Andor CB2

User Manual

Andor CB2 User Manual_20250206

TABLE

1. INTRODUCTION

Thank you for choosing Andor CB2!

The cameras' features and performances are described in detail within this User Manual.
This User Manual contains all information and advice needed to get the optimum performance from your camera.

You can also find the latest version of this User Manual on our website: https://andor.oxinst.com/learning/

Please contact our support for any question at: fli-support@oxinst.com

1.1. Overview

Andor CB2 is a family of high-performance scientific cameras based on Sony's CMOS sensors.

Andor CB2 simultaneously integrates a global shutter architecture and low noise acquisitions. This is critical for fast acquisition scientific applications. The global shutter mode is a key feature of the camera, enabling artefact-free acquisitions in dynamic imaging.

Andor CB2 cameras open new horizons for low noise high speed visible imaging.

The Andor CB2 24B camera is equipped with a Sony IMX530-AAMJ-C sensor.

The camera supports the sensor's native 8-, 10- and 12-bits quantization. It also supports dual ADC mode, providing a 16 bits High Dynamic Range (HDR) feature.

The Andor CB2 24B also supports 2x2 binning in 8-,10- and 12-bits modes.

Note: Binning is not supported in 16 bits HDR mode.

Table 1: Andor CB2 sensors' characteristics

Sensor	Binning	Resolution (pixels)	Pixel size (µm)	Max. framerate 8 bits	Max. framerate 10bits	Max. framerate 12 bits	Max. framerate 16 bits
IMX530	OFF	5328 x 4608	2.74 x 2.74	106	102	74	37
	ON	2664 x 2304	5.48 x 5.48	386	361	283	N/A

1.2. Camera interface and framerate

Andor CB2 cameras are equipped with CoaXPress or SFP+ interfaces.

The SFP+ model is operated using GigE Vision protocol.

⚠ *In the firmware 3.1.0 release, only the left SFP+ interface is activated.*

The CoaXPress model uses CoaXPress® 2.0 protocol to transfer the massive amount of data generated each second to ensure the lowest latency and highest real time capability.

The camera operates with the maximum sensor performance when used in its preferred CXP configuration (e.g 4 CXP-10 links).

Table 2: Camera performance when using CoaXPress® protocol (4xCXP-10 link configuration)

Sensor	Resolution Width x Height (pixels)	Maximum FPS			
		Mono8	Mono10	Mono12	HDR
IMX530	5328x4608	106	102	74	37
IMX530 (binned)	2664x2304	386	361	283	N/A

When operated using GigE Vision protocol, the camera may limit the maximum framerate achievable depending on the selected pixel format. The maximum achievable framerate depends on several network parameters, such as negotiated packet size, interpacket delay, *etc*.

The following table indicates the maximum acquisition framerates obtained using Zebra® GigE Vision stack with an Intel® Ethernet Server Adapter X520 (10 Gbit). Jumbo frames of 9014 bytes were enabled and interpacket delay was set to 4 (minimum value).

Table 3: Camera performance when using GigE Vision protocol

Sensor	Resolution Width x Height (pixels)	Maximum FPS			
		Mono8	Mono10 Packed	Mono12 Packed	HDR
IMX530	5328x4608	48	32	32	24
IMX530 (binned)	2664x2304	188	125	127	N/A

1.3. Global shutter

Figure 1: illustrates the *global shutter* configuration. The full array is exposed in its entirety at once. All the pixels start and finish their exposure simultaneously: they are all exposed for the same length of time at the same time. At the end of exposure, the image is transferred to the memory, allowing a new exposition cycle to begin during the image readout.

Global shutter is highly advantageous for dynamic imaging applications. Its key features are:

- No spatial distortion (see "Rolling shutter effect").
- Accurate temporal correlation of different areas of the sensor.
- Simpler and faster synchronization of the camera with other components (light source, *etc*).

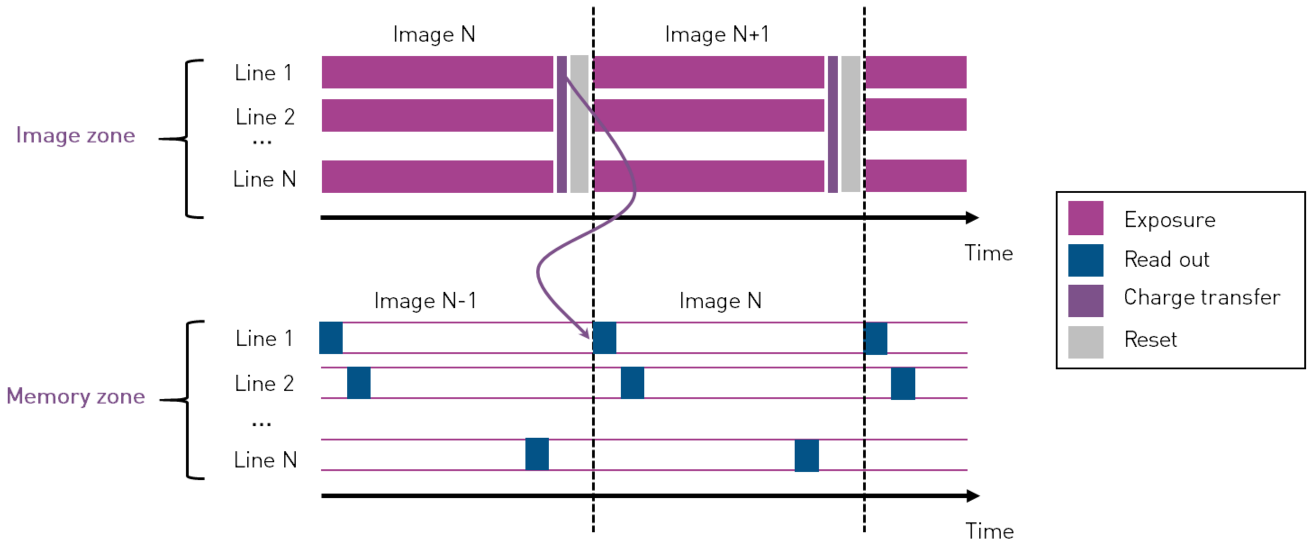


Figure 1: Schematic of the global shutter scheme

1.4. Dead time

The minimum delay between the end of an exposure and the start of the next one is referenced as dead time in this document. It depends on the sensor, the quantization and the control camera protocol used (CoaXPress® or GigE Vision).

The dead time of your camera can be retrieved by subtracting the maximum value of the `ExposureTime` register to $1/framerate$.

The following table indicates dead time values obtained when the camera is operated using CoaXPress® protocol for all available pixel formats.

Table 4: Dead times when using CoaXPress® protocol for Andor CB2 camera

Sensor / Format	IMX530	IMX530 (binned)
Mono8	85.41 µs	86.63 µs
Mono10	89.05 µs	94.62 µs
Mono12	101.68 µs	89.45 µs
Mono16	101.68 µs	N/A

The following table indicates typical dead time values obtained when the camera is operated using GigE Vision protocol. Exact values depend on the performance of the full GigE Vision setup.

Table 5: Dead times when using GigE-Vision protocol for Andor CB2 cameras

Format \ Sensor	IMX530	IMX530 (binned)
Mono8	191.47 µs	184.51 µs
Mono10	384.80 µs	369.11 µs
Mono10Packed	287.83 µs	276.82 µs
Mono12	315.95 µs	269.79 µs
Mono12Packed	236.22 µs	201.50 µs
Mono16	157.49 µs	N/A

1.5. Minimum and maximum exposure times

For a single exposure, the minimum exposure time depends on the sensor, the quantization and the control camera protocol used (CoaXPress® or GigE Vision).
The following table shows minimum exposure time values when the camera is operated using CoaXPress® protocol.

Table 6: Minimum exposure times when using CoaXPress® protocol for Andor CB2 cameras

Format \ Sensor	IMX530	IMX530 (binned)
Mono8	4.41 µs	3.48 µs
Mono10	4.49 µs	3.55 µs
Mono12	5.27 µs	3.87 µs
Mono16	5.27 µs	N/A

The following table shows typical minimum exposure time values obtained when the camera is operated using GigE Vision interface. Exact values depend on the performance of the full GigE Vision setup.

Table 7: Minimum exposure times when using GigE-Vision protocol for Andor CB2 cameras

Format \ Sensor	IMX530	IMX530 (binned)
Mono8	6.76 µs	4.56 µs
Mono10	11.06 µs	6.63 µs
Mono10Packed	8.91 µs	5.59 µs
Mono12	11.06 µs	6.64 µs
Mono12Packed	8.91 µs	5.59 µs
Mono16	6.78 µs	N/A

As for the maximum exposure time, for a single exposure it also depends on the sensor, quantization and the control camera protocol used (CoaXPress® or GigE Vision). It can be computed using the formula below:

$$\frac{1}{Framerate} - Dead\ time$$

For example, at the minimum framerate of Andor CB2 (which is 0.0001 frames/s) the maximum exposure time for a single exposure will be a little bit less than 10 000 seconds, or about 2h45.

1.6. Caution

This User Manual describes precisely how to handle your material properly and to avoid accidents.

Please follow the instructions of use to get the optimum performance out of your Andor CB2 camera.
Please carefully read the warnings (Section 2) and follow the safety precautions to avoid any personal injury or damage when using the camera.

Andor CB2 contains fragile components. Always follow the instructions of use.

2. READ BEFORE USE

2.1. General warnings

The equipment must be plugged on an electrical wiring compliant with the relevant standards in the country (in France: NFC 15-100). This wiring must be protected from overcurrent, overvoltage, and ground defaults.
Any connected equipment must be compliant with the EN 60950-1 Ed.2006 standard, or to their own standards.

The power cable plug serves as a disconnection device and should be easily accessible.

Do not place the equipment close to a heating source or a humidity source.

The security of the system which integrates the equipment is the responsibility of the system assembler only.

For your safety, the equipment must be TURNED OFF and the power supply UNPLUGGED before any technical intervention.

The safety mechanisms provided with this equipment are only guaranteed with a use in accordance with its specified purpose. Only use the provided power supply.

2.2. Never open your camera

Never attempt to open your camera. There are indicators inside the camera, if you try to open it your warranty will be void.

⚠ *Do not open the camera: the warranty will be void.*

2.3. Power circuitry

Use the camera within the specified voltage range. Using a different voltage may damage your camera and lead to fire or electric shock.

⚠ ***Always use the supplied power unit.***

2.4. Cooling water

If you are using water cooling, make sure that the cooling system is properly connected before turning the camera on. Please check that no leaks are visible.

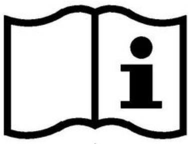
⚠ ***The camera's electronics will be permanently damaged if water leaks inside the camera***

2.5. Symbols and Indications

Please read this User Manual and the following definitions carefully to understand the potential dangers and the precautions to take.
Please refer to this User Manual if a WARNING symbol is marked on the camera.

CE — The CE marking indicates the camera's conformity to the European legislation

This pictogram indicates a direct current operation



This pictogram invites the user to refer to the instructions / user manual

This pictogram refers to indoor use

This pictogram refers to Protection class category 1

RoHS — This pictogram indicates that the product is compliant with the RoHS limitation

2.6. Disposal - DEEE

DO NOT throw the camera in municipal waste. This symbol of the crossed out wheeled bin indicates that the product (electrical and electronic equipment) should not be placed in municipal waste. Check local regulations for disposal of electronic products.

DO NOT throw the Li-ion button cell battery in municipal waste. This symbol of the crossed out wheeled bin indicates that the battery should not be placed in municipal waste.

In case of disposal, do not throw your camera in a waste disposal, you can send it back to Oxford Instruments Andor.

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3. CAMERA DELIVERY

3.1. Package content

Your Andor CB2 camera will be delivered in a hard Pelicase, with the following components:

Table 8: Package items description

Items	Quantity
Camera	1
Power supply	1
Power cord (IEC / NEMA / other)	1
Quick Coupling set (for hydraulic cooling)	1
Zebra GigE Vision dongle (for GigE Vision cameras)	1
Press button tool (cf. rescue software)	1
Quick Start Manual	1
USB key (User manual, software and camera test report)	1

Accessories can be ordered separately. Please contact your sales representatives for details and pricing of the items and accessory packs. Other references may be compatible if they comply with the minimum requirements (refer to Section 10.1.1).

Table 9: Optional items (can be bought separately)

Items	Quantity
TFL-Mount adapter (only for Andor CB2 24B cameras)	1
GigE Vision Ethernet Acquisition pack containing 4 SFP+ cages, 2 cables and a dual 10Gb/s network card (for GigE Vision cameras)	1
GigE Vision Fiber Acquisition pack containing 4 SFP+ cages, 2 fibers of 10m and a dual 10Gb/s network card (for GigE Vision cameras)	1
Ethernet network cables	2
Fiber optic cables	2
Zebra quad CXP Acquisition pack containing 4 CXP cables of 5m and a grabber 4 CXP	1
Coax cables	4
Synchro cables	1
Cooling pack	1
Personal computer	1

Figure 2: Opened Pelicase® with dedicated spaces.*

** Items may differ from pictures.*

3.2. Camera serial and part numbers

The camera's serial number (S/N) is available on a sticker at the rear of the camera. **All support requests require the involved camera (or cameras) serial number(s) (S/N). Please include them in your mail/support ticket outreach.**

Figure 3: Stickers at the bottom of the camera, with Serial number (S/N) indicated.

3.3. Resources

3.3.1. Test report

The performance of your camera has been evaluated by Oxford Instruments Andor to ensure compliance with our standards. The Test Report is available on the USB key delivered with the camera.

3.3.2. Additional resources

Additional resources, such as technical notes, user manuals, latest software releases, technical notes, etc. are available online. As a customer of Oxford Instruments Andor, you can request access to the documents and resources you are interested in on the website https://andor.oxinst.com/.

Table 10: List of additional resources

Items	URL
Download latest software release	https://andor.oxinst.com/downloads/?categories=28
Download latest firmware upgrade	https://andor.oxinst.com/downloads/?categories=28
3D CAD files	fli-support@oxinst.com
Technical notes	https://andor.oxinst.com/downloads/?categories=28
Product pages on the website	https://andor.oxinst.com/products/cb-series/cb2

If you have inquiries, do not hesitate to contact us.

For technical support: fli-support@oxinst.com
For commercial support: fli-sales@oxinst.com

4. SPECIFICATIONS

4.1. Operating conditions

The table below presents the operating conditions of Andor CB2. Do not operate the camera beyond these environmental specifications, as this may cause damage to the camera.

Table 11: Andor CB2 operating conditions

Parameter		Values	Units
Operation conditions (Non-condensing condition)	Maximum temperature	60	˚C
	Minimum temperature	-40	˚C
	Humidity	95%, non-condensing	
Typical power consumption	Without cooling	14	W

Table 12: Power supply operating conditions (TRH70A240-12E0 3-Level-VI)

Parameter		Values	Units
Operation conditions (Non-condensing condition)	Maximum temperature	70	˚C
	Minimum temperature	-20	˚C
	Voltage	90-264	VAC
	Frequency	47-63	Hz

4.2. Storage conditions

To avoid damaging the camera and altering its performance, the camera must be stored in the following conditions. Make sure the camera is stored in its hard Pelicase, to avoid any damage.

Table 13: Andor CB2 storage conditions

Parameter	Values	Units
Maximum temperature	85	˚C
Minimum temperature	-20	˚C
Humidity	Non-condensing	

Table 14: Power supply storage conditions (TRH70A240-12E0 3-Level-VI)

Parameter	Values	Units
Maximum temperature	70	˚C
Minimum temperature	-20	˚C

4.3. Sensor specifications

Andor CB2 integrates a SONY IMX530-AAMJ-C sensor.

Designed and manufactured by SONY, this sensor is a high speed and low noise CMOS monochrome sensor with a global shutter. This sensor can be used for numerous applications in astronomy, Laser Guide Star (LGS) wavefront sensing, life sciences, *etc*.

Table 15: Sensor specifications

Parameter	Values	Units
Sensor	IMX530-AAMJ-C	
Sensor type	CMOS	
Shutter architecture	Global shutter	
Spectral range	400 – 800 [1]	nm
Resolution	5328 (W) x 4608 (H) [2]	pixels
Pixel pitch	2.74, ratio 1:1	µm
Diagonal chip size	19.2 (Type 1.2)	mm

Notes:

- Spectral range is indicated for QE > 30%.
- The recommended recording area is 5320 x 5600 since pixels located at the edge of the detector may behave differently.

4.4. Quantum efficiency curve

The typical spectral response curve of the sensor measured at a sensor temperature of 20˚C is shown below. The peak quantum efficiency of > 70% is obtained at 490 nm.

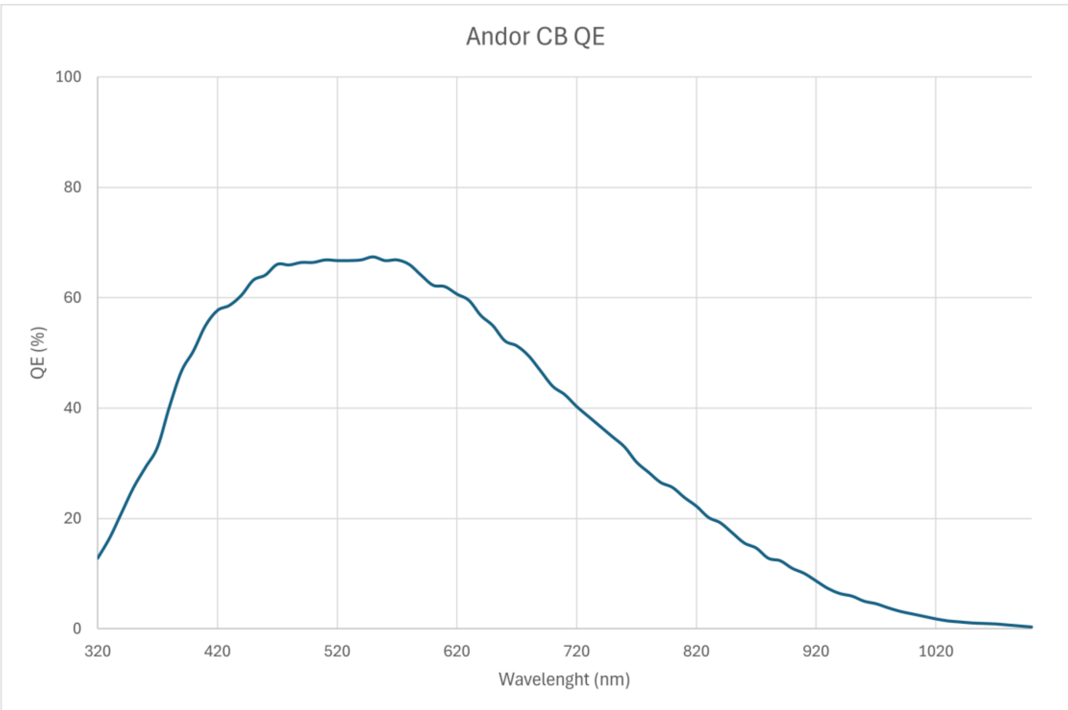


Figure 4: Experimental quantum efficiency of an Andor CB2 camera.

