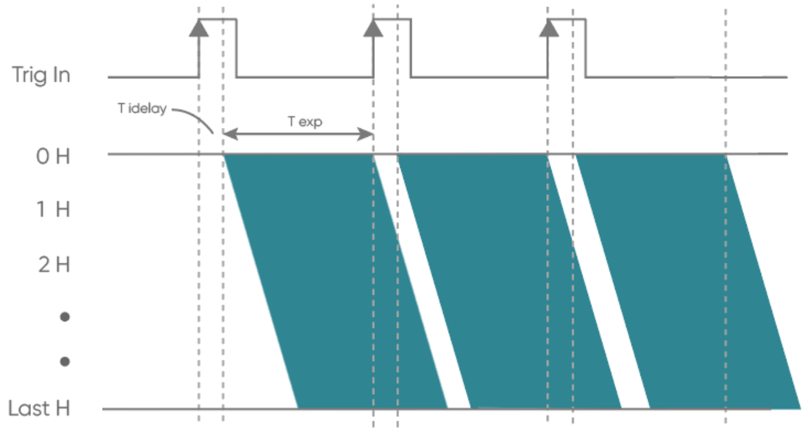


Figure 3-22 Edge Trigger timing diagram

3.14.3.4. Synchronization Trigger Mode

In this mode, when the camera receives a certain level signal, it starts exposure capture. When it receives the next level signal, it ends exposure, starts readout, and begins a new exposure cycle. This mode ensures complete synchronization of exposure start and readout with the external trigger signal.

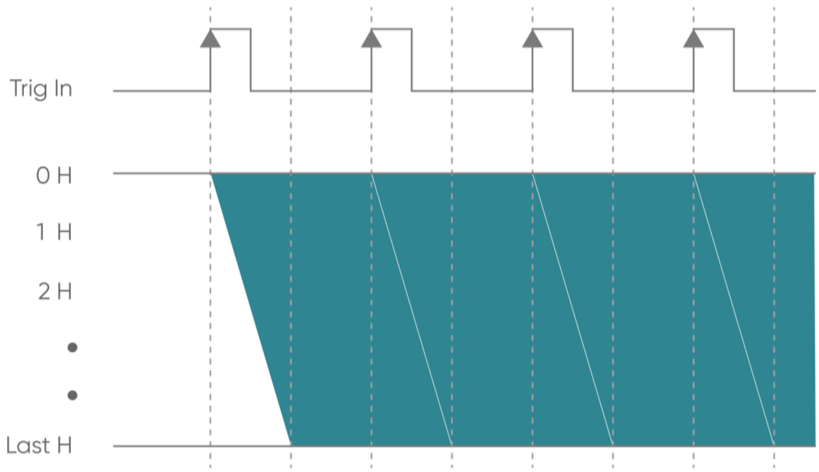


Figure 3-23 Synchronization Trigger mode timing diagram

The length of exposure time in this mode is determined by the time interval between the arrival of two trigger signal edges. After entering this mode, the camera starts the first frame exposure when the first trigger signal edge is detected, and does not terminate the first frame exposure and output the image until the trigger signal edge is detected for the second time, and at the same time starts the second frame exposure, and so on; that is, there is no image data for the first trigger signal after entering this mode, and there is an image output for each of the subsequent trigger signals, and the exposure time for each frame is the time interval between the arrival of the two trigger signal edges. The exposure time corresponding to each frame is the time interval between the arrival of the two trigger signal edges. The same mechanism is followed when the trigger signal is single pulse or multi-pulse.

This mode is very useful for confocal microscopy as it enables simultaneous control of the camera's exposure time and spinning disk confocal speed to eliminate the effects of inhomogeneous light.

3.15. Trigger Output

3.15.1. Hardware Trigger output circuit

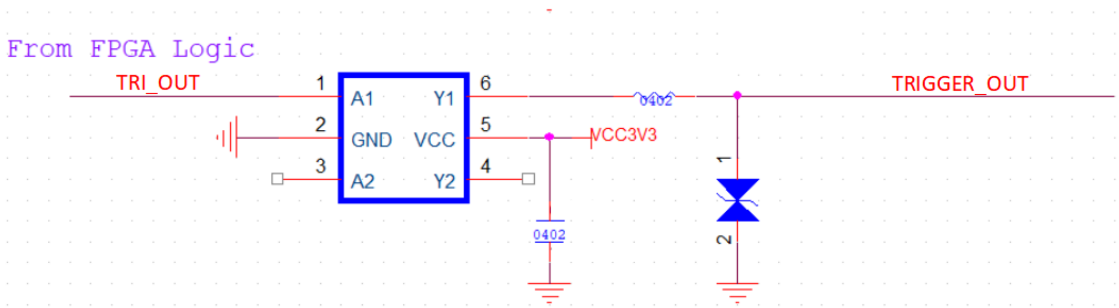


Figure 3-24

3.15.2. Trigger Output Timing Diagram

The camera has three external trigger output interfaces, each independently capable of outputting five timing signals. Each output signal can be independently configured on the three output ports and can simultaneously output to different devices.

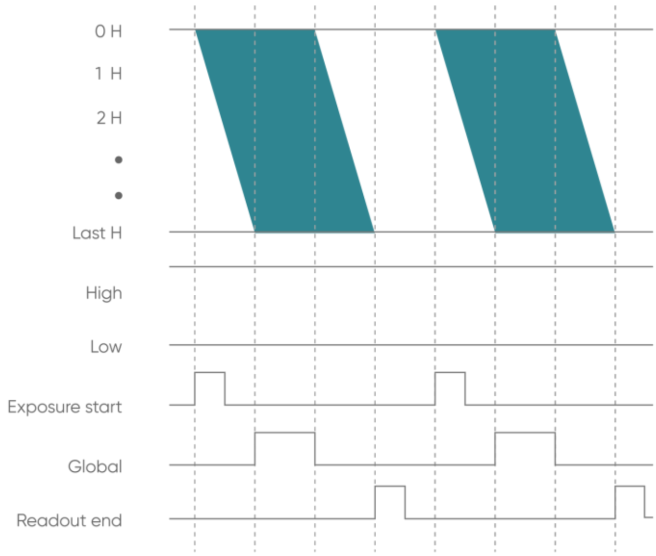


Figure 3-25 Trigger output timing diagram

- **High**: always output high level.
- **Low**: always output low level.
- **Exposure Start**: When the exposure of the first row begins, an output level signal is generated, with a default pulse width of 5 ms that can be customized.
- **Readout End**: An output level signal is generated with a default pulse width of 5 ms, which can be customized, when the last row finishes reading out.
- **Global**: From the start of exposure of the last row to the end of exposure of the first row(valid when the exposure time is larger than the readout time).

3.16. Cooling

Camera cooling effectively reduces "dark current noise" and the impact of hot pixels. The camera adopts semiconductor cooling using the Peltier effect, where an N-type and P-type material form a thermocouple. When a DC current is passed through the thermocouple, heating and cooling phenomena occur at the junctions due to the direction of the DC current. The cooling module is placed close to the chip to lower the chip's temperature and reduce dark current, while the hot end is connected to a metal heat sink to dissipate heat efficiently.

Both air cooling and water cooling are commonly used cooling methods. In air cooling, a fan exchanges excess heat with the surrounding air via airflow, while in water cooling, a liquid circulation system transfers excess heat. The Dhyana XF95 camera supports both air cooling and water cooling modes, allowing users to choose the appropriate cooling method based on the actual usage environment. In air cooling mode, the inlet and outlet vents are indicated as shown in the figure.