5. THERMAL MANAGEMENT

5.1. Sensor thermal management

The camera is equipped with a two-stage Peltier thermoelectric module to improve dark current and readout noise performance of the sensor.

5.2. Camera thermal management

5.2.1. Overview

The cameras can be configured to maintain the sensor's temperature at a setpoint specified by the user. This feature is disabled by default.

Andor CB2 is designed with an integrated liquid cooling system, allowing it to take advantage of the full capabilities of the IMX530 sensor.

As such, it can be used either:

- In air cooling mode, with reduced performance.
- In water cooling mode, with optimal performance.

5.2.2. Air cooling mode

With air cooling, in a 20-25°C environment Oxford Instruments Andor recommends setting the sensor temperature setpoint to -5°C to get optimal performance out of the camera without experiencing thermal throttling.

5.2.3. Water cooling mode

We recommend using Andor CB2 with a water-cooling system. Oxford Instruments Andor recommends using an active system, but a passive one can also be used.

Heat is evacuated by circulating a cooling fluid through two rears connectors (G1/8, 10 mm thread). Two male connectors (Figure 5: Stäubli CBI03) are provided with the camera.

Figure 5: Male Stäubli CBI03 connectors

If the temperature of the fluid is higher than 5°C, distilled water or deionized water can be used. For lower temperatures, we recommend using ethylene glycol. Please check the recommendations of your cooling system before choosing which fluid to use.

To avoid leaks, make sure that the cooling system is properly connected before turning on the chiller. Water will damage the camera.

Table 16: Cooling system recommendations

Parameter	Value	Unit
Recommended cooling fluid temperature	20	°C
Recommended cooling output at 20°C	120	W
Minimum pump flow	> 2	L/min
Maximum pressure	10	bars

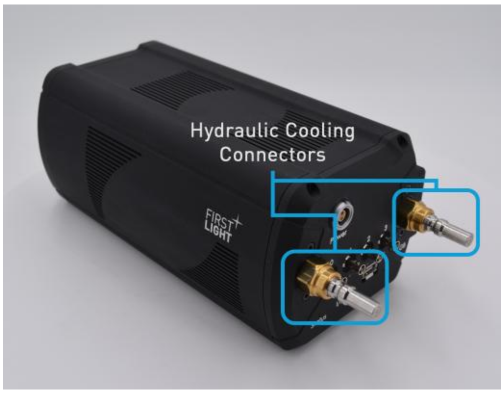


Figure 6: Hydraulic cooling connectors of Andor CB2. Andor CB2 CXP on the left, Andor CB2 SFP on the right.

5.2.4. Optional chiller

An optional quick coupling kit set includes Stäubli connectors, pipes and a chiller. This section details how to mount the pipes on the chiller. Stäubli female connectors are already plugged to the pipes.

In the Figure 7: the chiller and pipes with Stäubli connectors are presented. Oxford Instruments Andor recommends using an active water-cooling system (a chiller for example), but a passive, radiating system can also be used. The water-cooling system that can be bought with C-BLUE One is INR-244-831, 220W *(SMC).*

Oxford Instruments Andor can supply a full cooling pack including the chiller, hoses and connectors. Please contact us for more details at fli-sales@oxinst.com. If you want to use your own chiller system, please follow the recommendations in Table 1:.

Figure 7: Water pipes with the hydraulic connectors for the cooling plate (left side) and for the chiller (right side)

To mount the system:

- **Step 1**: Connect the two male white connectors to the chiller white female connectors (see Figure 8:). A small click should be heard when doing so.
- **Step 2**: Connect the Stäubli female connector to the provided cooling plate.

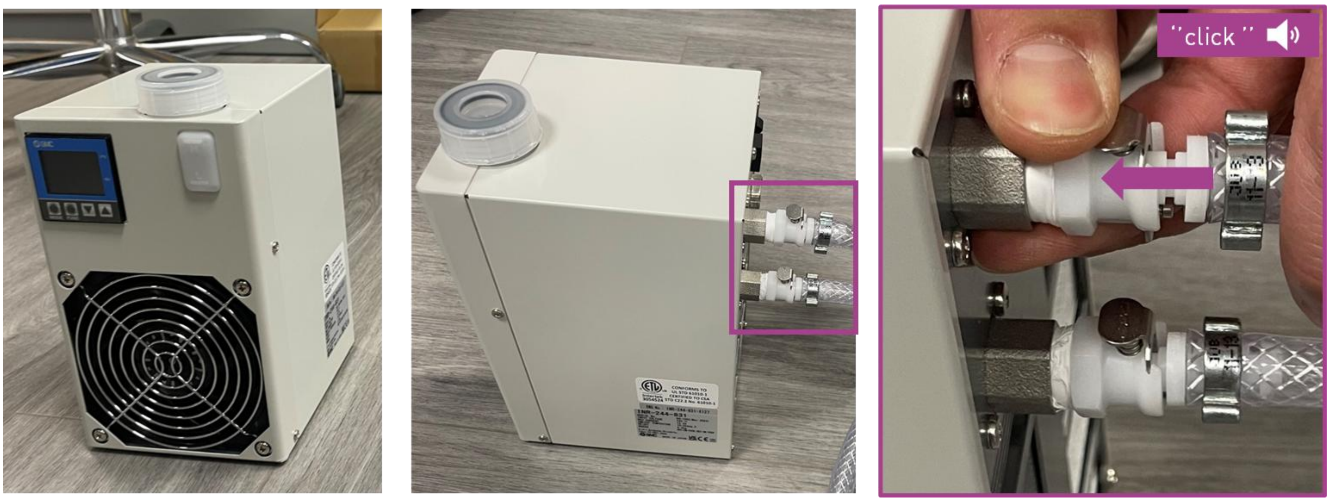


Figure 8: Cooling system main block. Left: front view. Center: side view. Left: pipe connection

For chiller's operation and settings, please read the chiller's user manual provided with your cooling pack.

Optimal camera performances are obtained when the sensor temperature is regulated around -20°C.

5.2.5. Thermal performances

The table below sums up the performances that can be expected from the camera with the different thermal management options available.

Table 17: Thermal management performances and temperature minimum set point

Cooling method	Air temperature	Water temperature	Sensor minimum set point
Air cooling, fan at full speed	< 25°C	-	-5°C
Water cooling / no fan	< 25°C	20°C	-25°C
		5°C*	-40°C

**Always stay over the dew point in your environmental conditions.*

5.2.6. Electronics protection

The camera will automatically shut itself down if it detects temperatures out of its operating range, either hot or cold. This shutdown is made to protect the camera's electronic components.

Please note that it is not possible to switch off this functionality.

The internal firmware constantly monitors the camera's parts and boards' temperature. Each temperature must stay within its valid range.

If the camera is overheating, before shutting it down the firmware will try to limit the power consumption of the camera to decrease the generated heat.

To recover the use of the camera, the user must wait for it to get back into the valid temperature range, then reboot the camera by unplugging and plugging the power back.

6. MECHANICS

6.1. Overview

Table 18: Physical parameters of the Andor CB2 camera.

	Parameter	Values	Units
Dimensions (without lens adaptor)	Length (CXP)	183.63	mm
	Length (GigE)	180.37	mm
	Width	93	mm
	Height	77.5	mm
Lens mounts	C-mount, TFL-mount		
Weight	1.3		kg

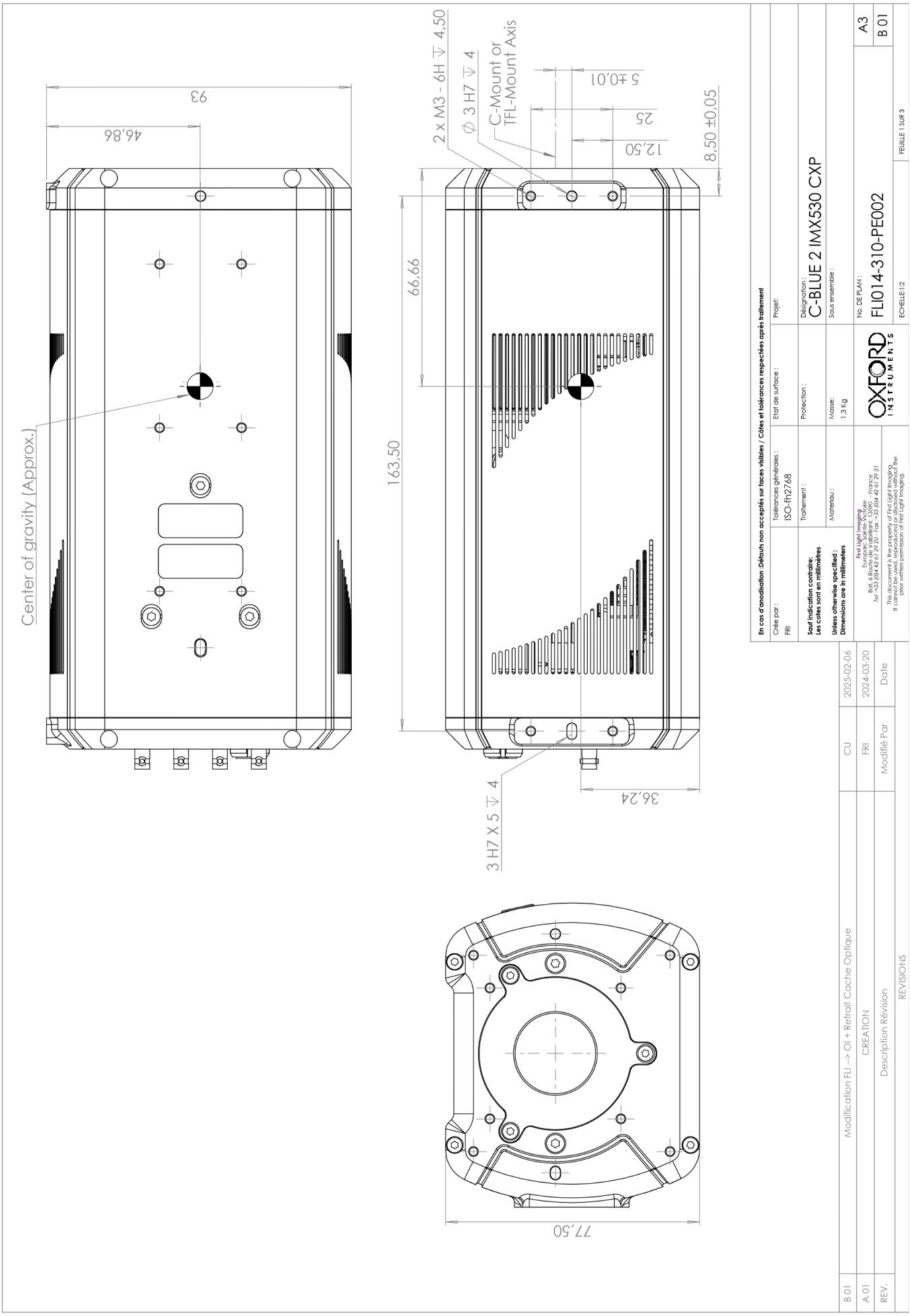
6.2. Mechanical drawings

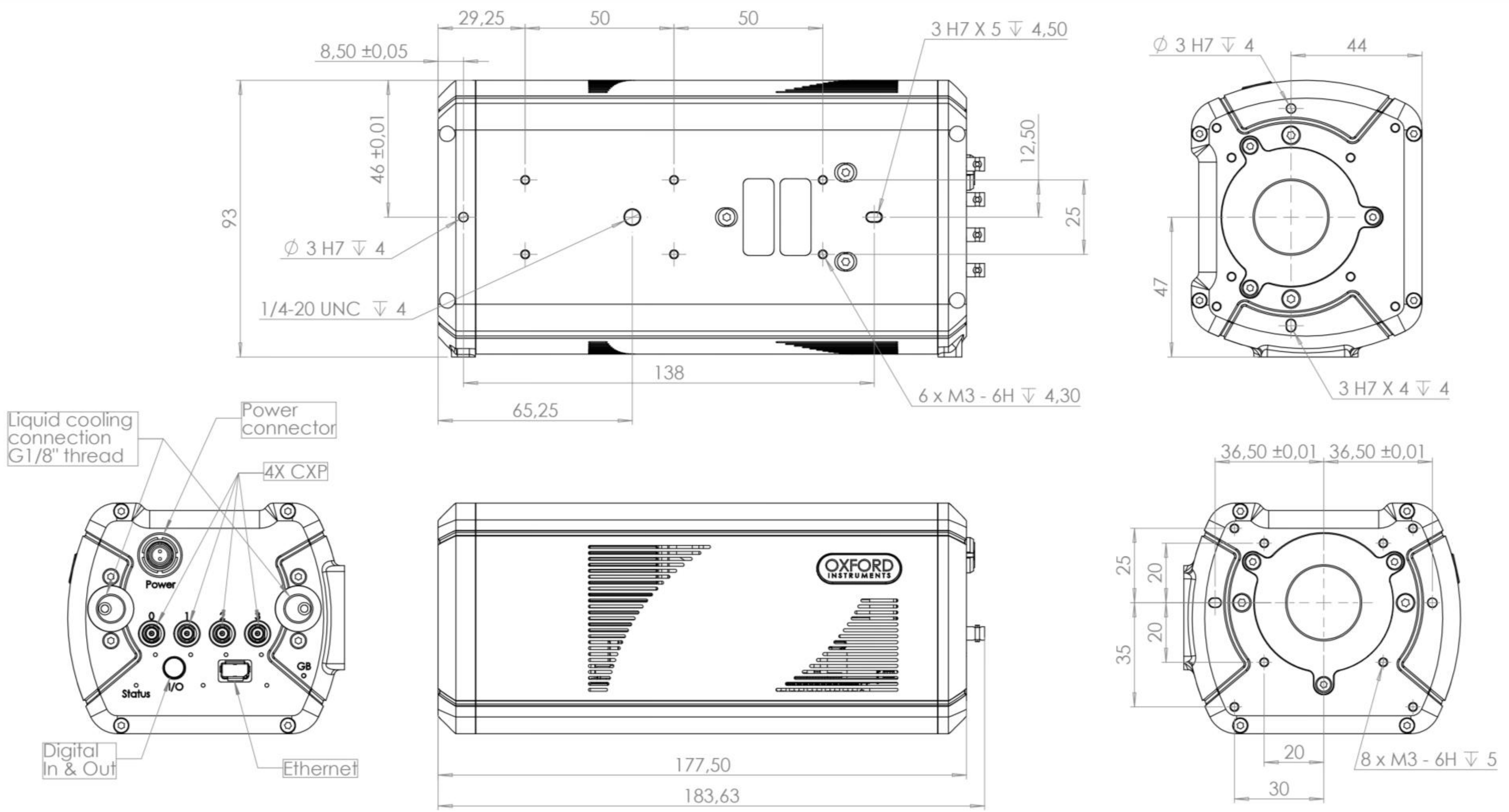
The camera is designed to get the best precision possible regarding the optical alignment of the sensor and the highest thermal performance.

For further information about mechanical tolerances, see drawings below.

The camera's latest mechanical drawings are available from Oxford Instruments Andor at: fli-support@oxinst.com, or on https://andor.oxinst.com/.