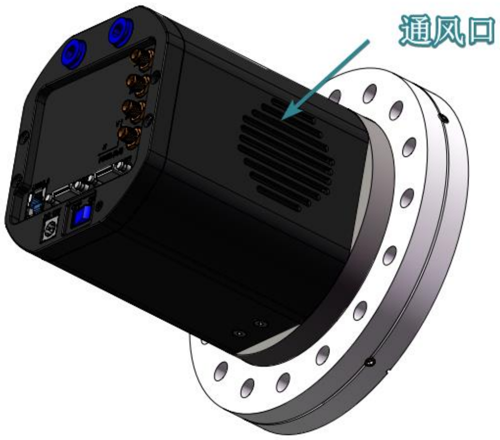


Figure 3-26 Schematic diagram of Dhyana XF95 vent

Under air cooling, the camera can achieve a cooling effect with a temperature difference of 60°C from the ambient temperature, while under water cooling, it can achieve a cooling effect with a temperature difference of 70°C from the ambient temperature. The camera fan features variable speed control, generally offering three speed settings: High, Medium, and Low. A higher fan speed improves cooling performance, while a lower speed results in reduced vibration. To achieve completely low vibration performance, the fan of the Dhyana XF95 camera can be fully turned off via software and provides a liquid cooling port (for water cooling installation, please refer to section 4.2).

4. Hardware Installation

4.1. Camera Installation

Please check the packaging list in section 2.1 to ensure no camera accessories are missing. If any accessories are missing, please contact the distributor. If all accessories are present, install the camera in the following order.

4.1.1. Reference for correct camera orientation

As shown in the image below, the data interface of the XF95 camera is labeled with the column (V-axis) and row (H-axis) directions for reference.

(1) When using a regular lens, mount the camera with the V-axis facing upward, which means rotating it 90° clockwise from the orientation shown below. In this position, the software will display the image in an upright and level orientation, similar to human vision by default.

(2) When using the camera without a lens and positioning the sensor directly towards the object, mount the camera with the V-axis facing downward, which means rotating it 90° counterclockwise from the orientation shown below. In this case, the software will also display the image in an upright and level orientation, similar to human vision by default.

Figure 4-1 Schematic Diagram of the XF95 Camera Data Interface

4.1.2. Host Installation

1. Removing the Window Plate

The camera chip is equipped with a dust cover and a dust protection component to protect the sensor and prevent dust contamination. Before connecting to the vacuum system, follow these steps to remove them:

(1) Removing the Dust Cover

As shown in Figure 4-1, loosen the four M8 screws to remove the dust cover and take out the sealing ring. At this point, there will still be a dust protection component on the camera sensor.

Figure 4-2 State with Sealing Dust Cover (Left) and State with Dust Cover Removed (Right)

(Includes dust cover, camera with dust cover removed, M8 screws, and sealing gasket)

(2) Removing the Dust Protection Component

Loosen the four M3 screws on the surface of the dust protection component and remove the dust protection component to connect the vacuum tubing. After removing the dust protection component, the sensor's target surface will be exposed to the environment, which carries a risk of contamination or damage*. Please ensure proper protection and dust prevention for the sensor.

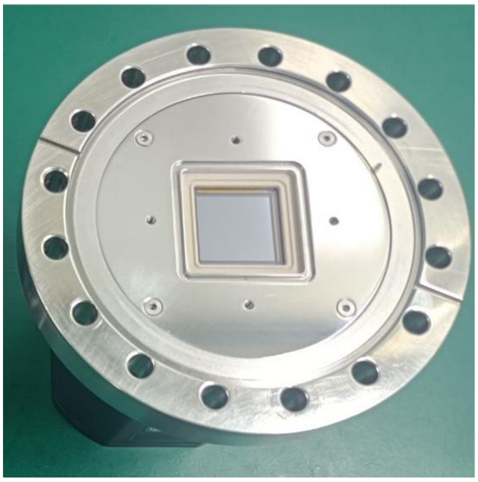


Figure 4-3 Figure of XF95 Camera with Dust Protection Component Removed

2. Camera Mounting

The camera is secured to the vacuum chamber via a flange. For the flange locking procedure, please refer to section 4.1.3.

Note:

1) Please ensure the process is conducted in a cleanroom environment and gloves are worn *throughout the operation.*

2) If testing is conducted outside of a vacuum environment, do not remove the camera's window protection components. Removing these parts will expose the stainless steel surface and the sensor, which could be damaged by oil or dust contamination. This could affect the camera's vacuum integrity and imaging performance, so please handle with care.

3) If space conditions allow, it is recommended to first connect and test the system externally before fixing the camera into the system for use.

4.1.3. Connecting the Camera

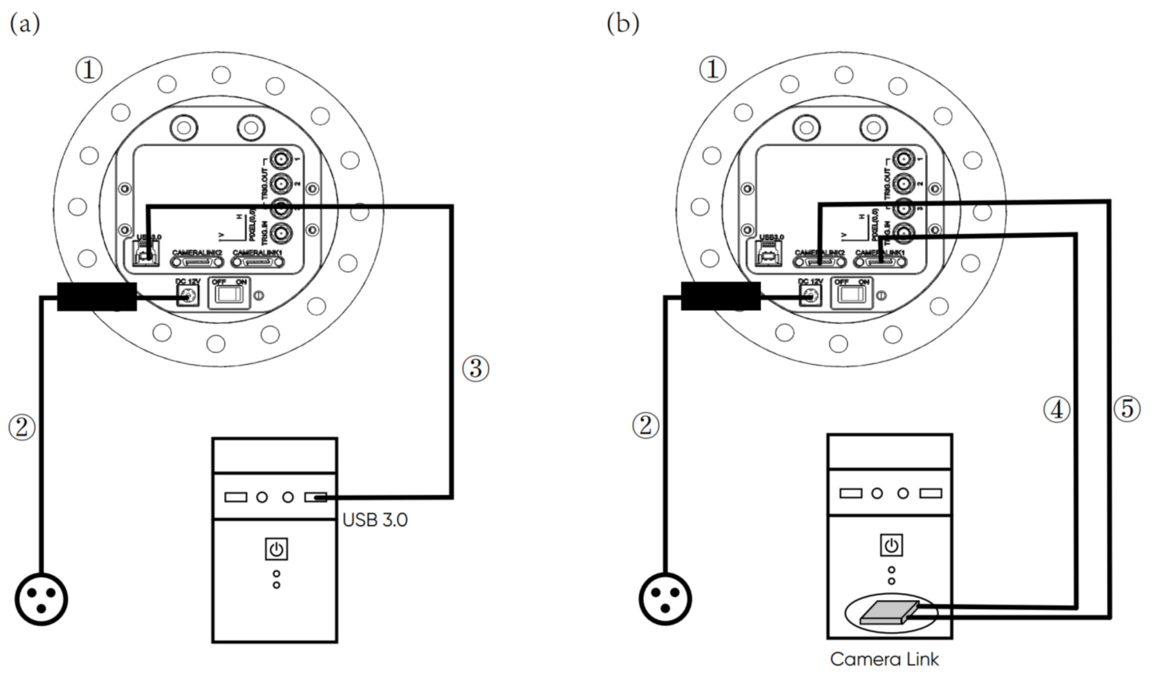


Figure 4-4 Dhyana XF95 Camera Connection Diagram

① Dhyana XF95 camera

② Power adapter

③ USB 3.0 data cable

④ CameraLink cable 1

⑤ CameraLink cable 2

Connect one end of the USB 3.0 data cable or CameraLink data cable to the PC, and connect the USB to the USB 3.0 interface on the back of the host. Connect the other end to the sCMOS camera, lock the screw, then plug in the power cord, turn on the power switch, and you will see the indicator light lit up in red.

Note:

1) To prevent overheating of the camera, do not cover the camera with cloth or any other *materials, or block the camera's ventilation openings in any way.*

2) *When operating the camera in an enclosed environment, ensure there is at least a 20 cm gap between the camera’s air intake and exhaust.*
3) *When connecting cables, turn off the power to the camera and peripheral equipment.*
4) *If the camera will not be used for an extended period, unplug the power cord from the outlet to prevent damage to the power cord and avoid risk of electric shock or fire.*
5) *Always turn off the camera before connecting or disconnecting cables.*

4.1.4. Tightening the CF100 flange

Steps:

(1) Prepare the following materials and tools.

Materials:

①304 stainless steel M8*40 hex socket bolts (length based on actual requirements), M8 nuts, M8 flat washers, 16 each (external hex bolts can also be used);

②CF100 copper gasket, 1 piece.

Tools:

①Cleanroom gloves; ②Alcohol; ③Super clean cloth; ④8 mm hex wrench.

(2) Put on cleanroom gloves and use a super clean cloth dipped in alcohol to wipe the copper gasket and the camera flange. After wiping, carefully place the copper gasket on the knife edge of the blank flange.

(3) Use a super clean cloth dipped in alcohol to wipe the knife edge of the chamber flange. Align the blind flange (with the copper gasket) with the chamber flange, ensuring the leak detection ports are aligned.

(4) Insert the hex socket bolts with washers into the through holes and tighten the bolts into the nut plates (or M6 nuts) in a cross pattern. Refer to the figure below for the tightening sequence.

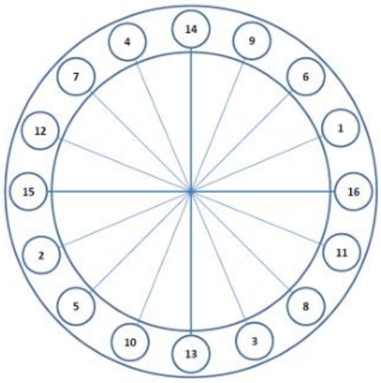


Figure 4-5 Bolt tightening sequence

Note:

During steps 2 and 3, check for any damage or scratches on the sealing knife edge and the copper gasket. If any issues are found, stop the installation. Defects in the copper gasket or flange can result in inadequate vacuum and potential damage to the flange.

4.2. Installation of external water cooling pipes

4.2.1. Connecting the water cooling pipes

(1) Place the camera on a stable workbench.

(2) Connect the water cooling pipes to the water pipe connectors on the camera, ensuring a proper fit as shown in the figure below.

Figure 4-6 Camera end water pipe connector

(3) Insert the water pipes into the nozzles of the cooling water circulator*, ensuring a proper fit as shown in the figure below.

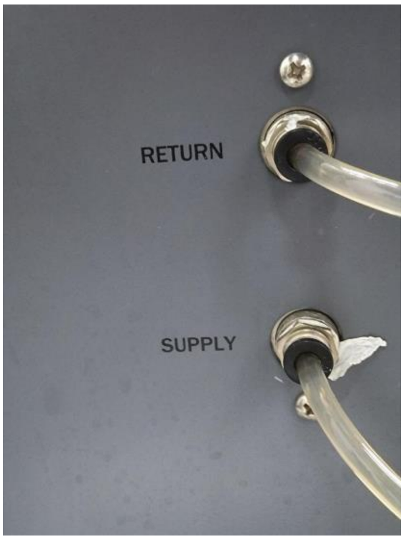


Figure 4-7 Cooling water circulator end water pipe connector

***Water Cooling Circulator Usage Notes：**

1) It is recommended to use deionized water.

2) The minimum water flow should be ⩾ 1 L/min, and the maximum water pressure should be ⩽ 2 bar.

3) The water temperature should be set above the dew point to prevent condensation water pipes and other water-cooling equipment. (see Appendix 3 for the dew point table).

4.2.2. Software Fan Status

(1) After installing the water cooling pipe, it is necessary to switch the cooling mode on the software. The default cooling method for the camera is air cooling, which can be switched to water cooling by adjusting the fan gear;

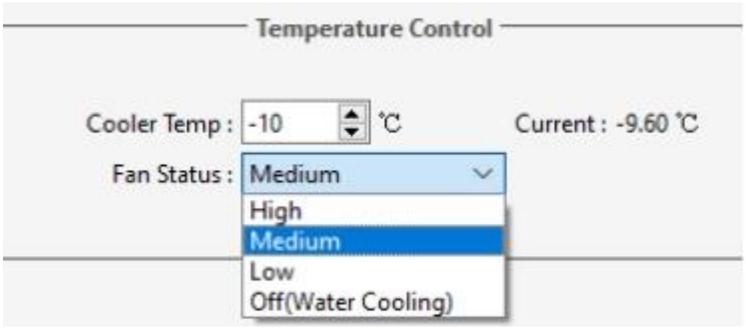


Figure 4-8

(2) If you choose to turn off the fan, the software will prompt you as follows. Click "Yes" to turn off the fan. Please ensure that the water cooling system is functioning properly before proceeding with this operation.

Figure 4-9

4.2.3. Disconnecting the water cooling pipes

(1) Disconnect the power supply to the camera and all other equipment, including the cooling water circulator.

(2) According to the instructions of the cooling water circulator, drain the water from the circulator.

(3) Press the sliding sleeve of the transfer valve and pull out the cooling water circulator hose to drain the internal water.

(4) Press the water connector and pull the camera water pipe out of the water pipe connector.

First, orient the installed water valve to the side (not upwards). When pulling out the water pipe, make sure the valve port faces downwards. Use an absorbent towel or paper towel to protect the area and ensure no water leaks into the camera.

Warning:

1) ***Do not activate TEC cooling when the camera is operating in a non-vacuum environment. Doing so may cause condensation on the chip and damage the camera due to prolonged high temperatures.***
2) ***In a non-vacuum environment, both water cooling and the fan can be turned on simultaneously, but they should not be turned off at the same time. At least one cooling method must be functioning properly to prevent damage from sustained high temperatures.***
3) ***In a vacuum environment, activate TEC cooling only after the vacuum level has reached at least 1E-3 Pa.***
4) ***After using the camera in a vacuum, first turn off the TEC cooling. Wait until the software indicates that the temperature has risen above room temperature before venting the vacuum and removing the camera.***

4.3. Frame grabber installation

Turn off the computer and open the cover of the computer host, as shown in Figure 4-9. Choose a PCIe slot with a transmission bandwidth greater than 850MB/s, insert the Frame grabber, secure it with screws, and then restart the computer. Connect the interface between the camera and the computer Frame grabber through a data transmission cable.

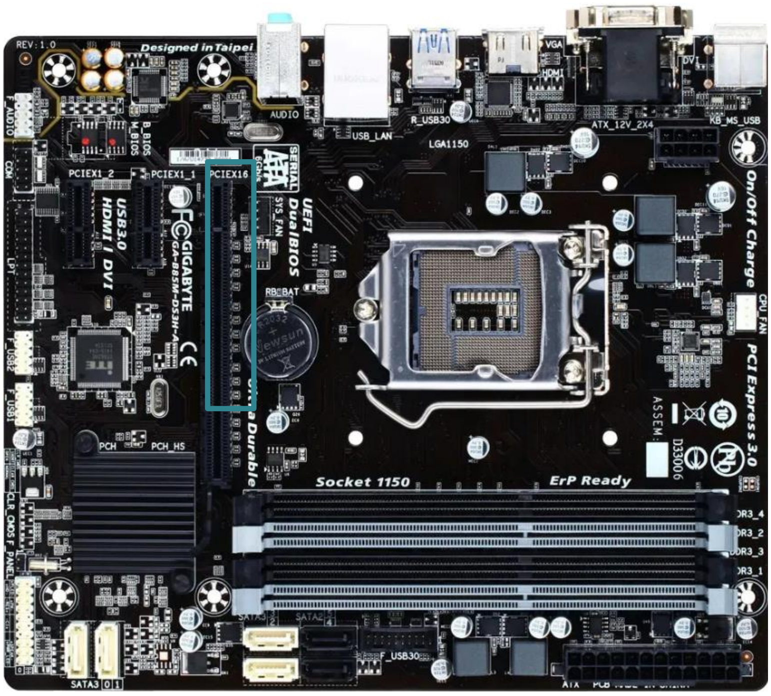


Figure 4-10 Computer motherboard diagram

Table 4-1 Maximum transfer rate corresponding to different PCIe slots

PCIe	X1	X4	X8	X16
1.0	250MB/s	1GB/s	2GB/s	4GB/s
2.0	500MB/s	2GB/s	4GB/s	8GB/s
3.0	985MB/s	3.9GB/s	7.8GB/s	15.7GB/s

Note:

1) *When installing and disassembling the* Frame grabber*, be sure to operate with power off;*
2) *When connecting the CamraLink cable, please operate with the camera power off and do not hot plug or unplug.*

5. Software Installation

5.1. Recommended computer configurations

Camera Interface	USB 3.0
CPU	I5 and above performance, with a main frequency of 2.6GHz and above
Operating system	Windows 10/11 64 bit PC
Memory	8GB and above

5.2. Driver installation and uninstallation

This section will introduce the installation of camera USB driver, Frame grabber driver installation and uninstallation.