For Andor CB2 CoaXPress camera:





En cas d'anodisation :Défauts non acceptés sur faces visibles / Côtes et tolérances respectées après traitement

Crée par : FRI	Tolérances générales : ISO-fh2768	Etat de surface :	Projet:
Sauf indication contraire: Les cotes sont en millimètres	Traitement :	Protection :	Désignation : C-BLUE 2 IMX530 CXP
Unless otherwise specified : Dimensions are in millimeters	Materiau :	Masse: 1.3 kg	Sous ensemble :
First Light Imaging Europarc Sainte-Victoire Bat. 6 Route de Valbrillant, 13590 – France Tel :+33 (0)4 42 61 29 20 - Fax :+33 (0)4 42 61 29 21	OXFORD INSTRUMENTS	No. DE PLAN : FLI014-310-PE002	A3 / B 01
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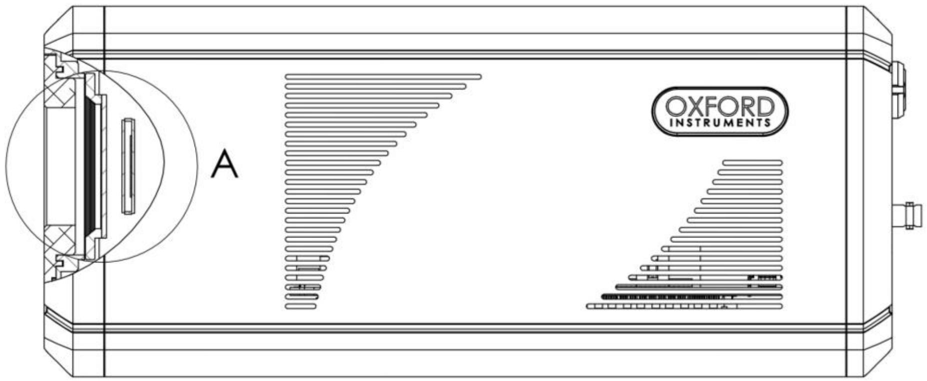

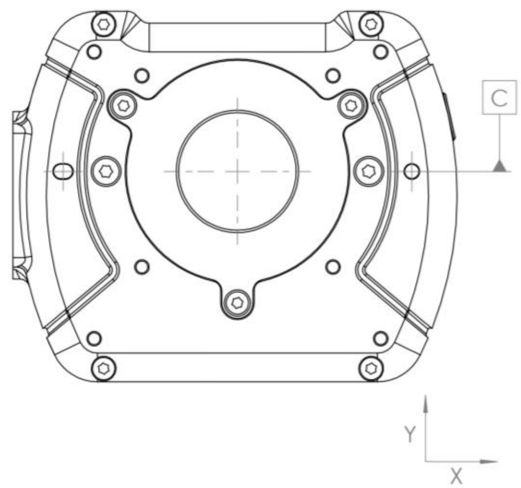

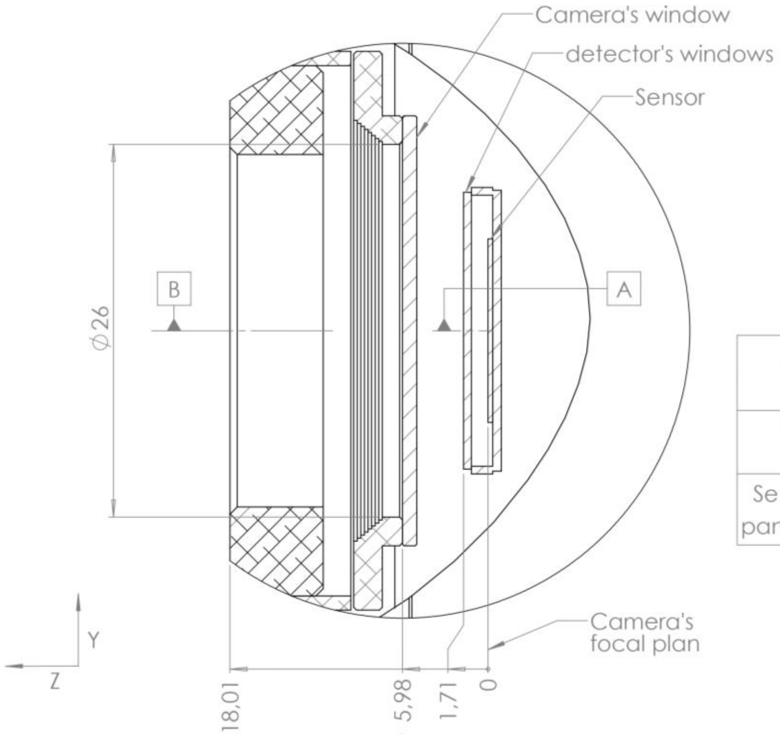

DÉTAIL A
ECHELLE 3 : 1

Optical glass properties				
Item	Thickness	Material	Refractive index	Transmission
Camera's window	1mm	N-BK7 coated	1.516	> 0.99
Detector window	0.5mm	Borosilicate Glass	1.5	Flat 0.92

Positioning accuracy	Position			Tilt		
	X	Y	Z (focus)	Rx	Ry	Rz
Sensor [A] relative to C-Mount axis [B]	± 0.3825	± 0.3825	± 0.453	± 1.383°	± 1.337°	± 1.100°
Sensor [A] relative to front panel H7 mounting holes [C]	± 0.3425	± 0.3425	+ 0.433 - 0.483	± 1.346°	± 1.313°	± 1.116°

En cas d'anodisation :Défauts non acceptés sur faces visibles / Côtes et tolérances respectées après traitement

Crée par : FRI	Tolérances générales : ISO-fh2768	Etat de surface :	Projet:	
Sauf indication contraire: Les cotes sont en millimètres	Traitement :	Protection :	Désignation : C-BLUE 2 IMX530 CXP	
Unless otherwise specified : Dimensions are in millimeters	Materiau :	Masse: 1.3 kg	Sous ensemble :	
First Light Imaging Europarc Sainte-Victoire Bat. 6 Route de Valbrillant, 13590 - France Tel :+33 (0)4 42 61 29 20 - Fax :+33 (0)4 42 61 29 21		OXFORD INSTRUMENTS	No. DE PLAN : FLI014-310-PE002	A3
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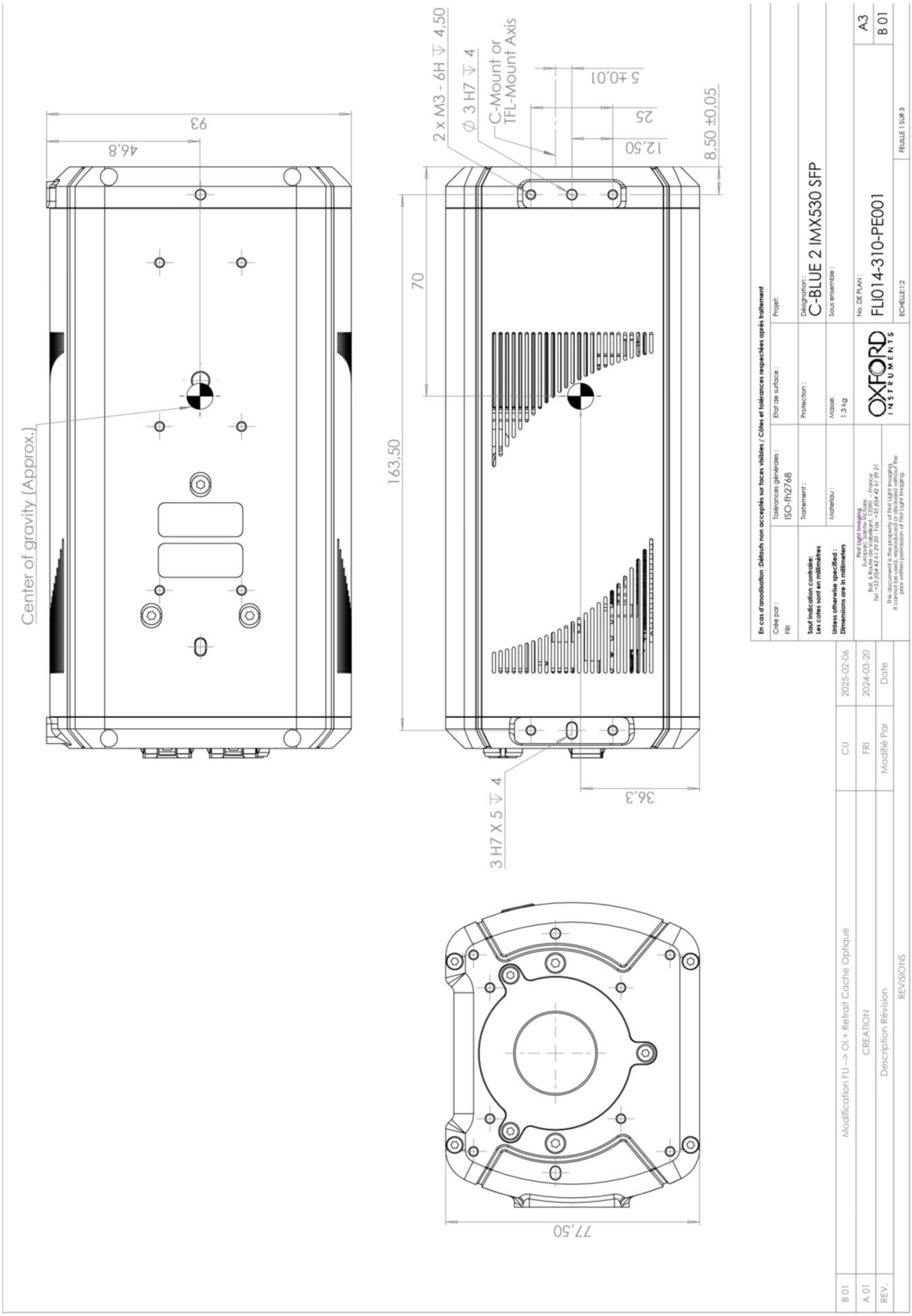
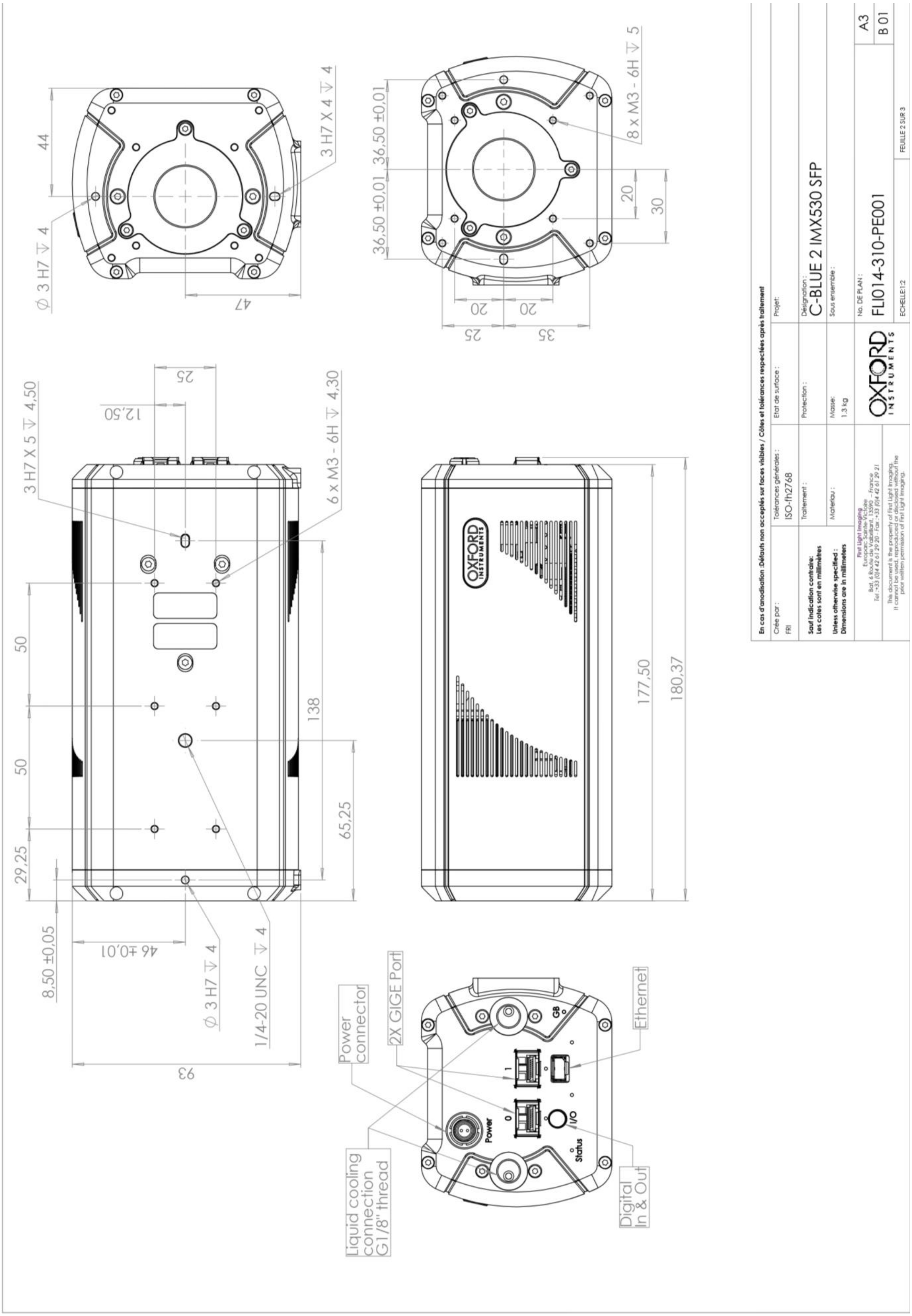
For Andor CB2 GigE Vision camera:




Ø 3 H7 ⊽ 4
44
47
3 H7 X 4 ⊽ 4
36,50 ±0,01
36,50 ±0,01
8 x M3 - 6H ⊽ 5
20
30
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35
3 H7 X 5 ⊽ 4,50
12,50
25
6 x M3 - 6H ⊽ 4,30
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50
29,25
138
65,25
177,50
180,37
8,50 ±0,05
46 ±0,01
Ø 3 H7 ⊽ 4
1/4-20 UNC ⊽ 4
93
Power connector
2X GIGE Port
Ethernet
Liquid cooling connection G1/8" thread
Digital In & Out
Power
Status
I/O
GB
En cas d'anodisation :Défauts non acceptés sur faces visibles / Côtes et tolérances respectées après traitement
Crée par : FRI
Tolérances générales : ISO-fh2768
Etat de surface :
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Traitement :
Protection :
Désignation : C-BLUE 2 IMX530 SFP
Matériau :
Masse: 1.3 kg
Sous ensemble :
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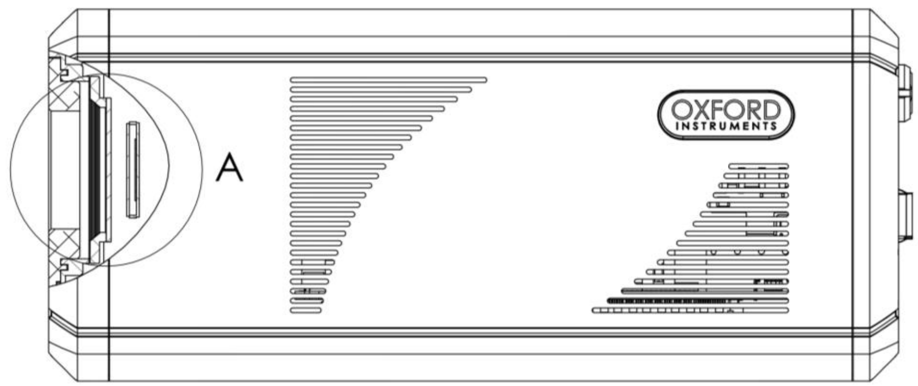
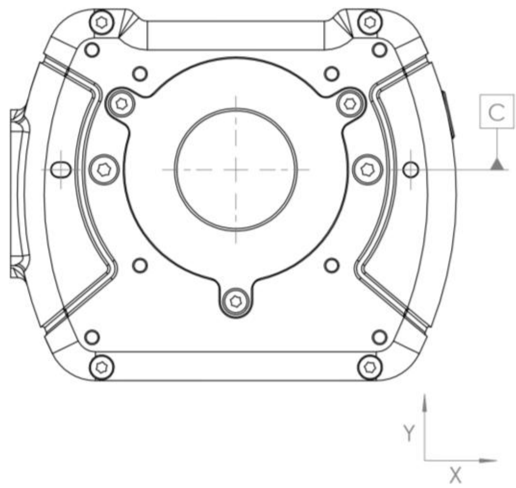
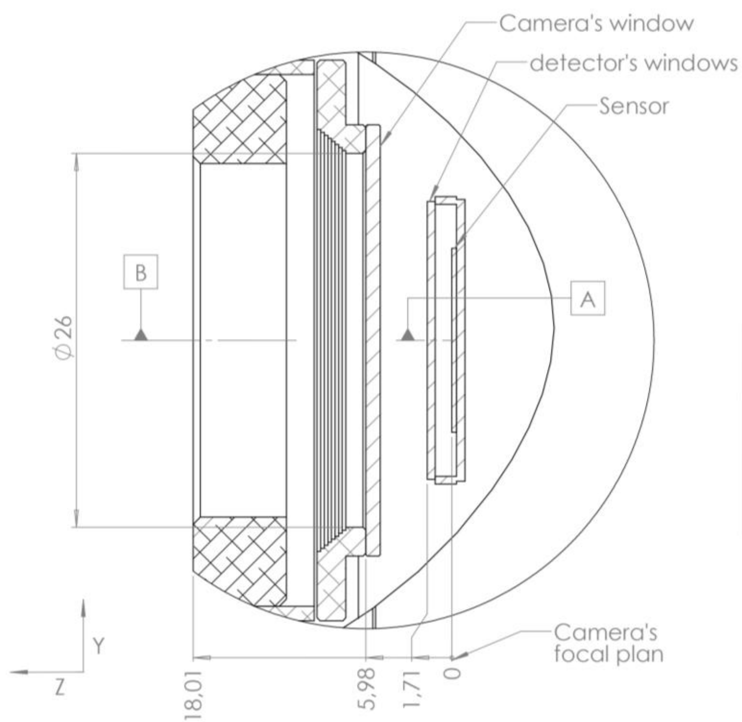






DÉTAIL A
ECHELLE 3 : 1

Optical glass properties				
Item	Thickness	Material	Refractive index	Transmission
Camera's window	1mm	N-BK7 coated	1.516	> 0.99
Detector window	0.5mm	Borosilicate Glass	1.5	Flat 0.92

Positioning accuracy	Position			Tilt		
	X	Y	Z (focus)	Rx	Ry	Rz
Sensor [A] relative to C-Mount axis [B]	± 0.3825	± 0.3825	± 0.453	± 1.383°	± 1.337°	± 1.100°
Sensor [A] relative to front panel H7 mounting holes [C]	± 0.3425	± 0.3425	+ 0.433 - 0.483	± 1.346°	± 1.313	± 1.116°

En cas d'anodisation :Défauts non acceptés sur faces visibles / Côtes et tolérances respectées après traitement

Crée par : FRI	Tolérances générales : ISO-fh2768	Etat de surface :	Projet:	
Sauf indication contraire: Les cotes sont en millimètres	Traitement :	Protection :	Désignation : C-BLUE 2 IMX530 SFP	
Unless otherwise specified : Dimensions are in millimeters	Materiau :	Masse: 1.3 kg	Sous ensemble :	
First Light Imaging Europarc Sainte-Victoire Bat. 6 Route de Valbrillant, 13590 - France Tel :+33 (0)4 42 61 29 20 - Fax :+33 (0)4 42 61 29 21		OXFORD INSTRUMENTS	No. DE PLAN : FLI014-310-PE001	A3
This document is the property of First Light Imaging. It cannot be used, reproduced or disclosed without the prior written permission of First Light Imaging.			ECHELLE:1:2	FEUILLE 3 SUR 3 / B 01

7. CAMERA INTERFACES

7.1. Rear panel overview

The connectors and status LEDs are all positioned on the rear panel of the camera.

Figure 9: Andor CB2 rear panel interface overview. Andor CB2 CXP on the left, Andor CB2 SFP with SFP+ modules plugged in on the right.

7.2. Camera status LEDs

Once the camera is properly powered up by following the steps of section 9, the system boots and Andor CB2 is ready to operate. A purple diode signal on the rear panel confirms the operability.

Figure 10: Rear panel of Andor CB2. The purple LED indicates camera status. Andor CB2 CXP on the left, Andor CB2 SFP on the right.

Table 19: Camera LED indication and description

Camera status	Camera LED indication		Description
Operational		Purple blink	The camera is operational
Operational cooling		White blink	The sensor is being cooled
Operational throttling		Double purple blink	The camera cannot reach the target temperature
Safe		Red blink	An error has been detected. The detector is turned off. The camera needs to be rebooted.