Operation steps:

(1) Connect the camera to the computer and open the matching USB drive;

(2) Double click to run the driver installation package;

(3) Follow the prompts to click [Next] for default installation;

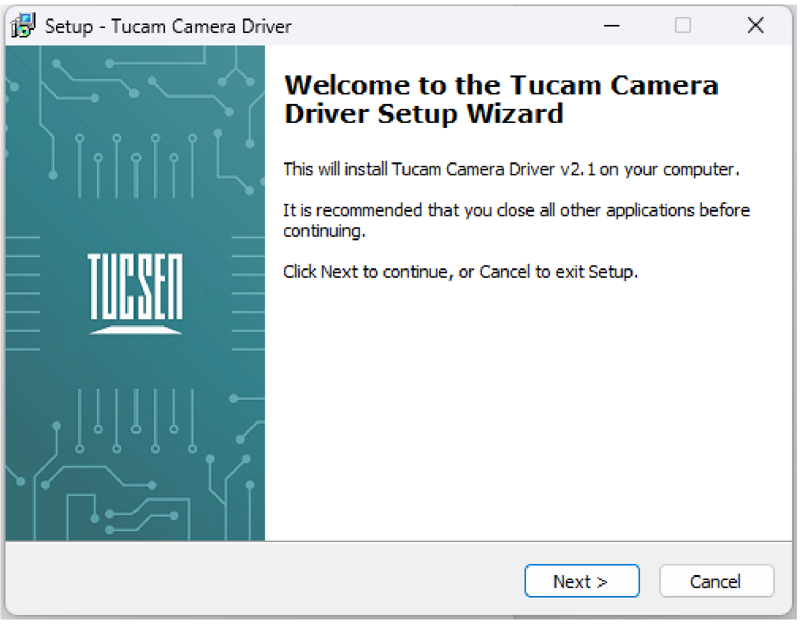


Figure 5-1 The driver installation start page

(4) Selecting the contents of the installation, by default check the box to install Microsoft runtime libraries vcredist_2008 and vcredist_2013, unchecking the box may result in the software or third-party plug-ins not working;

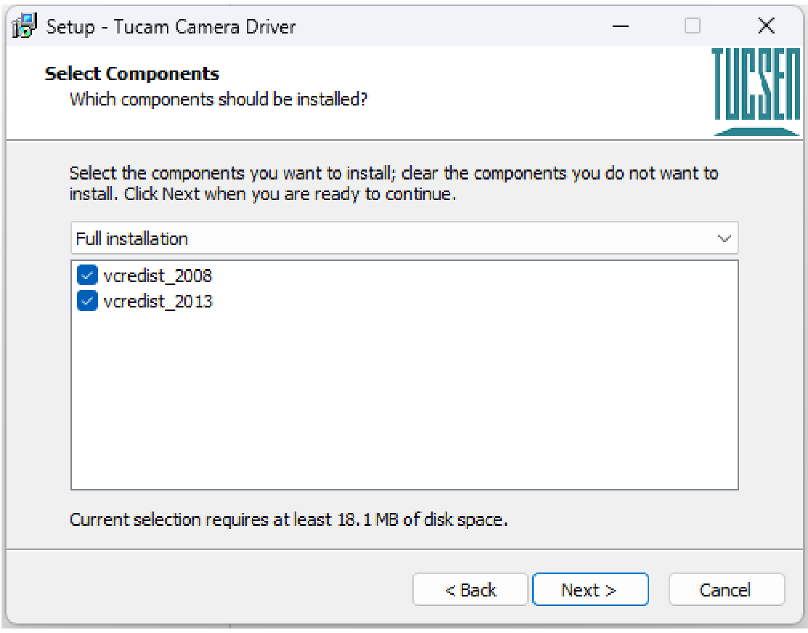


Figure 5-2 Optional installation content

(5) Waiting for the driver installation to be completed;

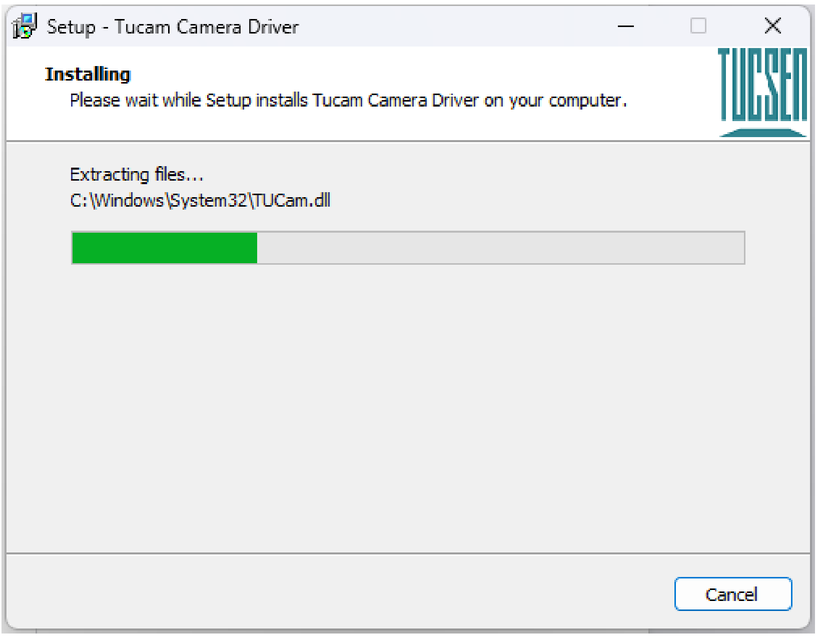


Figure 5-3 Under driver installation…

(6) Click "Finish" to complete the driver installation;

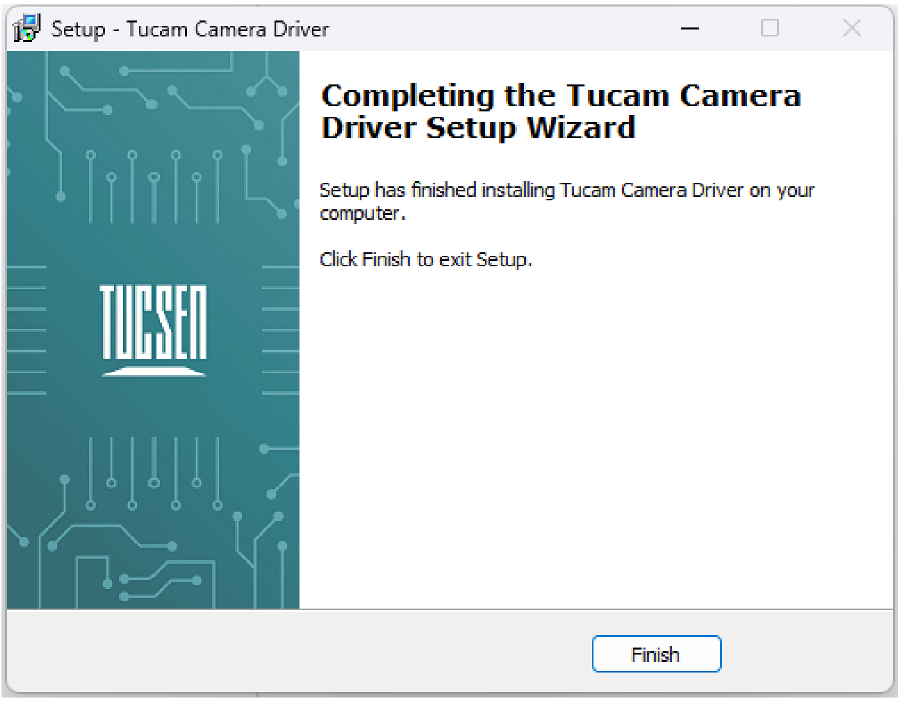


Figure 5-4 Finish the installation

After installing the camera USB 3.0 driver, open the device manager on the computer. When the driver is successfully installed, the camera will appear under the image device without any yellow markings, as shown in the picture. If a yellow symbol appears, it indicates that the driver needs to be reinstalled.