Note: A turned off LED does not necessarily mean that there is an issue with the camera. The camera can be configured to switch off the LED automatically once the boot is completed.

7.3. Power supply

Andor CB2 requires a single power input, supplied in the package.

The power supply must provide a stable 24 V DC, with at least 2.5 A of current available (60 W) to properly power Andor CB2 when cooling is enabled.

The mating connector is a LEMO connector FGG.0B.302.CLAD42Z.

Figure 11: On the left, Andor CB2 CXP back views. The orange box shows the female power connector. On the center, Andor CB2 GigE Vision back views. The orange box shows the female power connector. On the right, the female power connector pinout.

Always use the power supply provided by Oxford Instruments Andor. Using another power supply can damage the camera.

7.4. CoaXPress® interface

Refer to Section 8 for a complete description of the CoaXPress® interface.

7.5. GigE Vision interface

Refer to Section 9 for a complete description of the GigE Vision interface.

7.6. Ethernet interface

Andor CB2 cameras are equipped with an ix Industrial Ethernet connector.

On CoaXPress Andor CB2 camera model, this connection can be used for specific camera maintenance operations, such as camera firmware upgrade and log collection. It is not needed for standard camera operation.

The IP configuration is performed using custom registers.

The IP configuration of the camera can be done statically or dynamically, using DHCP.
When using DHCP, in the absence of an answer from a DHCP server, the camera will use link local fallback address 169.254.123.123, netmask 255.255.0.0.

Note: On GigE Andor CB2 camera model, this connection is inactive, all maintenance operations can be performed using the 10Gbit SFP+ connection.

For the firmware update procedure, please contact Oxford Instruments Andor at fli-support@oxinst.com.

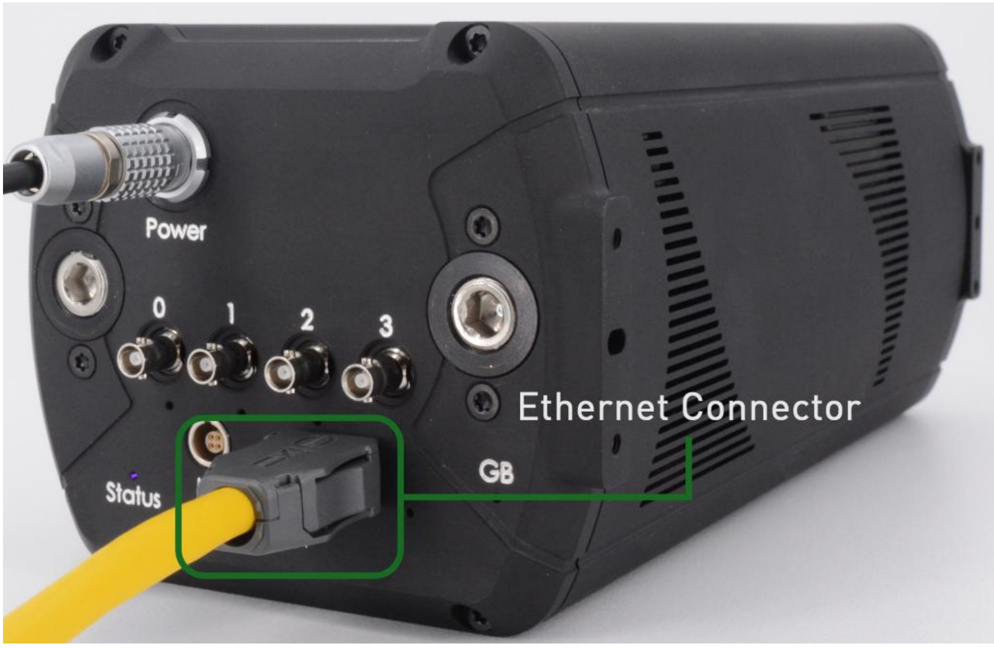


Figure 12: Ix Industrial Ethernet cable connected to the Ethernet port on an Andor CB2 CXP camera.

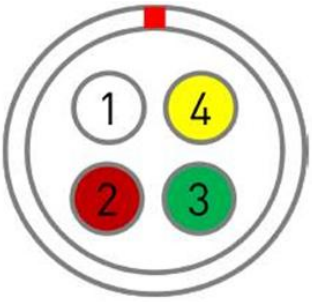
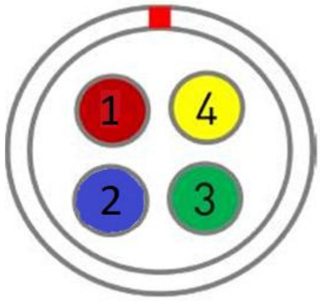
7.7. I/O port

Electronic sensitive interface
Please use appropriate grounding methods

Please use a shielded cable

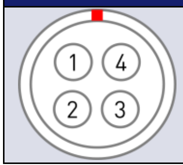
The colors of the cable on the male end of the connector will correspond either to version A or to version B of the wiring, as detailed below:

Table 20: Pinout of Cable version A and B

Cable version A	Cable version B
	
1 White 2 Red 3 Green 4 Yellow	1 Red 2 Blue 3 Green 4 Yellow

The I/O Port is composed of two input trigger signals and two output trigger signals.

Table 21: Pin Signal description

Connector	Pin	Signal	Dir	Description
	1	LEMO 0	in	Source Trigger in 0
	2	SYNC_O1	out	Camera synchro output #1
	3	SYNC_O2	out	Camera synchro output #2
	4	LEMO 1	in	Source Trigger in 1

The SYNC_O1 and SYNC_O2 outputs can be configured by the user.

Table 22: Available signals

Parameter symbol	Parameter Description
Sensor readout	Active high during readout of the image. This is the default value for SYNC_O2.
Sensor exposure	Active high during image exposure. This is the default value for SYNC_O1.
Clock	Clock sent to the sensor, running at 74.25 MHz

Configuration of the signals is done using the SFNC `LineSelector` and `LineSource` registers

`LineSelector = Line2` selects the SYNC_O1 signal.
`LineSelector = Line3` selects the SYNC_O2 signal.

`LineSource = ExposureActive` selects the sensor exposure.
`LineSource = SensorReadout` selects the sensor readout.
`LineSource = SensorClock` selects the clock.

Table 23: Voltage Parameter description for trigger signal

Parameter symbol	Parameter Description	Test conditions	Min	Max	Units
V_{IH}	High-level input voltage threshold		2.02		V
V_{IL}	Low-level input voltage threshold			0.8	V
V_I	Input voltage		0	2.54	V
V_{OH}	High-level output voltage	I_{OH} = −5.5 mA	2.9		V
V_{OL}	Low-level output voltage	I_{OL} = 3.0 mA		0.11	V
V_{OL}	Low-level output voltage	I_{OL} = 5.5 mA		0.21	V
V_I	Input voltage	Maximum range	-0.5	7	V
V_O	Output voltage	Maximum range	-0.5	3.8	V

Input impedance: **High Z**

Failure to observe the voltages indicated in the table will permanently damage the camera

Figure 13: Andor CB2 I/O LEMO Port. Andor CB2 CXP is on the left, Andor CB2 SFP is on the right.

8. COAXPRESS®

8.1. Overview

CoaXPress® is a standard protocol of communication widely used in industrial vision applications. This standard is developed by the Japan Industrial Imaging Association. Version 2.0 was released in May 2019. This new version supports bit rates up to 12.5 Gbps per cable.

CoaXPress® uses GenICam standard (abbreviation of Generic Interface Camera) which defines standard registers and access for communication with the camera. GenICam is developed by the European Machine Vision association.

The Andor CB2 CXP camera needs four CoaXPress® links for normal operation. The camera uses one Master connection, and three Extension connections as defined in CoaXPress® standards, as illustrated in the two figures below.

The Master connection is indicated by digit 0 and the Extension connections are indicated by digits 1, 2 and 3.

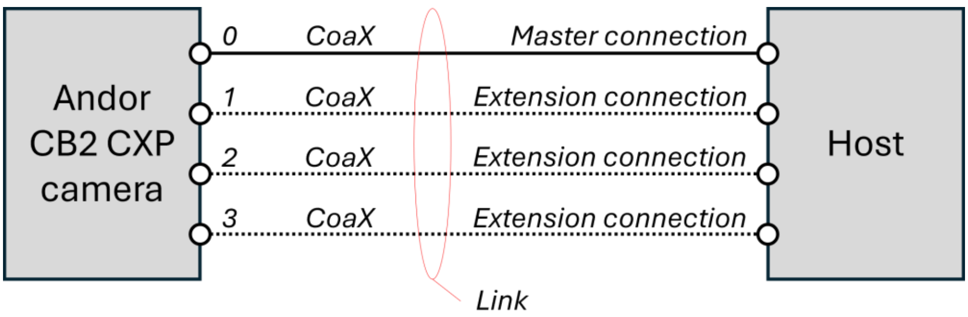


Figure 14: Schematic of the four CoaXPress® links required in the configuration implemented in Andor CB2 CXP.

Each connection (Master and Extension) provides:

- A high-speed downlink of 12.5 Gbps (camera to frame grabber).
- A low-speed uplink at 41.6 Mbps speed (frame grabber to camera).

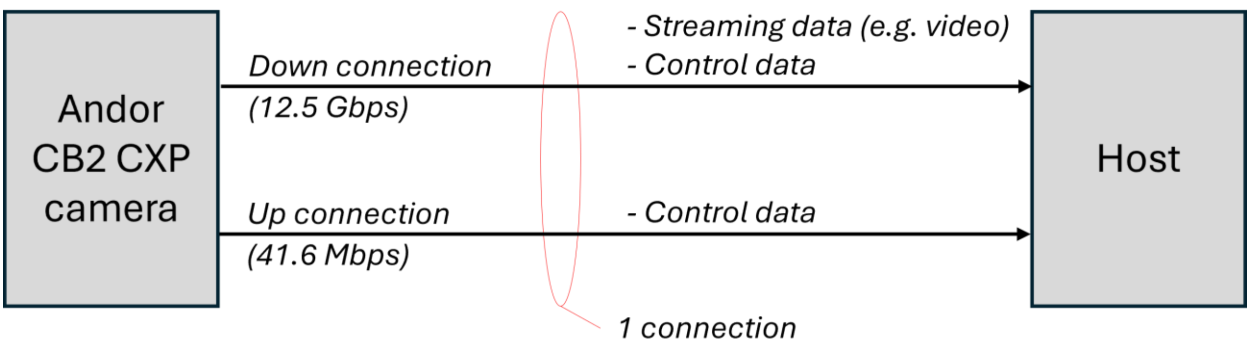


Figure 15: Schematic representation of the features provided by each CoaXPress® link.

8.2. Recommended frame grabbers

Andor CB2 CXP is compatible with CoaXPress® 2.0 frame grabbers.

However, please note that our cameras have been developed and tested with specific grabbers, and we highly recommend using these grabbers.

- Zebra® Rapixo CXP (quad CXP-12)
- Euresys Coaxlink Quad CXP-12

8.3. CoaXPress® communication

8.3.1. Configuration

The camera is CoaXPress® and GenICam compatible, allowing seamless integration with existing CoaXPress®/GenICam compliant solutions.

The default Andor CB2 camera configuration uses 4 CXP links, operating at CXP-10 speed. This configuration lets the camera operate its sensor at full speed. This configuration can be changed with degraded performances (decrease of maximum framerate) using the user set GenICam features. For example, users can configure their setup with 2 CXP links at CXP-6.

Table 24: List of supported CXP configurations

Sensor	CoaXPress configuration	Full framerate
IMX530	4 x CXP-12	YES
	4 x CXP-10(1)	YES
	4 x CXP-6	NO
	4 x CXP-3	NO
	2 x CXP-12	NO
	2 x CXP-10	NO
	2 x CXP-6	NO
	2 x CXP-3	NO
	1 x CXP-12	NO
	1 x CXP-10	NO
	1 x CXP-6	NO
	1 x CXP-3(2)	NO

Note:
(1) Native configuration
(2) Discovery configuration

Control and data acquisition are carried out through CoaXPress® 2.0 connection.

Note: Some frame grabbers require the Master connection of the camera to be connected to a specific port of the grabber (for example, Euresys Coaxling Quad CXP-12), whereas others do not. Please refer to the user manual of your frame grabber to ensure proper detection of the camera.

Figure 16: Andor CB2 CXP back view. The HD-BNC connectors are plugged in.

8.3.2. Connectors

The CoaXPress® protocol uses 75 Ω coaxial cables. The CoaXPress® 2.0 interface requires four cables with male HD-BNC connectors (also known as Micro BNC).

Figure 17: CoaXPress cables with HD-BNC connectors.

8.3.3. Cable lengths

The maximum CXP® cable length supported for the connection is dependent on the cable used and on the link speed.

Table 25: Maximum cable length for various cable references (at CXP-12)

Belden cable	1694A	4694R	4855R	4731R
Maximum cable distance (m)	40	45	24	65
Belden qualified frequency (GHz)	6	12	12	12
CoaXial cable outer diameter (mm)	6.96	6.96	4.04	10.16

Note : These recommended maximum cable length were obtained from information of the CXP emitter component's manufacturer (Link).

8.3.4. Connector Indicator lamps

Each connection has its own indication lamp.

Table 26: Connector indicator lamp states

State	Lamp	Indication
No power		Off
System booting		Solid orange
Powered, but nothing connected		*Flash_1 red*
Connection detection in progress		*Flash_12_5* orange Shown for a minimum of 1s even if the connection detection is faster
Device / Host connected, but no data being transferred		Solid green
Device / Host connected; waiting for event (e.g. trigger, trigger-controlled exposure)		*Flash_1_orange*
Device / Host connected; data being transferred		*Flash_12_5* green
Error during data transfer (e.g., CRC error, single bit error detected)		500 ms red pulse In case of multiple errors, there shall be at least two green *Flash_12_5* pulses before the next error is indicated.
Connection test packets being sent		AlternateFlash_0_5 green / orange

The timings associated with these states are summarized in the table below.

Table 27: Connector indicator lamp timings

Indication	Frequency (±20%)	Duty Cycle (on) (±20%)
Flash_12_5	12.5 Hz	25% (20ms on, 60ms off)
Flash_1	1 Hz	25% (200ms on, 800ms off)
AlternateFlash_12_5	12.5 Hz	25% (20ms on color 1, 60ms off, 20ms on color 2, 60ms off)
AlternateFlash_0_5	0.5 Hz	50% (1s on color 1, 1s off, 1s on color 2, 1s off)

8.3.5. CoaXPress® supported functionalities

The main functionalities offered by CoaXPress® and supported by the Andor CB2 CXP camera are the following:

- **CoaXPress® 2.0**. This enables to reach the maximum frame offered by the sensor.
- **Mono8, Mono10, Mono12 and Mono16** pixels formats.
- **One stream**. The camera sends one image at a time.
- CoaXPress® speeds:
  - Discovery rate: **CXP-3**
  - Operation rates: CXP-3, CXP-6, **CXP-10** and CXP-12
- **Heartbeat**. A timestamp is sent regularly to enable synchronizing the PC time with the camera time. Note that event messages are not supported by the camera.
- **Connection test uplink and downlink.** This feature enables testing the CoaXPress links.

9. GigE Vision

9.1. Overview

GigE Vision is a standard protocol of communication widely used in industrial vision applications. This standard is maintained by the Automated Imaging Association (AIA). Version 2.1 was released in November 2018.

GigE Vision uses GenICam standard (abbreviation of Generic Interface Camera) which defines standard registers and access for communication with the camera. GenICam is developed by the European Machine Vision association.

Andor CB2 GigE Vision cameras are equipped with two SFP+ cages compatible with 10 Gbit SFP+ RJ45 or 10 Gbit SFP+ optical modules

Note : In the current Firmware version (version 3.1.0), only the left SFP+ connector is active. The rest of this document will thus consider that Andor CB2 cameras only work through 1 SFP link.
This document will be updated once support for both SFP links is added.

The control of the camera is done using the GVCP (GigE Vision Control Protocol) and images are encapsulated using the GVSP (GigE Vision Stream Protocol). Both protocols are transmitted through the IP connection established using the SFP+ interface.

9.2. Standard Compliancy

Even if Andor CB2 GigE Vision cameras have been developed and tested with Zebra®GigE Vision application, used for camera control and image acquisition, they should be compatible with any GigE Vision Application and GVSP Receiver.

The NIC (Network Interface Controller) used for our tests is an Intel X520 Network Adapter.

To achieve maximum performance, jumbo frames must be activated and set to the maximum allowable value (9014 for the Intel controller we use). It is also recommended to set the number of received buffers at its maximum (4096 for the Intel controller we use).

9.2.1. Supported functionalities

Andor CB2 GigE Vision implements the following GigE Vision features:

- **Single Link Configuration**, link speed fixed to **10 GBps**
- IP Configuration: Persistent, DHCP or link local address.
- **Mono8**, **Mono10**, **Mono10Packed**, **Mono12**, **Mono12Packed, Mono16** pixels formats.
- **One stream**. The camera sends one image at a time.

9.3. GigE Vision Communication

9.3.1. Configuration

Andor CB2 GigE Vision only supports Single Link Configuration, as defined in the GigE Vision standard. The connection with the camera is done through the left SFP+ cage located at the rear side of the camera. The SFP+ cage can be equipped with 10Gbit copper or fiber SFP+ module, at the user's convenience.

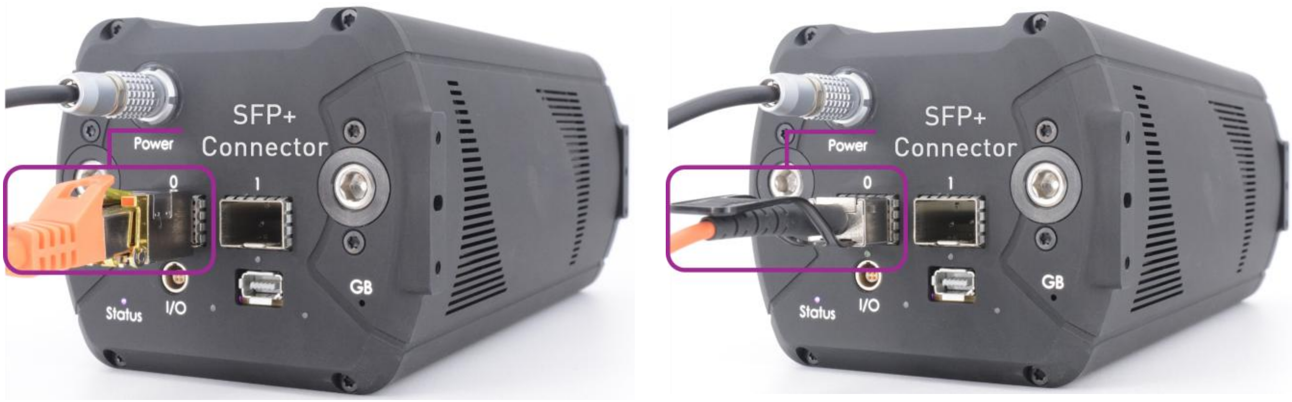


Figure 18: Andor CB2 CXP back view. The SFP+ transceiver is connected : RJ45 on the left, optical fiber on the right.