Figure 5-5 XF95 display in device manager

5.2.1. CameraLink driver installation

Installation steps:

(1) The camera is connected to the installed CameraLink Frame grabber CameraLink1 and

CameraLink2 interfaces on the computer host through two CameraLink cables, and the interface sequence needs to be one-to-one corresponding;

(2) Open the matching USB flash drive. Find the installation package for the acquisition card driver;

(3) Double click to run the CameraLink acquisition card driver, follow the prompts to click [Next] for default installation, and finally click [Finish]. After restarting the computer host, the driver installation is completed.

(4) After the driver installation is completed, please restart the computer;

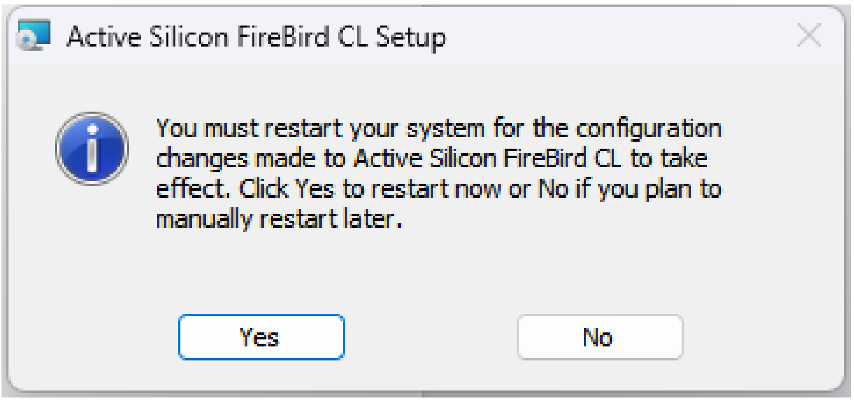


Figure 5-6

After installing the CameraLink driver, open the device manager on your computer. When the driver installation is successful, the CameraLink Frame grabber will appear in the device manager and display FireBird Baseboard. After connecting the camera, it will occupy the COM port, as shown in the following figure.

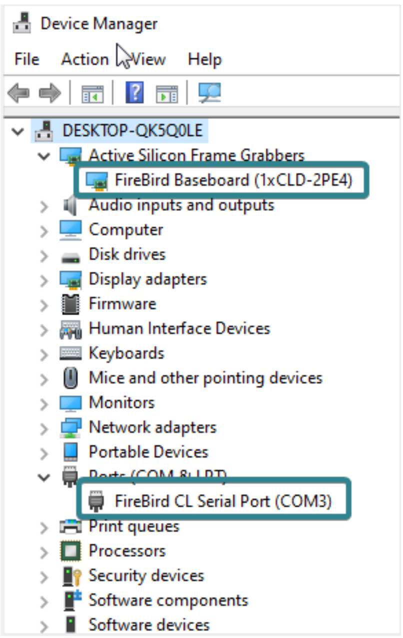


Figure 5-7

5.2.2. CameraLink driver uninstallation

Taking the Windows 11 system as an example, in the computer settings, click on Applications>Installed Applications, find Active Silicon FireBird CL, click on the three points on the right to uninstall, and follow the prompts to complete the uninstallation.

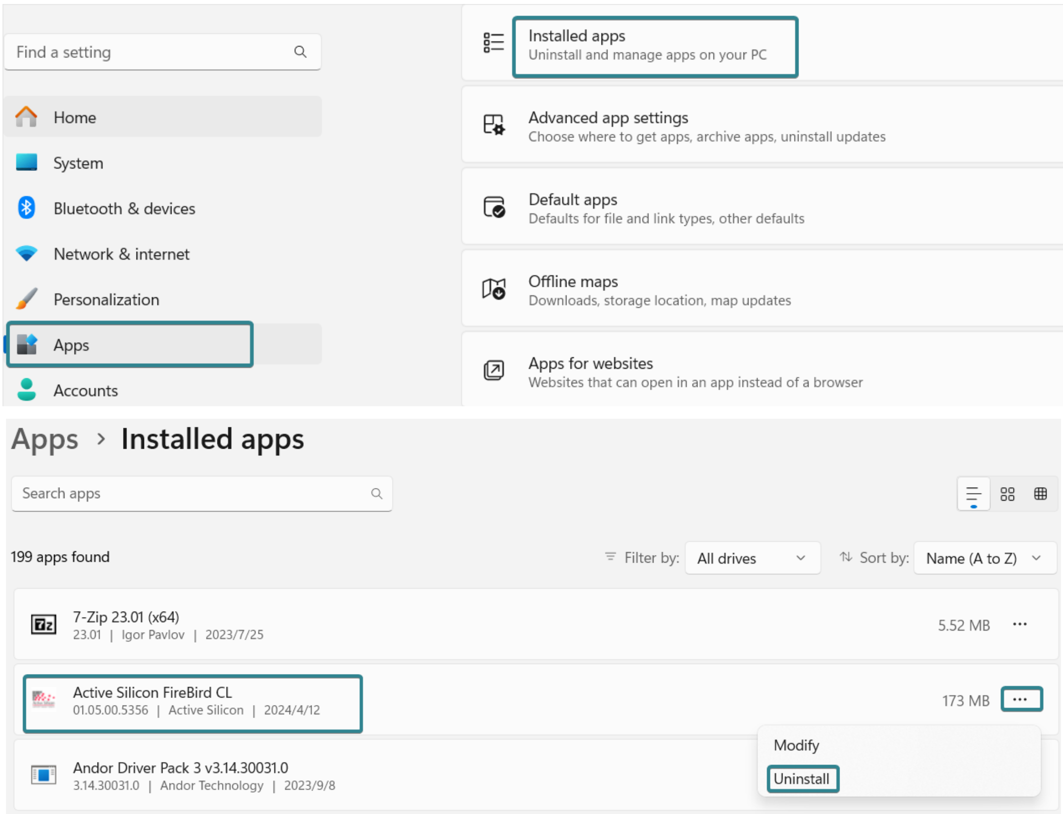


Figure 5-8

5.3. Software installation and uninstallation

5.3.1. Installation

Operation steps:

(1) Open the supporting USB drive, double-click to run Mosaic V3 software;

(2) Select the installation path, default to C drive, users can customize the installation path according to your needs;

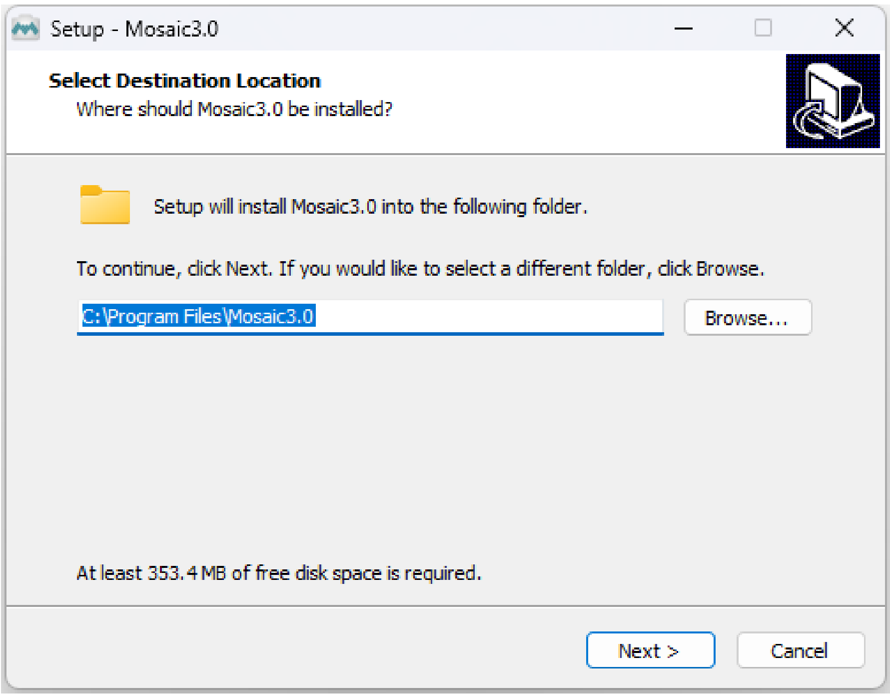


Figure 5-9 Installation of Mosaic V3

(3) Select the installation content. By default, select the option to install drivers, canceling the installation can result in the camera not being recognized by the software;

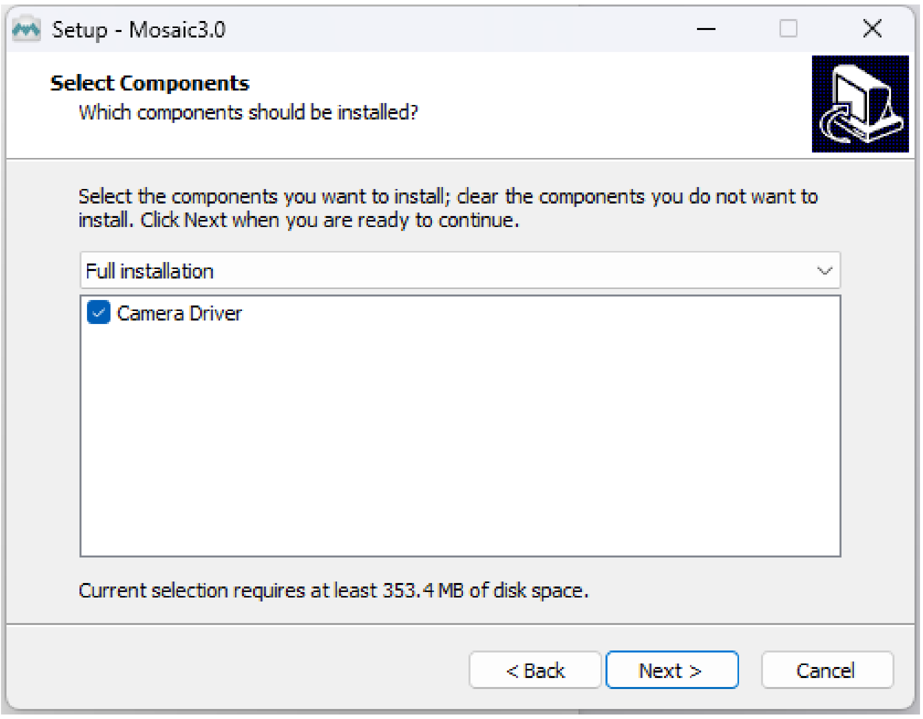


Figure 5-10 Check the camera driver

(4) Configure installation parameters and select whether to generate desktop shortcuts;

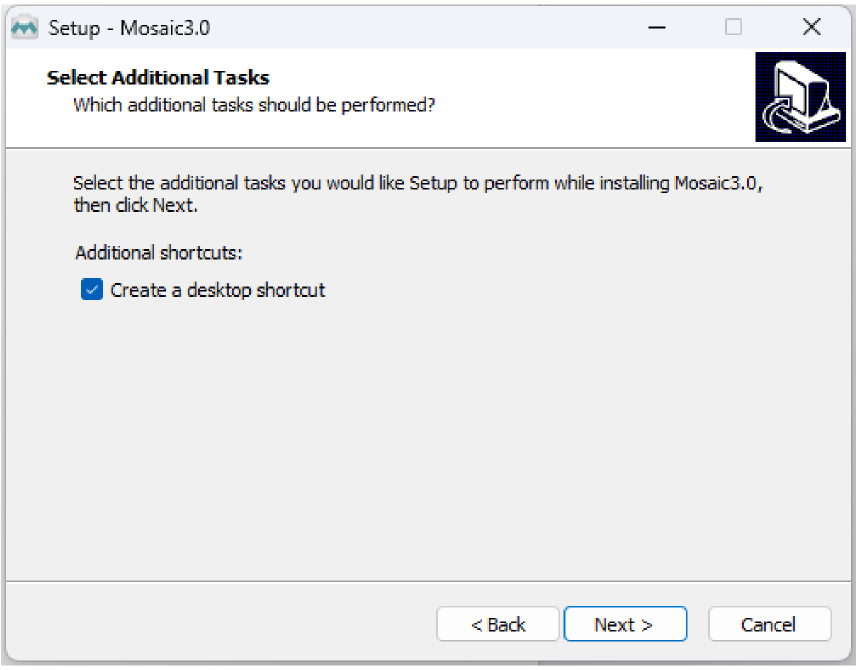


Figure 5-11 Check to create a desktop shortcut

(5) After confirming all installation parameters, click "Install" to start executing the installation action;

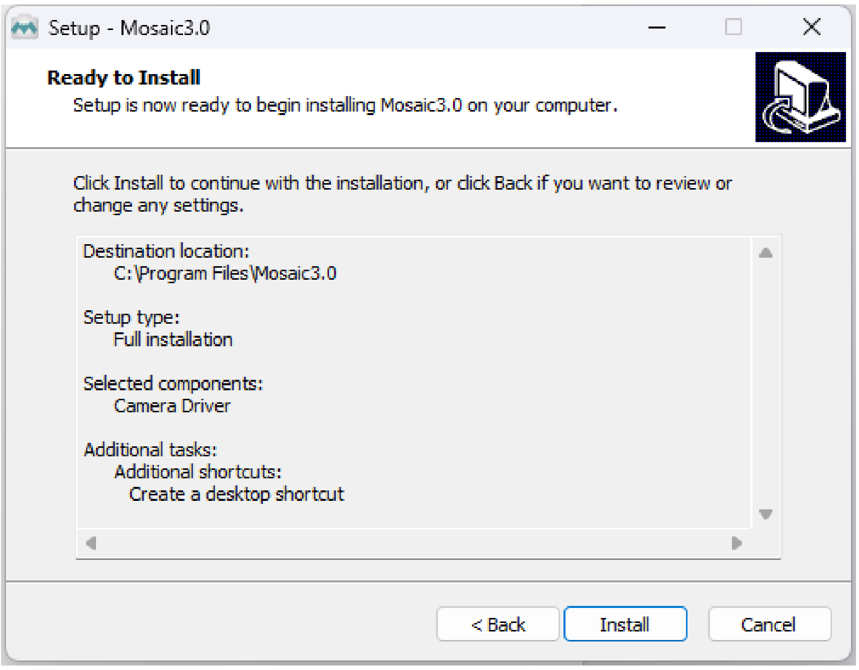


Figure 5-12 The page for settings check

(6) Waiting for installation to complete;