To increase acquisition reliability, the settings of the Network Interface Card (NIC) should be tuned:

- Increase the packet size by enabling jumbo frames, ideally to at least 9000 / 9014 bytes.
- Set the number of receive buffers/receive descriptors to its maximum value.
- Enable interrupt moderation and set it to its maximum value.

To ensure proper operation of the camera, the entire network infrastructure between the camera and the GigE Vision application / GVSP receiver must support 10Gbit transfer and jumbo frames up to 9014 bytes.

If acquisition errors still occur, it is possible to slow down the camera's throughput by increasing the inter-packet delay, accessible through the SFNC `GevSCPD` register This comes at the cost of decreased camera performance: the maximum achievable framerate is decreased.

10. SETTING UP AND STARTING UP CAMERA

10.1. Configuring your computer

10.1.1. Recommended system requirements

The recommended system requirements are the following:

- Intel 13th Gen Core i9-13900K 3.00 GHz (with 24 cores) or better (meaning latter Generations, higher speeds and / or higher core counts will work as well).
- At least 128 GB of DDR4 RAM. DDR5 is better. At least 3000 MHz.
- SSD capable of more than 4.00 GB / s sustained writes. For example, the 'Samsung 990 PRO 2TB SSD' drive is sufficient.
- A dedicated GPU is required for live playback and displaying live statistics about your images.

The following configurations are officially supported:

Table 28: Supported acquisition devices and operating systems

Protocol	Acquisition device / protocol	Supported operating system
CoaXPress	Zebra® Rapixo CXP Quad	Windows®10, Windows® 11, Ubuntu 18.04, 20.04
CoaXPress	Euresys CoaXLink QuadCXP-12	Windows®10, Windows®11, Ubuntu 18.04, 20.04
GigE Vision	Zebra® GigE Vision	Windows®10, Windows®11, Ubuntu 18.04, 20.04

Windows® 7 is not officially supported, and Oxford Instruments Andor will not provide any support for this OS.

For more information on recommended configurations (particularly for GigE Vision operation), please refer to the 'Computer configuration Andor CB' Technical note (https://andor.oxinst.com/downloads/).

10.2. Software installation

10.2.1. Oxford Instruments Andor Graphical User Interface software

The Graphical User Interface (GUI) demo software is provided in the USB key supplied with the Andor CB2 camera, or available in Your Library on the website. It is a dedicated interface developed by Oxford Instruments Andor which allows you to control almost all the parameters of the camera.

This software development kit has its own manual.

Please refer to the Graphical User Interface manual

10.2.1. Software Development Kit

A Software Development Kit (SDK) is also provided with your camera.
It will allow developers to code their own interface to control the camera. A code in C/C++ is provided to make a demo, and additional example codes are provided in several languages: C, Python, Matlab, LabVIEW.

This software development kit has its own manual.

Please refer to the Software Development Kit user manual

10.3. Quick start

10.3.1. Powering ON & camera connection

The camera is powered when power is applied on LEMO® FGG.0B.302.CLAD42Z connector.

10.3.2. Powering OFF & camera disconnection

Please use the register *DeviceShutdown* before unplugging the camera. The shutdown is recommended (particularly to store the latest logs), however, the direct switch off does not damage it.

First unplug the power supply from the line plug, then unplug the LEMO® connector cable from the camera.

10.3.3. Camera storage

Please follow the recommendations concerning camera storage in Section 4.2.

11. CAMERA FUNCTIONALITIES

This section will describe non-exhaustively the camera's features provided by Oxford Instruments Andor. Functionalities can be configured using First Light Vision, Oxford Instruments Andor's graphical user interface, your custom developed interface using Oxford Instruments Andor's SDK, or GenICam's API and GUI.

In the GenICam standard, the Standard Features Naming Convention (SFNC) provides a standard feature naming convention and a standard behavioral model for the devices. The main camera features will be defined by their name, access type, values and unit. A short description will be provided.

The access type can be:

- RO: Read Only
- RW: Read / Write

The full list of registers can be found in the Feature Reference Manual.

Please refer to the Feature Reference Manual

11.1. Device control

11.1.1. Basic device information

Some basic information about the device is available from SFNC registers.
For the documentation of all the registers please refer to the documentation "C-BLUE_2-FeatureReference".

Table 29: Description of the basic device information registers

Name	Access	Values	Description
DeviceScanType	RO	AreaScan	2D. sensor
DeviceModelName	RO	String	Model of the device
DeviceManufacturerInfo	RO	String	Manufacturer information about the device
DeviceVersion	RO	String	Version of the device
DeviceFirmwareVersion	RO	String	Version of the firmware in the device
DeviceSerialNumber	RO	String	Device serial number. This string is a unique identifier of the device.
DeviceUserID	RW	String	User-programmable device identifier.

11.1.2. Basic device control

Table 30: Description of the commands used to control the camera's state

Name	Access	Values	Description
DeviceReset	WO	Command	Resets the device. After reset, the device must be rediscovered.
DeviceShutdown	WO	Command	Turns the device off.

11.1.3. Temperature control

The temperature of the camera can be monitored thanks to several measurement probes.

Table 31: Description of the SFNC registers associated to temperature control

Name	Access	Value	Description
`DeviceTemperatureSelector`	RW	`Sensor, CPU, Power, Frontend, Heatsink, Case`	Temperature of the defined part
`DeviceTemperature`	RO	Float	Device temperature in degrees Celsius. It is measured at the location selected by `DeviceTemperatureSelector`.
`DeviceTecSelector`	RW	`TEC1`	Primary TEC
`DeviceTecVoltage`	RO	Float	Voltage applied to TEC in volts. Measured at the TEC selected using `DeviceTecSelector`.
`DeviceTecCurrent`	RO	Float	Current consumed by the TEC in Amperes. Measured at the TEC selected using `DeviceTecSelector`.
`DeviceTecPower`	RO	Float	TEC power consumption in Watts. Measured at the TEC selected using `DeviceTecSelector`.
`DeviceFanMode`	RW	`Automatic Manual`	The fan speed is controlled by the user or automatically.
`DeviceFanSpeed`	RW	Integer	Selects the speed of the fan in manual mode.
`DeviceCoolingEnable`	RW	Boolean	Controls if the sensor cooling is enabled.
`DeviceCoolingSetpoint`	RW	Float	Specifies the sensor temperature target when cooling is enabled

11.2. Acquisition Control

11.2.1. Basic commands

The acquisition mode and the commands available to control the acquisition are the following.

Table 32: Description of the acquisition control registers

Name	Access	Value	Description
`AcquisitionMode`	RW	`Continuous`	The frames are captured continuously until stopped with the `AcquisitionStop` command.
`AcquisitionStart`	RW	*Command*	Starts the Acquisition of the device. The number of frames captured is specified by `AcquisitionMode`.
`AcquisitionStop`	RW	*Command*	Stops the Acquisition of the device at the end of the current Frame.

11.2.2. Integration time and framerate

The minimum/maximum frame rates and exposure durations depends on the sensor configuration and are accessible using the following registers

Table 33: Description of the integration time and framerate controls

Name	Access	Value	Description
`ExposureMode`	RW	`Timed`	Exposure duration is controlled using `ExposureTime` register.
		`TriggeredControlled`	Exposure duration is controlled using trigger signals.
`ExposureTime`	RW	Use min and max GenICam properties to get the allowed range.	Sets the Exposure time (in µs) when `ExposureMode` is Timed. This controls the duration where the photosensitive cells are exposed to light.
`AcquisitionFrameRate`	RW	Use min and max GenICam properties to get the allowed range.	Controls the acquisition rate (in Hz) at which the frames are captured.

11.2.3. Trigger mode

This section describes how to use Andor CB2 triggers and the related set of registers.

Andor CB2 camera trigger implementation closely follows GenICam and SFNC specifications, with some limitations.

The camera supports four trigger modes associated with their own, independent settings.

- `AcquisitionStart` and `AcquisitionEnd` handle continuous acquisitions of frames.
- `FrameBurstStart` and `FrameBurstEnd` handle the acquisition of a fixed number of frames. The burst size is indicated in the `AcquisitionBurstFrameCount` register.
- `FrameStart` handles acquisitions of single frames.
- `ExposureStart` and `ExposureEnd` also handle the acquisition of single frames. `ExposureStart` starts the exposition of a frame, until an `ExposureEnd` trigger occurs.

11.2.3.1. Trigger behavior

For example, to change the polarity of the `FrameBurstStart` trigger, you must first set the `TriggerSelector` register to the value "`FrameBurstStart`", then change the value of the register `TriggerActivation`. This new configuration will only apply to the `FrameBurstStart` trigger, thus changing the value of the `TriggerSelector` register will also update the value of the `TriggerActivation` register.

When using triggers, please keep in mind that they are specific to an acquisition mode.
In addition, once all the trigger registers are set up, you must first send the `AcquisitionStart` command to enable the use of the triggers. Without this command, triggers simply will not work.

Once the `AcquisitionStart` command is sent, the camera's CoaXPress® LED blinks orange, indicating that the camera is waiting for a trigger. At this stage, a trigger signal sent to the camera will be processed.

When generated, each "`Start`" trigger starts a corresponding acquisition. Each corresponding "`End`" trigger will interrupt it. Note that as long as the `AcquisitionStop` command is not sent, multiple trigger start/end sequence can be sent.

11.2.3.2. Example use of triggers

In this section, an example of using triggers with the SFNC registers is provided.

We will configure an acquisition of 10 frames, which are taken after a delay of 10 µs when the user requests them via the `TriggerSoftware` register. We will also implement the possibility of interrupting the capture of these 10 frames with a falling edge on the LEMO0 connector.

11.2.3.2.1. Trigger setup sequence

Start by setting up the trigger as mentioned above. The following sequence must be used:

`TriggerSelector`: `FrameBurstStart`
`TriggerMode`: `On`
`TriggerSource`: `Software`
`TriggerDelay`: `10`
`TriggerSelector`: `FrameBurstEnd`
`TriggerMode`: `On`
`TriggerSource`: `Line0`
`TriggerActivation` : `FallingEdge`
`AcquisitionburstFrameCount`: `10`

11.2.3.2.2. Using the configured triggers

Now we want to grab 2 full bursts, one interrupted and one uninterrupted. To do so, the following sequence must be used:

`AcquisitionStart`: Execute Command
`TriggerSelector`: `FrameBurstStart`
`TriggerSoftware`: Execute Command
(10 frames are sent)
`TriggerSoftware`: Execute Command
(10 frames are sent)
`TriggerSoftware`: Execute Command
(Some frames are sent)
Apply a falling edge on the LEMO0 line
(The full burst has not been sent)
`TriggerSoftware`: Execute Command
(10 frames are sent)
`AcquisitionStop`: Execute Command

The sequence is illustrated below:

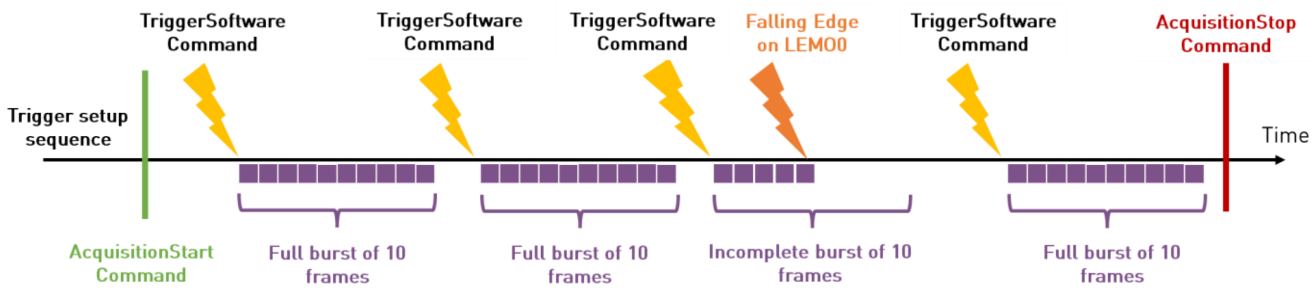


Figure 19: Illustration of the trigger sequence

11.2.4. Trigger registers

The registers used to configure the various triggers are the following.

Table 34: Description of the trigger control registers

Name	Access	Values	Description
`TriggerSelector`	RW	`AcquisitionStart`	Selects the trigger used to start a continuous acquisition of frames.
		`AcquisitionEnd`	Selects the trigger used to stop a continuous acquisition of frames.
		`FrameBurstStart`	Selects the trigger used to start an acquisition of N frames. The number of frames acquired for each occurrence of the current trigger is specified using the `AcquisitionBurstFrameCount` register.
		`FrameBurstEnd`	Selects the trigger used to stop the current acquisition of N frames.
		`FrameStart`	Selects the trigger used to start an acquisition of a single frame.
		`FrameEnd`	Not implemented
		`ExposureStart`	Selects the trigger used to start the exposure of a single frame acquisition.
		`ExposureEnd`	Selects the trigger used to stop the exposure of a single frame acquisition. The frame is automatically read once the exposure is finished.
`TriggerMode [TriggerSelector]`	RW	`ON`	The selected trigger is enabled
		`OFF`	The selected trigger is disabled
`TriggerSource [TriggerSelector]`	RW	`Software`	The selected trigger will be generated using the *TriggerSoftware* command.
		`Line0`	The selected trigger will be sent through the *Source Trigger in 0* pin of the LEMO I/O connector.
		`Line1`	The selected trigger will be sent through the *Source Trigger in 1* pin of the LEMO I/O connector.
		`LinkTrigger0`	The selected trigger will be sent through the master CoaXPress cable.
`TriggerActivation [TriggerSelector]`	RW	`RisingEdge`	The selected trigger will trigger on a rising edge of the input signal.
		`FallingEdge`	The selected trigger will trigger on a falling edge of the signal.
`TriggerDelay [TriggerSelector]`	RW	0 – 2147.10^6 microseconds	The selected trigger will be applied after a delay of this register's value microseconds
`TriggerSoftware [TriggerSelector]`	WO	Command	Sends a software rising edge trigger if the selected trigger is a start trigger. Otherwise sends a software falling edge trigger.

Note 1: The trigger mode of a given trigger must be ON to change its source. This rule is set to be SFNC compliant.

Note 2: When a trigger is activated, the only other trigger that can be activated is its counterpart. For example, if `AcquisitionStart` is ON, the only other trigger that can be enabled is `AcquisitionEnd`.

Note 3: The polarity of the start and stop cannot be set on the same edge of the same source. If they are, the `TriggerStopPolarity` will automatically be opposed when starting the acquisition.

Note 4: A trigger start can be enabled without its trigger counterpart being ON. A capture can then be started using a trigger, and the stopping condition will depend on the type of acquisition :

- `AcquisitionStart`: The acquisition will continue until manually stopped,
- `FrameBurstStart`: The acquisition will end `AcquisitionBurstFrameCount` frames have been acquired.
- `ExposureStart`: `ExposureStop` is required.

Note 5: When the external trigger mode is used, the maximum framerate is lower because of the introduced jitter. In full frame, this only accounts for a decrease of a few FPS. The exact value can be retrieved from the `MaximumExternalAcquisitionFrameRate` register, which is updated when the external synchronization is enabled.

For all trigger modes, triggering will only be available after an AcquisitionStart command is issued.

11.2.4.1. AcquisitionStart

This mode captures frames at the rate indicated by the `AcquisitionFrameRate` register, exposed according to the `ExposureTime` register.
Below is an example of the output through the LEMO connector when using this trigger.