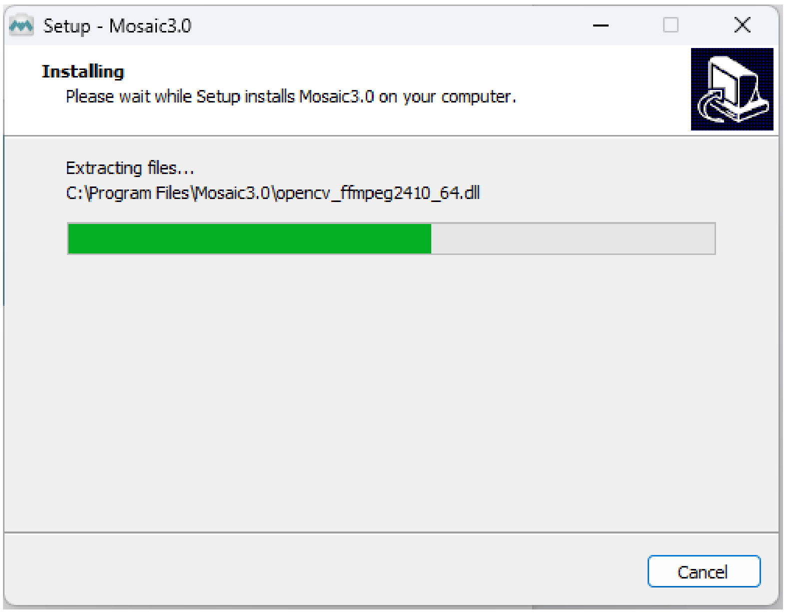


Figure 5-13 Software installing...

5.3.2. Uninstallation

There are three ways to uninstall Mosaic software:

(1) By uninstalling through the installation package, the existing version on the computer will be uninstalled when the installation package runs, and the default C drive path will take effect;

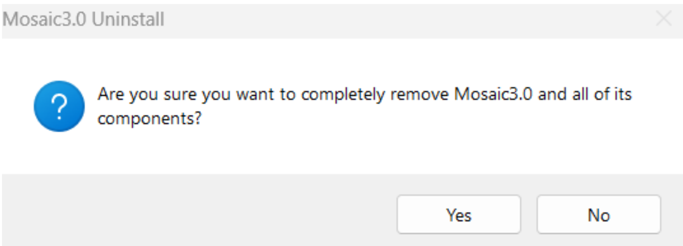


Figure 5-14 Uninstalling through installation package

(2) Under the installation path, find unins000.exe to uninstall, double-click uninstall;

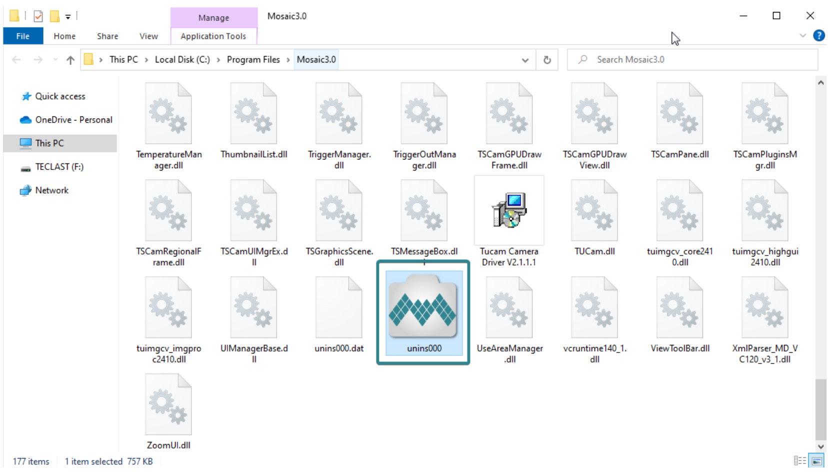


Figure 5-15 Uninstalling through installation path

(3) Uninstall from the computer program management interface;

Note:

After uninstalling and reinstalling the software, all software configuration information and calibration table data will be deleted.

6. Maintenance

Damage caused by unauthorized maintenance or procedures will void the warranty.

6.1. Regular inspection

Regularly check the condition of the product, especially the integrity of external power and main cables. Do not use damaged equipment.

6.2. Electrical safety inspection

- It is recommended to check the insulation and protective grounding integrity of the AC/DC converter every year
- Do not use damaged equipment

6.3. Cooling hoses and connectors

Users should regularly check all coolant hoses and connections for signs of leakage, damage, or wear. All seals must be intact before the camera system can be turned on, and any worn or damaged components must be replaced immediately.

6.4. Basic usage

(1) Avoid opening the lens dust cover in dusty environments;

(2) When removing the camera's protective cover and dust-proof components, please operate in a clean environment to prevent dust from entering the sensor.

(3) When not in use for an extended period, the dust-proof components should be reinstalled, and the dust cover should be put on for storage..

7. Troubleshooting

7.1. Computer unable to recognize the camera

(1) Ensure the camera is properly powered on.

(2) Confirm the camera is correctly connected to the computer:

① CameraLink: Verify the connection sequence of the two cables.

② USB Connection: Use the USB 3.0 port on the back of the desktop computer.

(3) Check that the driver is functioning properly.

7.2. Software pauses or freezes

(1) The computer may have turned on the energy-saving mode, the system CPU performance is reduced, resulting in the software can not work properly, there are dropped frames or software jamming and so on. You can check to ensure that the computer is in high-performance mode.

(2) The computer has opened too many applications, resulting in the computer CPU occupation is too high, the software CPU utilisation is low and can not work properly. Can close the redundant applications.

(3) Data cable connections may be loose or extended too far, leading to unstable software operation. Check and secure all data and fiber optic cables.

7.3. Camera fails to reach target cooling temperature

(1) Check if the water temperature is too high. The maximum cooling temperature difference of the camera is 70°C below the ambient temperature (water cooling).

(2) Ensure that the water cooling circulation channels are not blocked.

(3) Verify that the water cooling system is functioning properly.

(4) Check that the air exhaust is not obstructed.

(5) Confirm that the fan is operating normally.

7.4. Frame rate not reaching specified value

(1) Ensure that you are using the correct data transfer interface. USB requires a USB 3.0 connection, while CameraLink requires attention to the PCIe slot bandwidth.

(2) Verify if the exposure time affects the frame rate. You can set the minimum exposure time to check the frame rate.

(3) The frame rates in the table are measured under ideal bandwidth conditions. The actual

frame rate in use will be influenced by data transfer and is related to the type of data interface and cable length.

(4) Confirm that the correct data transfer interface is being used. USB requires a USB 3.0 interface; using a non-3.0 interface may result in a frame rate lower than the nominal rate.

(5) If you are using a USB 3.0 interface but have added a HUB/extension/adapter, it may also prevent achieving the nominal frame rate.

8. FAQs

8.1. Why is the brightness of the captured image inconsistent with the preview window?

When using the camera for the first time and the target is dark, the software preview may show an all-black image. It is recommended to check Auto Left Scale (Auto Min) and Auto Right Scale(Auto Max) in the Histogram setting area, in which case the software preview will show the most suitable brightness and contrast. However, when you save the image, the default image saved by the software will not save the effect of auto colour gradation, resulting in inconsistency between the preview image and the captured image.

You can try the following solutions:

(1) Disable the automatic colour gradation function of the software, the preview image will be consistent with the saved image;

(2) Use professional image viewing tools such as ImageJ to open the tif image and adjust the colour gradation.

(3) Use Mosaic V3 software to tick "Save the Adjusted Image" in the Capture section (can be used when you don't need the original image data value).

8.2. Stripe like flicker appears in the camera preview image

May be caused by an unsynchronised external light source. There may be a strobe light source in the environment, which can be judged by extending the exposure time. If it is an ambient light source, switching off the illumination source is sufficient. If from an irradiated sample light source, a regulated light source is required for illumination.

9. After-sales Support

(1) Log in to the official website, click on the [Technical Support] module, and get answers to common questions.

(2) Contact professionals for technical support:

- TEL: +86-591-28055080-818
- Email: service@tucsen.com
- Visiting the official website to leave a message: http://www.tucsen.com

(3) Please prepare the following information in advance:

- Camera model and S/N (product serial number);
- Software version number and computer system information;
- Description of the problem and any related images.

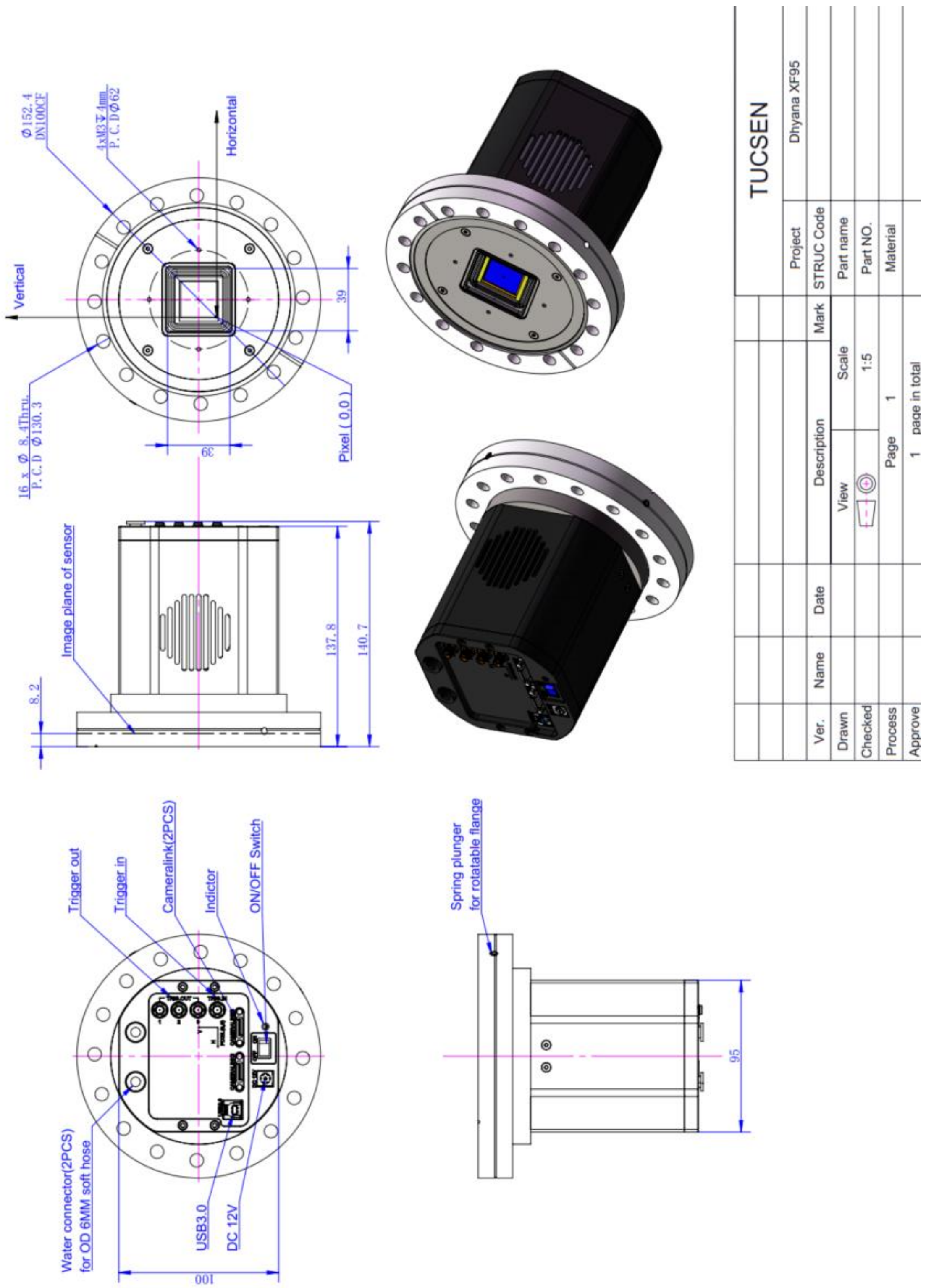
Appendix 1 : Specifications

Model	Dhyana XF95
Sensor Type	Back-Illuminated sCMOS
Sensor Model	GSENSE 400BSI-PS / GSENSE 400BSI
Peak QE	~100% @80-1000 eV / 95% @ 560 nm
Color / Mono	Mono
Array Diagonal	31.9 mm
Effective Area	22.5 mm x 22.5 mm
Resolution	2048(H) x 2048(V)
Pixel Size	11 µm x 11 µm
Full-Well Capacity	85 ke- (Typ.)
Dynamic Range	90 dB
Frame Rate	HDR: 24 fps; STD: 48 fps
Readout Noise	High Gain: 1.6 e- (Median)
Shutter Type	Rolling shutter
Exposure Time	21 µs ~300 s
DSNU	0.2 e-
PRNU	0.3%
Bit Depth	12 bit， 16 bit
Cooling Method	Air cooling, Water cooling
Max. Cooling	-35°C@25°C ambient temperature -50°C@20°C water temperature
Dark Current	0.5 e-/pixel/s @-40°C chip temperature
Vacuum compatibility	1E-7Pa(Max)
Binning	2 x 2, 4 x 4
ROI	Support
Timestamp Accuracy	1 µs
Trigger Mode	Hardware & Software
Output Trigger Signals	Exposure start, Global, Readout end, High level, Low level
Trigger Interface	SMA
Data Interface	CameraLink， USB 3.0
Power Supply	12V/8A
Power Consumption	< 65W

Flange size	Standard DN100CF/Customized
Dimensions	152.4mm x 152.4 mm x 140.7 mm
Weight	~3700 g
Software	Mosaic/Samplepro/LabVIEW/Micro-manager/Matlab
SDK	C, C++, C#, python
Operating System	Windows/Linux
Operating Environment	Operating Temperature: 0~40°C Humidity: < 70%, Non-condensing Baking Temperature: ＜ 70°C

Note: The parameters in this table are typical values and are subject to change without notice.

Appendix 2 : Dimensions



Appendix 3 : Dew point table

		Humidity							
		20%	30%	40%	50%	60%	70%	80%	90%
Temperature	5							1.8	3.5
	6							2.8	4.5
	7						1.9	3.8	5.5
	8						2.9	4.8	6.5
	9					1.6	3.8	5.7	7.4
	10					2.6	4.8	6.7	8.4
	11					3.5	5.7	7.7	9.4
	12				1.9	4.5	6.7	8.7	10.4
	13				2.8	5.4	7.7	9.6	11.4
	14				3.7	6.4	8.6	10.6	12.4
	15			1.5	4.7	7.3	9.6	11.6	13.4
	16			2.4	5.6	8.2	10.5	12.6	14.4
	17			3.3	6.5	9.2	11.5	13.5	15.3
	18			4.2	7.4	10.1	12.4	14.5	16.3
	19		1.0	5.1	8.4	11.1	13.4	16.4	18.3
	20		1.9	6.0	9.3	12.0	14.4	16.4	18.3
	21		2.8	6.9	10.2	12.9	15.3	17.4	19.3
	22		3.6	7.8	11.0	13.9	16.3	18.4	20.3
	23		4.5	8.7	12.0	14.8	17.2	19.4	21.3
	24		5.4	9.6	12.9	15.8	18.2	20.3	22.3
	25	0.5	6.2	10.5	13.9	16.7	19.1	21.3	23.2
	26	1.3	7.1	11.4	14.8	17.6	20.1	22.3	24.2
	27	2.1	8.0	12.3	15.7	18.6	21.1	23.3	25.2
	28	3.0	8.8	13.2	16.6	19.5	22.0	24.2	26.2
	29	3.8	9.7	14.0	17.5	20.4	23.0	25.2	27.2

Appendix 4 : Third party software applications

Provide plugins for calling third-party software (LabVIEW, Matlab, Micro-Manager, etc.), please click on the link to download the configuration: sCMOS and CMOS Camera Third Party Softwares -TUCSEN - Tucsen

Appendix 5 : Update log

Version	Date	Modified Content
V1.0.0	2024-10-18	Create this document.