Configuration sequence:

- ***TriggerSelector:*** *AcquisitionStart*
- ***TriggerMode:*** *ON*
- ***TriggerSource:*** *Line0*
- ***TriggerActivation:*** *RisingEdge*
- ***TriggerDelay:*** *0*

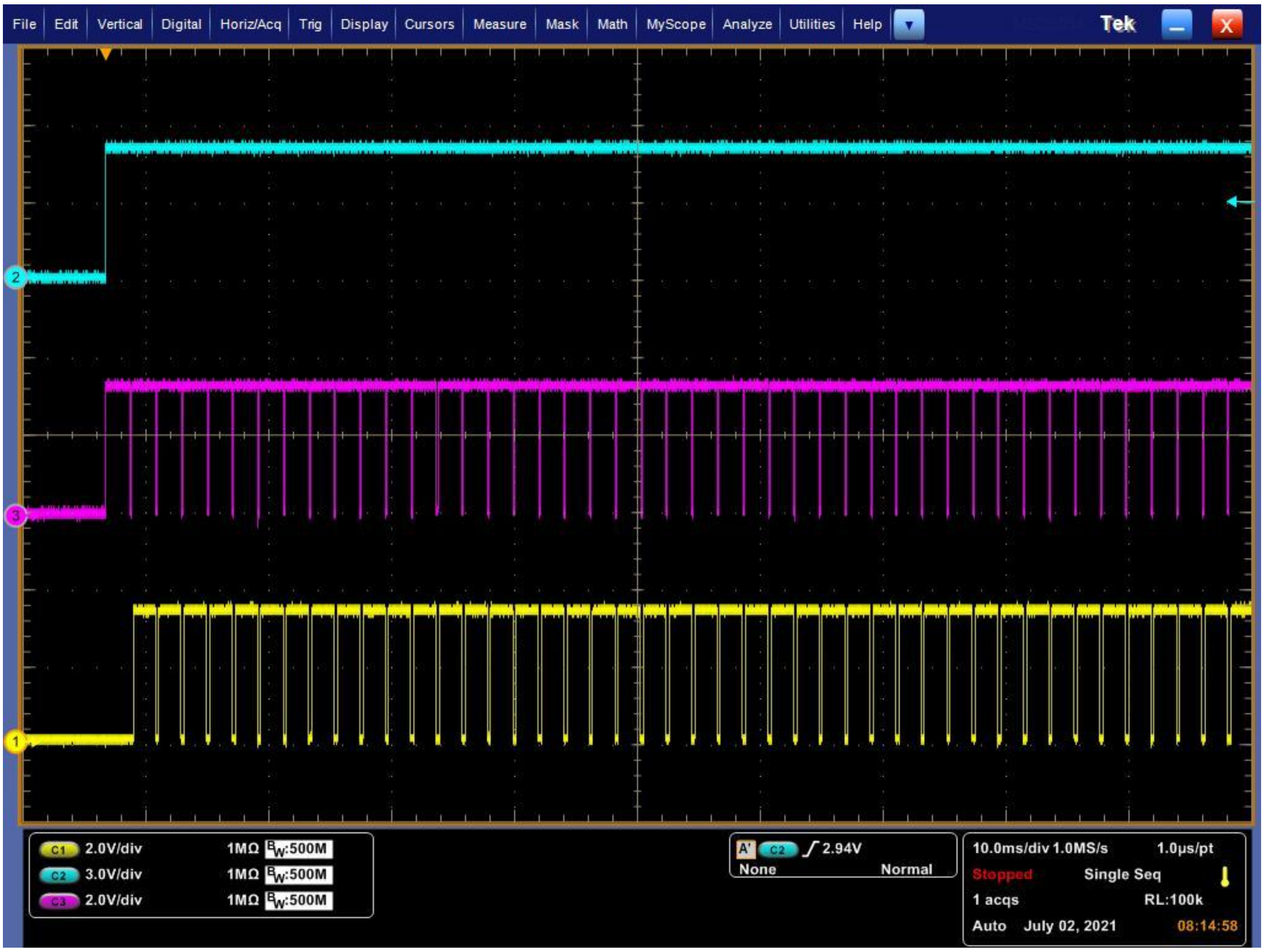


Figure 20: Example of AcquisitionStart

Legend : Blue = AcquistionStart (Line0) ;Pink = SENSOR_EXPOSURE ; Yellow = SENSOR_READOUT

11.2.4.2. AcquisitionEnd

Configuration sequence:

- ***TriggerSelector:*** *AcquisitionEnd*
- ***TriggerMode:*** *ON*
- ***TriggerSource:*** *Line0*
- ***TriggerActivation:*** *FallingEdge*
- ***TriggerDelay:*** *0*

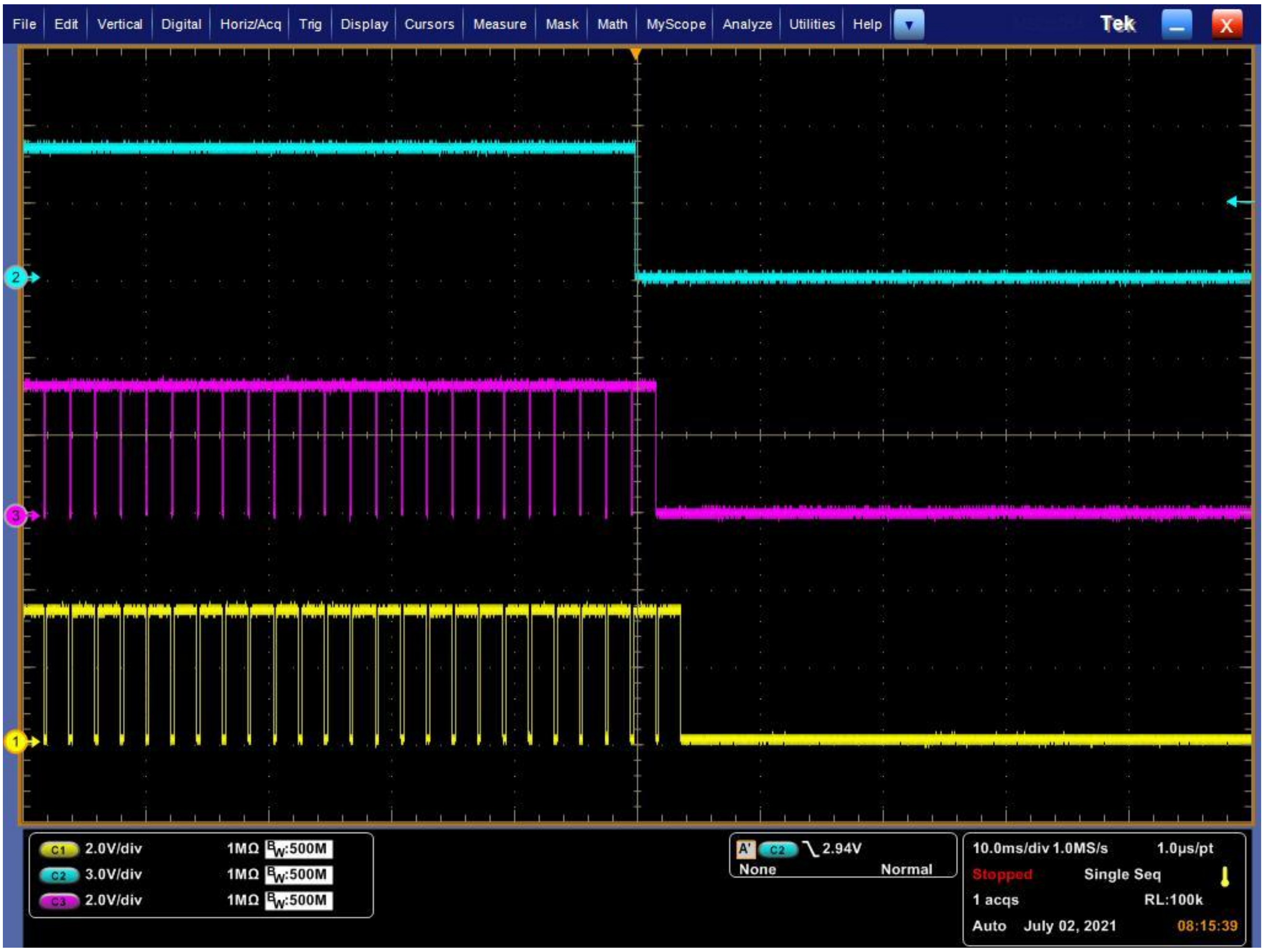


Figure 21: Example of AcquisitionStop

Legend : Blue = AcquistionStop (Line0) ; Pink = SENSOR_EXPOSURE ; Yellow = SENSOR_READOUT

11.2.4.3. FrameBurstStart

This mode captures the number of frames indicated by the `AcquisitionFrameCount` register at the rate indicated by the `AcquisitionFrameRate` register, exposed according to the `ExposureTime` register.

Below is an example of the output through the LEMO connector when using this trigger.

Configuration sequence:

- ***TriggerSelector:*** *FrameBurstStart*
- ***TriggerMode:*** *ON*
- ***TriggerSource:*** *Line0*
- ***TriggerActivation:*** *RisingEdge*
- ***TriggerDelay:*** *0*
- ***TriggerSelector:*** *FrameBurstStop*
- ***TriggerMode:*** *OFF*
- ***AcquisitionFrameCount:*** *10*

Figure 22: Example of FrameBurstStart

Legend : Blue = FrameBurstStart (Line0) ; Pink = SENSOR_EXPOSURE ; Yellow = SENSOR_READOUT

11.2.4.4. FrameBurstStart + FrameBurstEnd

Settings sequence:

- ***TriggerSelector:*** *FrameBurstStart*
- ***TriggerMode:*** *ON*
- ***TriggerSource:*** *Line0*
- ***TriggerActivation:*** *RisingEdge*
- ***TriggerDelay:*** *0*
- ***TriggerSelector:*** *FrameBurstEnd*
- ***TriggerMode:*** *ON*
- ***TriggerSource:*** *Line0*
- ***TriggerActivation:*** *FallingEdge*
- ***TriggerDelay:*** *0*
- ***AcquisitionFrameCount:*** *10000*

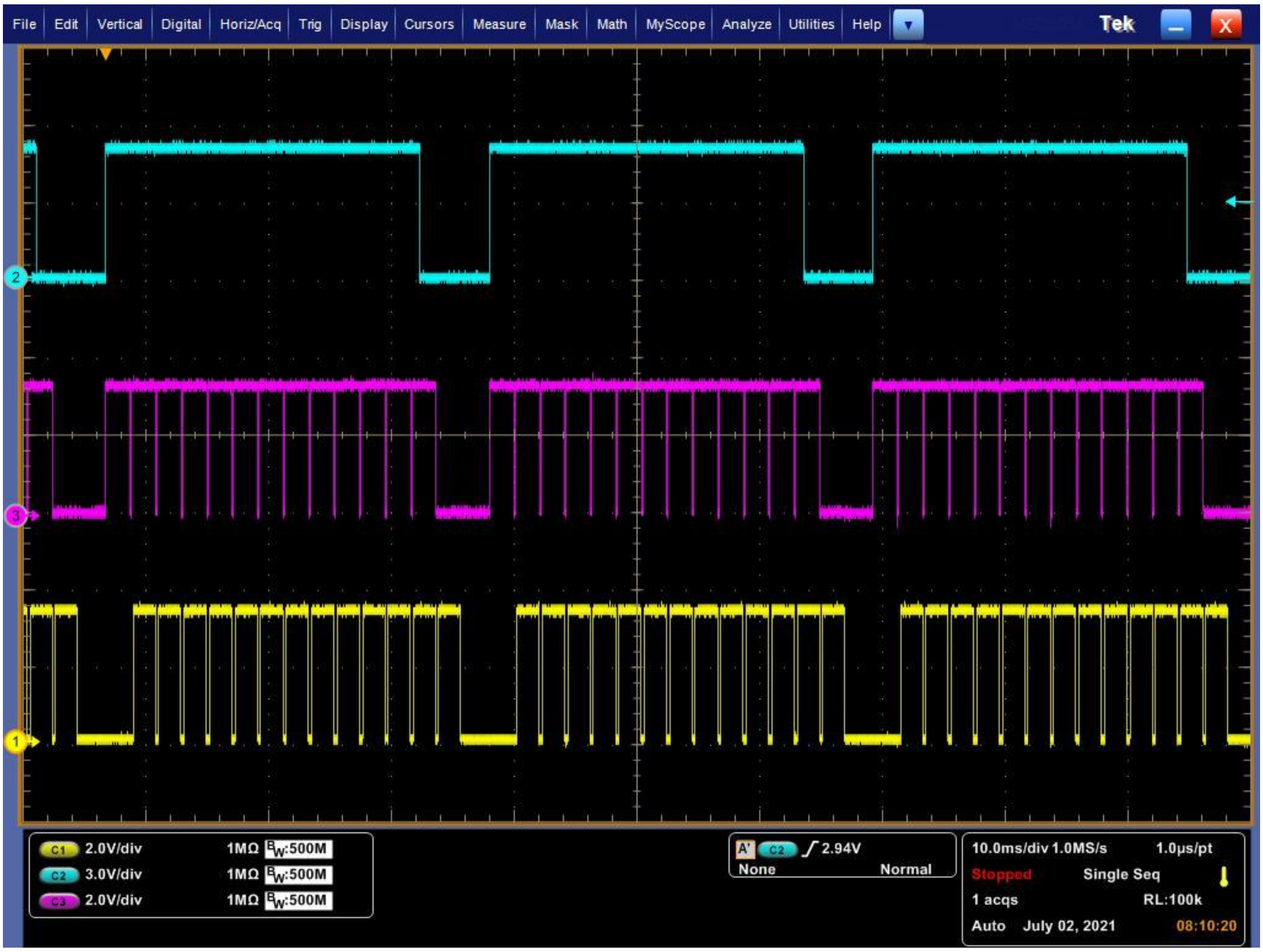


Figure 23: Example of FrameBurstStart + FrameBurstStop

Legend : Blue = FrameBurstStart (Line0) + FrameBurstEnd (Line0); Pink = SENSOR_EXPOSURE ; Yellow = SENSOR_READOUT

11.2.4.5. FrameStart

This mode captures frames exposed according to the `ExposureTime` register.
The value of the `MaximumExternalAcquisitionFrameRate` register is the maximum trigger frequency allowed by the camera.

Below is an example of the output through the LEMO connector when using this trigger.

Configuration sequence:

- ***TriggerSelector:*** *FrameStart*
- ***TriggerMode:*** *ON*
- ***TriggerSource:*** *Line0*
- ***TriggerActivation:*** *RisingEdge*
- ***TriggerDelay:*** *0*

Figure 24: Example of FrameStart

Legend : Blue = FrameStart (Line0); Pink = SENSOR_EXPOSURE ; Yellow = SENSOR_READOUT

11.2.4.6. ExposureStart/ExposureEnd

This mode starts exposing a frame on an `ExposureStart` trigger and stops on an `ExposureEnd` trigger.
The value of the `MaximumExternalAcquisitionFrameRate` register is the maximum trigger frequency allowed by the camera.
The value of the `MinimalExternalExposureTime` register is the minimum time that must be respected between an `ExposureStart` and `ExposureEnd` trigger.

Below is an example of the output through the LEMO connector when using this trigger.

Configuration sequence:

- ***TriggerSelector:*** *ExposureStart*
- ***TriggerMode:*** *ON*
- ***TriggerSource:*** *Line0*
- ***TriggerActivation:*** *FallingEdge*
- ***TriggerDelay:*** *0*
- ***TriggerSelector:*** *ExposureEnd*
- ***TriggerMode:*** *ON*
- ***TriggerSource:*** *Line0*
- ***TriggerActivation:*** *RisingEdge*
- ***TriggerDelay:*** *0*

Figure 25: First example 1 of ExposureStart/ExposureEnd

Legend : Blue – ExposureStart (FalingEdge Line0) + ExposureStop (RisingEdge Line0); Pink – SENSOR_EXPOSURE; Yellow – SENSOR_READOUT

Figure 26: Second example of ExposureStart/ExposureEnd

Legend : Blue – ExposureStart (FallingEdge Line0) + ExposureStop (RisingEdge Line0); Pink – SENSOR_EXPOSURE; Yellow – SENSOR_READOUT

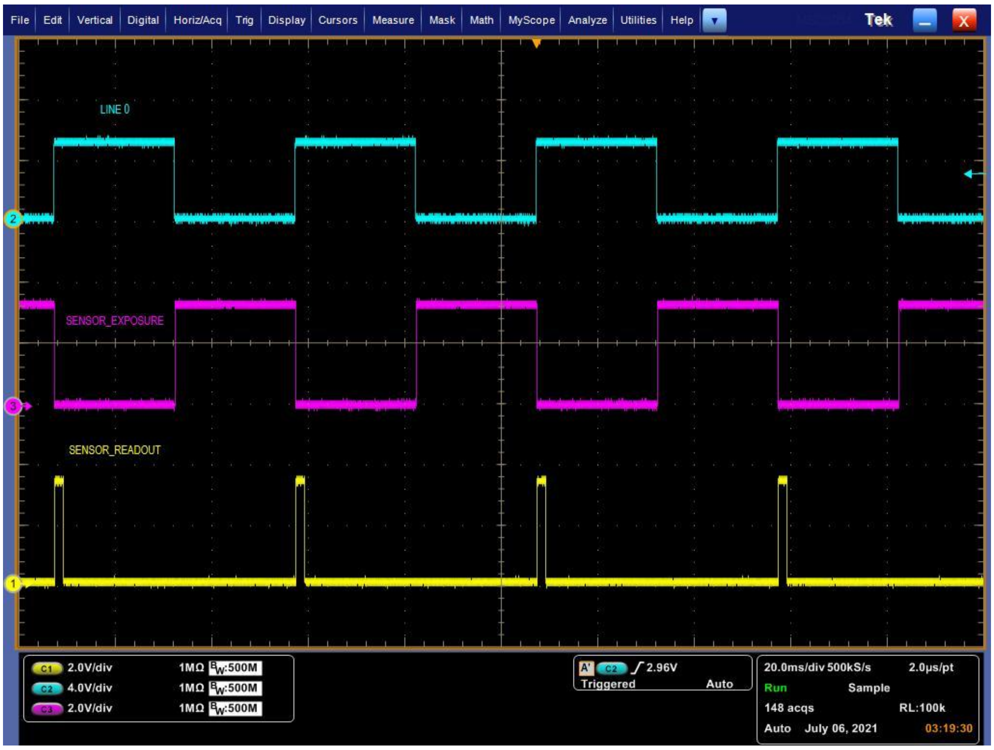


Figure 27: Third example of ExposureStart/ExposureEnd

Legend : Blue – ExposureStart (FallingEdge Line0) + ExposureStop (RisingEdge Line0); Pink – SENSOR_EXPOSURE; Yellow – SENSOR_READOUT

When the exposition of the sensor is controlled with the ExposureStart and ExposureEnd triggers, two consecutives ExposureEnd trigger must not occur at a faster rate than the value specified in **`MaximumExternalAcquisitionFrameRate`** *register.*
Sensor frame output is disabled after at most 10 wrong consecutives ExposureEnd.
Sensor frame output is re-enabled after at most 10 correct consective ExposureEnd.

11.2.4.7. Trigger timings

This section will detail timings related to the triggers. The timing diagram is shown below :

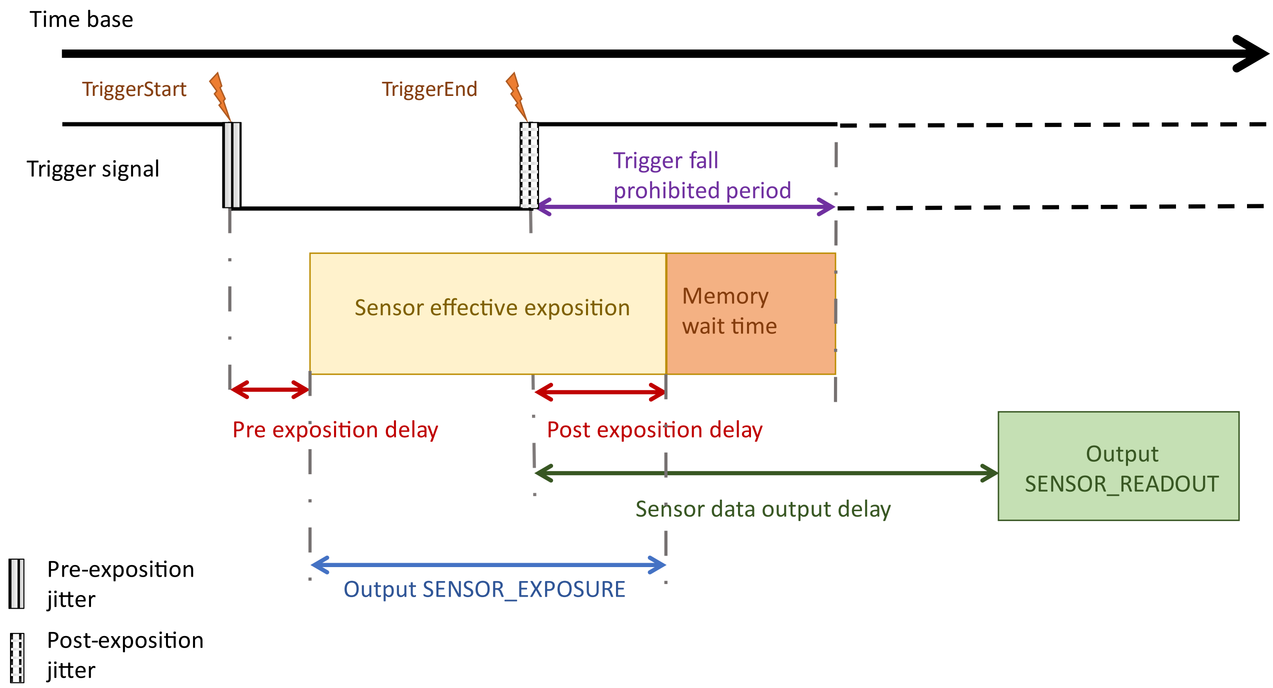


Figure 28: Sensor effective exposition datagram

Note: When the sensor uses a trigger, there is a delay before the start of the exposition, and another delay before the end of the exposition.

The "Trigger fall prohibited period", in purple; is the minimum acceptable time between a *`TriggerEnd`* and a following *`TriggerStart`*. It depends on the post exposition delay, and the memory wait time. The memory wait time cannot be read from the sensor.
The *`TriggerEnd`* must not occur before a full sensor readout.

The "Sensor data output delay" is the latency between *`TriggerEnd`* and the sensor readout.

In addition to the delay, a jitter is present when integration starts. This jitter comes from the sampling of the input trigger signal, which is aligned to line multiples. The same jitter is present at the end of integration if the trigger mode used drives the integration time too.

The following table gives the trigger delay, using the generic H unit. The H unit value depends on the sensor, the pixel format and the mode of operation of the camera (CoaXPress® or GigE Vision).

Table 35: Generic timings for trigger

	IMX530			IMX530 (BINNED)		
	8 bits	**10 bits**	**12 bits 16bits**	**8 bits**	**10 bits**	**12 bits**
Pre-exposition delay	16 H			32 H		24 H
Post-exposition delay	16 H + 2.46 µs			8 H + 2.46 µs		24 H + 2.46 µs
Pre-exposition jitter	1 H					
Pre + Post exposition jitter	2 H					
TriggerFall prohibited period	45 H		37 H	89 H		65 H
Sensor data output delay	65 H		57 H	105 H		81 H

Table 36: H unit value, for CoaXPress® operation

	IMX530				IMX530 BINNED		
	Mono8	Mono10	Mono12	Mono16	Mono8	Mono10	Mono12
H value (µs)	1.952	2.033	2.814	2.814	1.023	1.090	1.414

Table 37: IMX530 Typical H unit value, for GigE® operation

IMX530						
	Mono8	Mono10	Mono10 Packed	Mono12	Mono12 Packed	Mono16
H value (µs)	4.309	8.606	6.451	8.606	6.451	4.423

Table 38: IMX530 (BINNED) Typical H unit value, for GigE® operation

IMX530 BINNED					
	Mono8	Mono10	Mono10 Packed	Mono12	Mono12 Packed
H value (µs)	2.101	4.175	3.138	4.188	3.138

Figure 29: Example of the 12bits pre-exposition delay, here 14.39 µs

Figure 30: Example of the 12bits post exposition delay, here 18.30 µs

Figure 31: Example of the 12bits sensor data output delay, here 187.00 µs

11.3. Basic Image Format Control

The Image Format Control register contains the features related to the format of the transmitted images.

11.3.1. Sensor format

The dimensions of the sensor and pixels depend on the sensor and are provided by the following registers.

Table 39: Description of the sensor characteristics registers

Name	Access	Values	Description
`SensorWidth`	RO	xxx	Effective width of the sensor in pixels.
`SensorHeight`	RO	xxx	Effective height of the sensor in pixels.
`SensorPixelWidth`	RO	xxx µm	Physical size (pitch) in the x direction of a photo sensitive pixel unit.
`SensorPixelHeight`	RO	xxx µm	Physical size (pitch) in the y direction of a photo sensitive pixel unit.
`SensorShutterMode`	RO	Global	The shutter opens at the same time for all pixels but ends in a sequential manner. The pixels are exposed for different lengths of time.
`WidthMax`	RO	xxx	Maximum width of the image (in pixels). The dimension is calculated after horizontal binning, decimation or any other function changing the horizontal dimension of the image.
`HeightMax`	RO	xxx	Maximum height of the image (in pixels). This dimension is calculated after vertical binning, decimation or any other function changing the vertical dimension of the image.

11.3.2. Pixel bit depth

The sensor has a configurable 8-, 10- or 12-bits integrated Analog/Digital converter.

The sensor also supports a dual ADC mode, used by the camera to create HDR images, transferred using 16-bits values.

The choice of pixel bit depth influences the maximum achievable framerate.

The pixel format is selected using the standard *SFNC* `PixelFormat` register.

Table 40: Description of the pixel format control using the CoaXPress protocol

Name	Access	Values	Description
PixelFormat	RW	*Mono8,* *Mono10,* *Mono12,* *Mono16*	Monochrome 8-bits, Monochrome 10-bits, Monochrome 12-bits, Monochrome 16-bits (HDR)

Table 41: Description of the pixel format control using the GigE Vision protocol

Name	Access	Values	Description
PixelFormat	RW	*Mono8,* *Mono10,* *Mono10Packed,* *Mono12,* *Mono12Packed,* *Mono16*	Monochrome 8-bits Monochrome 10-bits unpacked Monochrome 10-bits packed Monochrome 12-bits unpacked Monochrome 12-bits packed Monochrome 16-bits (HDR)

Note: Modification of the pixel format reverts many registers to their default value.

Table 42: Pixel formats description

Pixel format	Bit depth	Number format	Storage
Mono8	8-bits	Unsigned integers	Unpacked
Mono10	10-bits	Unsigned integers	Unpacked
Mono10Packed	10-bits	Unsigned integers	Packed
Mono12	12-bits	Unsigned integers	Unpacked
Mono12Packed	12-bits	Unsigned integers	Packed
Mono16	16-bits	Unsigned integers	Unpacked

11.3.3. HDR Mode

HDR mode is implemented through the Dual ADC feature of the sensor, using 12-bits quantization and a difference of 24 dB of analog gain between the two ADC.

The camera can be configured to send the raw image sent by the sensor, or to process it to send a single combined image.

In RAW HDR mode, the image sent by the camera has twice the number of lines provided by the sensor's geometry.

Odd lines correspond to pixels acquired using no analog gain.
Even lines correspond to pixels acquired using 24dB analog gain.

In standard HDR mode, the image sent by the camera has the same number of lines as the sensor.

Due to the difference of 24dB between the two ADCs, which roughly corresponds to a x16 gain, the resulting image is sent using a 16-bits pixel format.

Depending on the level of illumination of a pixel, the resulting pixel value is computed differently.

The result of the conversion performed by the ADC associated to the 24 dB gain is used to classify the pixels as either dimly lit, highly lit or intermediately lit.

- Dimly lit pixels are pixels that are below one quarter of the full ADC range. The resulting pixel value is the value returned by the 24 dB ADC conversion.
- Highly lit pixels are pixels that are above three quarters of the full ADC range. The resulting pixel value is the value returned by the 0 dB ADC conversion, multiplied by 15.85 (corresponding to a 24 dB gain).
- Intermediately lit pixels are pixels that are neither dimly nor highly lit. The resulting pixel value is interpolated between the two ADC conversions.

Activation of the HDR feature of the sensor is done by selecting the `Mono16` pixel format.
Selection of the HDR mode is done using the `HDRMode` register.

- When set to `Standard`, the camera sends the combined HDR image.
- When set to `Raw`, the camera sends the raw image from the sensor.
- When set to `Low`, the camera sends the odd lines of the raw image of the sensor (meaning pixels converted without any analog gain).
- When set to `High`, the camera sends the even lines of the raw image of the sensor (meaning pixels converted with a 24 dB analog gain).

Note : Independently from the HDR mode selection, pixels are always sent using the 16 bits pixel format. The `Standard` mode uses the full 16 bits range while the other formats only use 12 bits values, leaving the 2 additional bits unused.

When the camera is operating in 16 bits HDR mode, no extra analog gain can be set.

11.4. Analog control

11.4.1. Analog and digital gains

When operated in 8-, 10- and 12-bits pixel format mode, the sensor has a configurable gain up to 48 dB:

- 0 dB to 24 dB: Analog Gain (0.1 dB step)
- 24.1 dB to 48 dB: Digital Gain (0.1 dB step)

When operated in 16 bits HDR mode, the sensor has a configurable gain up to 24 dB:

- 0 dB to 24 dB : Digital Gain (0.1 dB step)

Analog gain is advantageous to reduce noise. Digital gain only multiplies pixels values without any effect on noise values.

Table 43: Description of the SFNC registers associated to gain management

Name	Access	Values	Description
`GainSelector`	RW	`AnalogAll`	Gain will be applied to all analog channels or taps.
		`DigitalAll`	Gain will be applied to all digital channels or taps.
`Gain`	RW	0-24 dB	Controls the selected gain as an absolute physical value. This is an amplification factor applied to the video signal.

11.4.2. Black level adjustment

The SONY IMX530-AAMJ-C sensor integrates a function of automatic black adjustment which is an on-chip sensor bias correction. When black level adjustment is enabled, the sensor uses Optical Black (OB) pixels as a level reference for black pixels. This reference level is then subtracted to all other pixels (non-Optical Black pixels) to ensure that these pixels return a fixed value when put in the dark.

The control of the black level adjustment is done using SNFC *BlackLevelAuto* register.

Table 44: Description of the black level auto adjustment

Name	Access	Values	Description
`BlackLevelSelector`	RW	`All`	Black Level will be applied to all channels or taps.
`BlackLevel`	RW		Controls the analog black level as an absolute physical value. This represents the DC offset applied to the video signal.
`BlackLevelAuto`	RW	`OFF`	Black level adjustment is disabled.
		`Continuous`	The black level adjustment is enabled. 8 bits conversion: black level is set to 15. 12 bits conversion: black level is set to 240.

Note: By default, the black level auto adjustment is enabled.

11.5. Camera presets

The camera contains factory-defined user sets, corresponding to generic use cases. In addition, Andor CB2 can store up to ten custom user configurations. These user sets can be used to switch easily from one configuration to another.

The user set management of the camera is compliant with SFNC.

Table 45: User set control

Name	Access	Value	Description

`UserSetSelector`	RW	`Default8bits`
		`Default10bits`
		`Default12bits`
		`HighSensitivity8bits`
		`HightSensitivity10bits`
		`HighSensitivity12bits`
		`UserSet0`, …, `UserSet9`
			Selection of the preset

`UserSetDefault`	RW	Command	Selection of the user set loaded at camera startup
`UserSetLoad`	RW	Command	Loads the preset specified by the selector to the device and makes it active.
`UserSetSave`	RW	Command	Save the current configuration in the preset selected by `UserSetSelector.`

Note: A factory user set can only be loaded, not saved.

The factory presets are currently defined as:

Table 46: Factory presets in full frame

Factory preset name	Framerate (fps)	Bit depth (bits)	Analog gain (dB)	Digital gain (dB)
`Default8Bits`	FPS_{max}	8	0	0
`HighSensitivity8bits`	FPS_{max}	8	24	0
`Default10Bits`	FPS_{max}	10	0	0
`HighSensitivity10bits`	FPS_{max}	10	24	0
`Default12bits`	FPS_{max}	12	0	0
`HighSensitivity12bits`	FPS_{max}	12	24	0

Note: There are currently no factory presets using HDR mode. It can simply be enabled by changing the Pixel Format to *Mono16.*

11.6. Region of interests

The sensors support up to 64 Regions of Interest (ROIs). The CoaXPress® specifies that data associated to different ROIs must be sent using different data streams, but none of the grabbers tested in our lab is able to handle 64 streams.

To bypass this limitation, all the ROIs data are sent in a single stream which should be handled properly by any CoaXPress® grabber. When using a single ROI, the definition of the ROI is totally compatible with the CoaXPress® standard. To handle multiple ROIs, custom registers have been added.

The same mechanism has been kept when the camera is controlled using GigE Vision protocol.

11.6.1. Single ROI support

When a single ROI is defined, the data sent by the camera corresponds to a contiguous rectangular area of the sensor, as illustrated in Figure 32:.

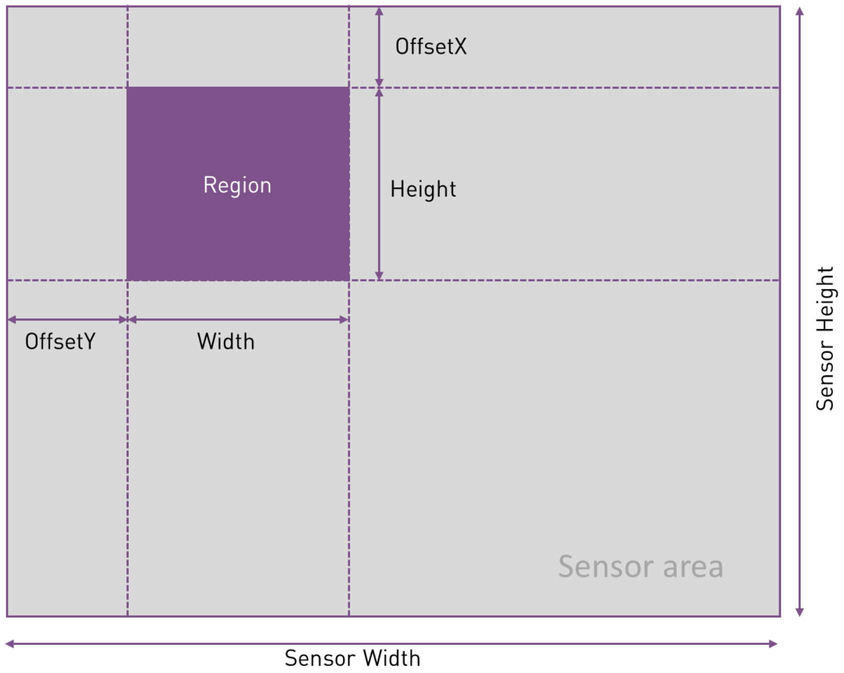


Figure 32: Definition of a single ROI.

<u>Rules for IMX530</u>

When binning is disabled:

- The width of the ROI must be multiple of 16 columns, the height of 16 lines.
- The position of the ROI must be aligned on 16 columns and 16 rows boundaries.

When binning is enabled:

- The width of the ROI must be multiple of 8 columns, the height of 8 lines.
- The position of the ROI must be aligned on 8 columns and 8 rows boundaries.

To define a single ROI, set the proprietary `Sparse` register to OFF, then use standard `Width`, `Height`, `OffsetX` and `OffsetY` SFNC registers to define the ROI.

Note: The SFNC `RegionMode` is read only and always TRUE.

Table 47: Description of the SFNC registers associated to single ROI support (without binning)

Name	Access	Values	Description
`Sparse`	RW	ON/ OFF (Boolean)	Controls whether the region is contiguous or split in different areas.
`Width`	RW	16, 32, …, WidthMax	Width of the image provided by the device (in pixels).
`Height`	RW	16, 32, …, HeightMax	Height of the image provided by the device (in pixels).
`OffsetX`	RW	0, 16, …, WidthMax-16	Horizontal offset from the origin to the region of interest (in pixels).
`OffsetY`	RW	0, 16, …, HeightMax-16	Vertical offset from the origin to the region of interest (in pixels).

Table 48: Description of the SFNC registers associated to single ROI support (with binning)

Name	Access	Values	Description
`Sparse`	RW	ON/ OFF (Boolean)	Controls whether the region is contiguous or split in different areas.
`Width`	RW	8, 16, …, WidthMax	Width of the image provided by the device (in pixels).
`Height`	RW	8, 16, …, HeightMax	Height of the image provided by the device (in pixels).
`OffsetX`	RW	0, 8, …, WidthMax-8	Horizontal offset from the origin to the region of interest (in pixels).
`OffsetY`	RW	0, 8, …, HeightMax-8	Vertical offset from the origin to the region of interest (in pixels).

11.6.2. Multiple ROI support

The sensor allows to define different ROIs by selecting multiple sets of active columns and rows, the active area corresponding to the intersection of the defined ranges.

To define multiple ROIs, the proprietary `Sparse` register must be set to `TRUE`.
Note that once `Sparse` is set to `TRUE`, the standard registers `Width`, `Height`, `OffsetX`, `OffsetY` are read only and are automatically computed by the camera.

The user can define up to 8 sets of active columns and rows. This lets the user specify a total of 1, 4, 9, 16, or 64 areas.

The configuration of the active set of rows and columns intervals is done using the proprietary registers `SparseWidth`, `SparseHeight`, `SparseOffsetX` and `SparseOffsetY`. The register `SparseSelector` specifies which set of columns and rows is currently modified. Once configured, the set must be enabled using `SparseMode`.

Note that `SparseMode` is always `TRUE` for the first set of columns/rows.

The sets of columns/rows must be configured and activated in increasing order, *e.g.*, using `SparseSelector` to `Region0`, then `Region1` and so on. It is possible to activate the Nth set of columns only if all N-1 first sets have been enabled. Deactivation must be done in decreasing order.

Rules for IMX530 (normal mode)

- All ROIs must be aligned on 16 columns and 16 rows boundaries
- All ROIs width must be multiple of 16 columns
- All ROIs height must be multiple of 16 rows

Rules for IMX530 (binning mode)

- All ROIs must be aligned on 8 columns and 8 rows boundaries
- All ROIs width must be multiple of 8 columns
- All ROIs height must be multiple of 8 rows
- All ROIs must be separated: they cannot overlap

It is also possible to define up to 8 horizontal or 8 vertical ROIs.

- When defining horizontal ROIs, all ROIs have a fixed width, corresponding to the sensor width.
- When defining vertical ROIs, all ROIS have a fixed height, corresponding to the sensor height.

Table 49: Description of the SFNC registers associated to multiple ROI support

Name	Access	Values	Description
`SparseSelector`	RW	`Region0`, `Region1`, … , `Region7`	A selector is used to index which instance of the feature is accessed. The selected feature will control the sparse region #X.
`SparseMode`	RW	`Off`, `On`	Disable / enable the usage of the sparse area defined by the sparse selector.

Table 50: Description of the SFNC registers associated to multiple ROI support (without binning)

Name	Access	Values	Description
`SparseWidth`	RW	16, 32, …, WidthMax	Width of the sparse area (in pixels) defined by the sparse selector.
`SparseHeight`	RW	16, 32, …, HeightMax	Height of the sparse area (in pixels) defined by the sparse selector.
`SparseOffsetX`	RW	0, 16, …, WidthMax-16	Horizontal offset from the origin to the sparse area (in pixels) defined by the sparse selector.
`SparseOffsetY`	RW	0, 16, …, HeightMax-16	Vertical offset from the origin to the sparse area (in pixels) defined by the sparse selector.

Table 51: Description of the SFNC registers associated to multiple ROI support (with binning)

Name	Access	Values	Description
`SparseWidth`	RW	8, 16, …, WidthMax	Width of the sparse area (in pixels) defined by the sparse selector.
`SparseHeight`	RW	8, 16, …, HeightMax	Height of the sparse area (in pixels) defined by the sparse selector.
`SparseOffsetX`	RW	0, 8, …, WidthMax-8	Horizontal offset from the origin to the sparse area (in pixels) defined by the sparse selector.
`SparseOffsetY`	RW	0, 8, …, HeightMax-8	Vertical offset from the origin to the sparse area (in pixels) defined by the sparse selector.

Below are examples of the definition of multiple ROIs. Figure 33: shows the configuration in which multiple sets of full columns are selected. Figure 34: illustrates the case when multiple sets of lines are selected. Figure 35: is an example of the definition of multiple ROIs.

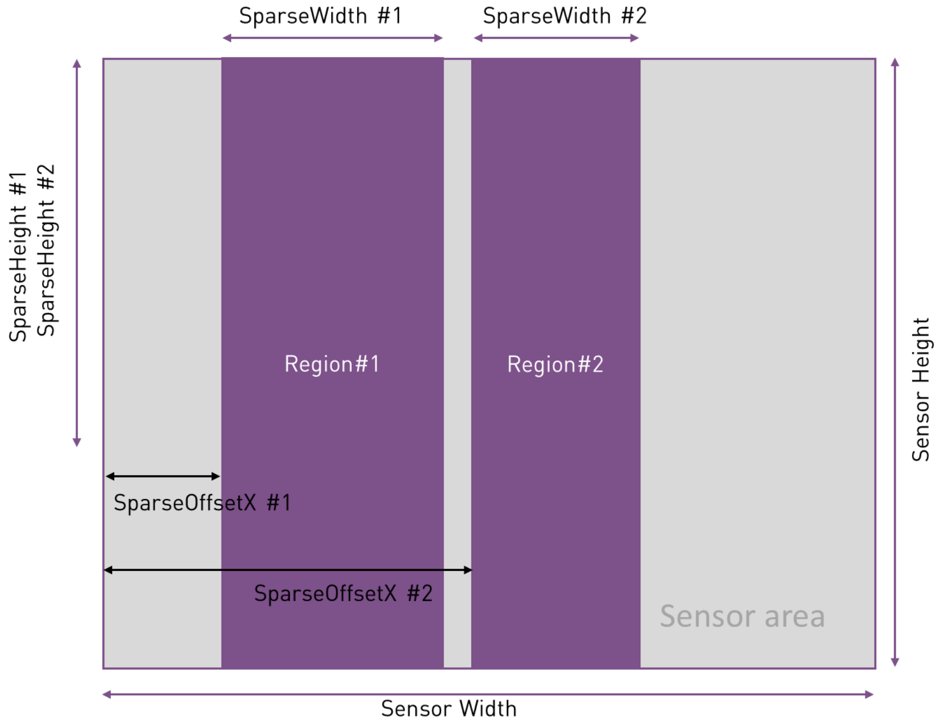


Figure 33: Example of 2 vertical ROIs, defined using 2 sets of active columns/rows.

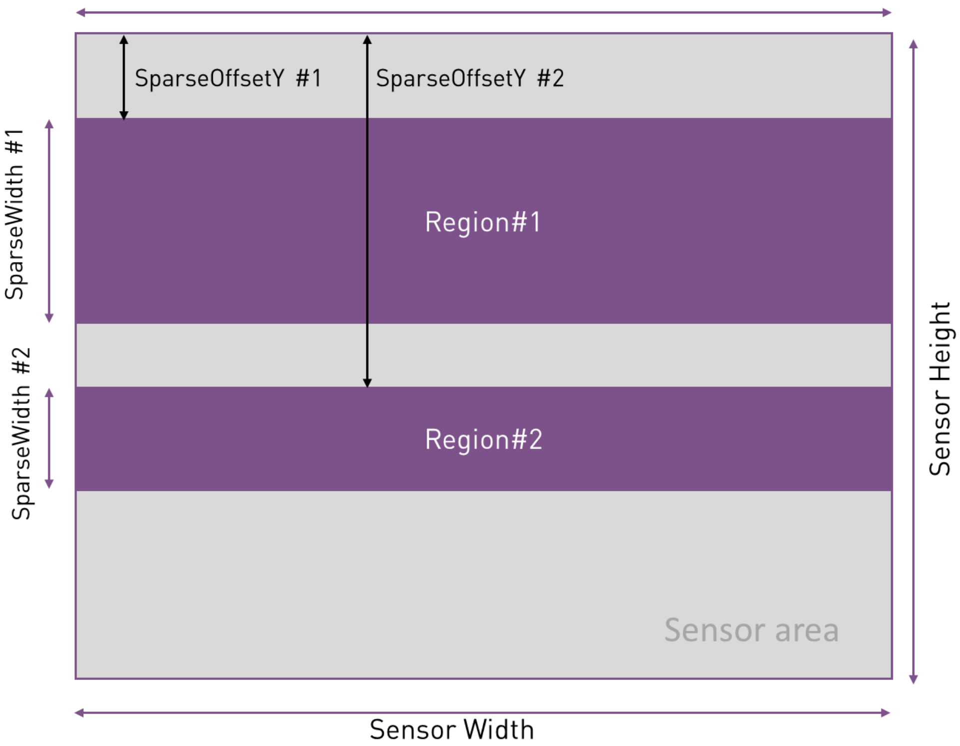


Figure 34: Example of 2 horizontal ROIs, defined using 2 sets of active columns/rows.

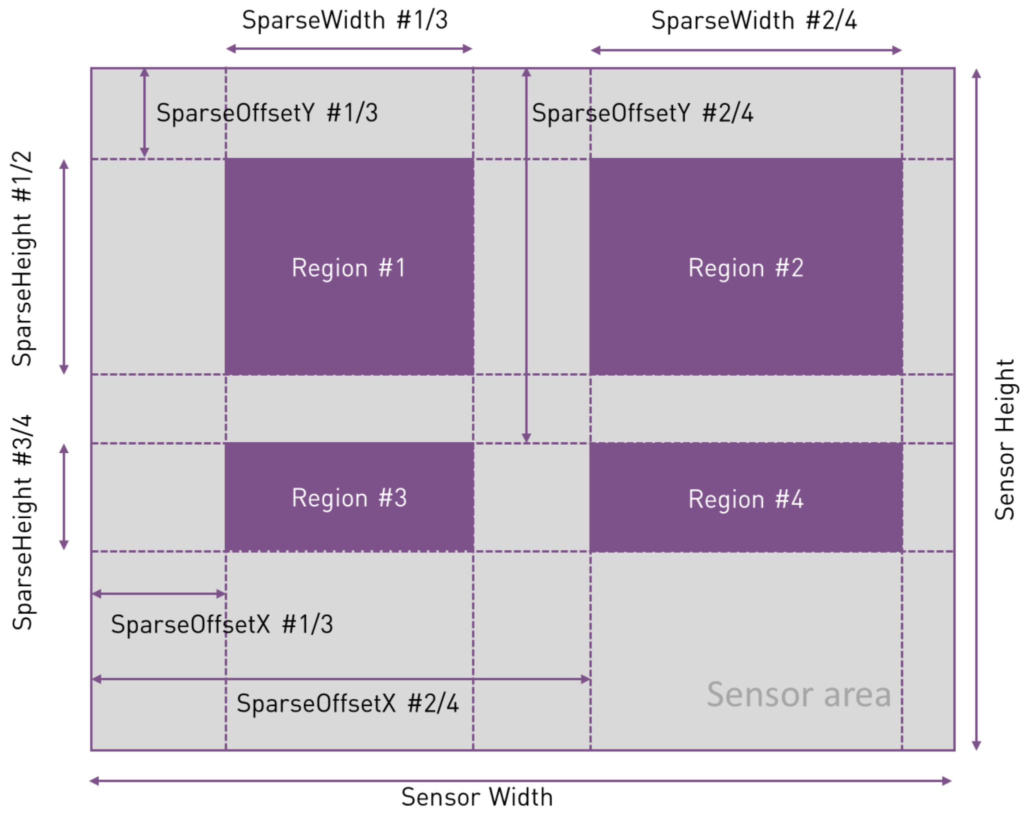


Figure 35: Example of definition of 4 ROIs, defined using two sets of rows and columns

All ROIs must be separated: they cannot overlap and cannot be adjacent. The figure below illustrates ROIs that cannot be defined once Region#1 is set.

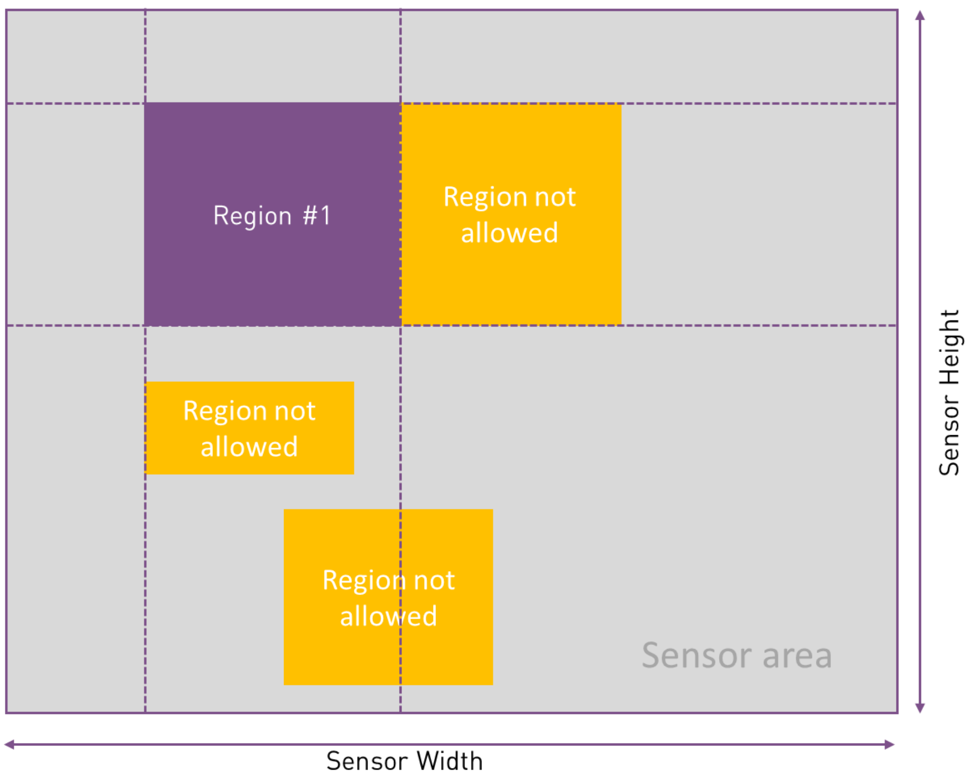


Figure 36: Example of ROIs that cannot be defined

11.6.3. Impact of the ROI on the acquisition frame rate

11.6.3.1. CoaXPress

When the camera is operated using CoaXPress® protocol, it can operate at the maximum frame rate supported by the sensor.

In this mode, due to the sensor's communication protocol, the acquisition frame rate can only be increased when the number of active **lines** is reduced. The number of columns does not affect the acquisition speed. The cropping granularity is described in the previous sections.

When a single ROI is defined, the number of active lines corresponds to the ROI height. When multiple ROIs are defined, the number of active lines is the sum of all ROIs height.

Table 52: Frame rates as a function of the number of lines when using CoaXPress

		IMX530			
		Quantization			
		8 bits	10 bits	12 bits	HDR
Lines	16	2560	2458	1973	1366
	32	2370	2276	1812	1216
	64	2064	1982	1558	997
	128	1641	1576	1216	734
	256	1163	1117	845	480
	512	735	706	525	283
	624	633	608	450	240
	1104	397	381	280	145
	2208	214	205	149	76
	4608	106	102	74	37

11.6.3.2. GigE Vision

When the camera is operated using GigE Vision protocol, the maximum framerate the camera can achieve may be lower than the theoretical maximum framerate achievable by the sensor due to bandwidth limitation.

In practice, this limitation is done by the camera by increasing the line readout intervals. When a cropping is configured horizontally, the necessary bandwidth to transfer the frames will thus decrease. This can result in a decrease of the line readout interval, which in turn results in higher achievable framerates.

The table below lists the maximum image width with which the sensor can perform at its theoretical maximum framerate when the camera is operated through GigE Vision. Highlighted values correspond to reduced geometries compared to Full frame.

Table 53: Maximum width to operate at full speed in GigE

		IMX530					
		Quantization					
		8 bits	10 bits	10bits Packed	12 bits	12 bits Packed	HDR
Lines	16	5328	5136	5328	5328	5328	5328
	32	5328	3840	4592	4688	5328	5328
	64	4512	2960	3552	3632	4416	4480

	128	3696	2336	2848	2912	3584	4272
	256	3152	1904	2368	2432	3056	3888
	512	2816	1632	2064	2128	2720	3680
	624	2752	1568	2000	2064	2656	3648
	1104	2608	1440	1872	1936	2512	3552
	2208	2496	1344	1760	1824	2400	3504
	4608	2448	1296	1712	1776	2352	3472

The table below lists the maximum achievable framerate with GigE Vision in Full width as a function of the number of lines. Highlited values correspond to reduced framerate compared to what is theoretically achievable by the sensors.

Table 54: Frame rates as a function of the number of lines when using GigE

		IMX530					
		Quantization					
		8 bits	10 bits	10bits Packed	12 bits	12 bits Packed	HDR
Lines	16	2560	2320	2458	1973	1973	1366
	32	2370	1342	1790	1479	1812	1216
	64	1636	818	1088	889	1184	891
	128	1017	509	679	544	726	566
	256	622	311	414	326	434	340
	512	361	181	241	186	248	192
	624	306	153	204	157	209	161
	1104	186	93	124	94	126	96
	2208	98	49	65	49	66	50
	4608	48	24	32	24	32	24

11.7. Image enhancements

Andor CB2 cameras support bias and flat corrections.

Each pixel of the sensor has its own dark level and its own sensitivity to light.
The bias correction is used to compensate the difference in dark level and the flat correction to compensate the difference in sensitivity between all the pixels.

Since the cosmetic of the Andor CB2 sensors is natively good, the bias and flat corrections are more useful for long exposure duration acquisitions.

Prior to enabling the bias and flat correction, the corresponding correction files must be loaded in the camera. The camera can either compute the correction files by itself, or custom correction files uploaded to the camera can be used.

Building the bias correction requires putting the camera in the dark.
Building the flat correction requires putting the camera in front of a flat field.

The Bias correction is applied to the pixel values read from the sensor.
The Flat correction is applied to the pixel values resulting from the bias correction.

The active corrections are enabled using the `NucMode` register.
When set to `None`, no correction is applied
When set to `Bias`, only the bias correction is applied
When set to `Bias and Flat`, both bias and flat corrections are applied.

The camera also allows you to add an extra offset to all pixels of the image.

11.7.1. ADU offset

The *AduOffset* register allows to specify an offset applied to all the pixels of the sensor. This is the last operation done on the pixels before their conversion in the Mono8, Mono10/Mono10Packed or Mono12/Mono12Packed pixel formats.

The main purpose of this offset is to allow to ensure no pixels are truncated to 0 when a bias correction is applied. Indeed, whereas bias, flat and ADU operations are performed internally on signed integers, the final pixel value is converted to a value compatible with the pixel format selected.

For *Mono8* pixel format, values below 0 are set to 0, values above 255 are set to 255.

For *Mono10/Mono10Packed* pixel formats, values below 0 are set to 0, values above 1023 are set to 1023.

For *Mono12*/*Mono12Packed* pixel formats, values below 0 are set to 0 and values above 4095 are set to 4095.

11.7.2. Bias and flat computation

The number of images used for the computation is specified using the *BuildNucNbImages* register.

The estimation of the remaining time of the computation is indicated by the *BuildNucDuration* register.

At any time, the computation can be aborted using the *BuildNucAbort* command.

The result of the computation is indicated by the *BuildNucStatus* register. To ensure that the status is correct, it is recommended to use the *BuidNucStatusRefresh* command prior to reading the *BuidNucStatus* register.

To compute the bias correction file, the camera must be put in the dark, the *AduOffset* register must be set to 0, *NucMode* register must be set to *None*, and the frame acquisition must be started. The launch of the computation is done by the *BuildBiasExecute* command.

To compute the flat correction file, the camera must be put in front of a flat field, the *NucMode* register must be set to *Bias* and the frame acquisition must be started. The launch of the computation is done by the *BuildFlatExecute* command.

11.7.3. Bias correction file format

The bias correction file contains an array of values to be subtracted from the frame sent by the sensor. The bias correction allows to counterbalance the difference of offsets between the different pixels.

The bias correction file geometry must be identical to the actual sensor geometry.

Example :

For a geometry of 320x256, the bias correction file geometry is 320x256

The values are stored in left-to-right/top-to-bottom order, *e.g.* the same order as the pixels in a received frame from the sensor.

For *Mono8* pixel format, the value to be subtracted is stored on an unsigned 8-bits integer.

For *Mono10* and *Mono10Packed* formats, the value to be subtracted in stored on the 10 least significant bits of an unsigned 16-bits register. The 6 most significant bits must be set to 0.
The coding of the 16-bits value in the bias correction file is Least Significant Bit (LSB).

For *Mono12* and *Mono12Packed* formats, the value to be subtracted in stored on the 12 least significant bits of an unsigned 16-bits register. The 4 most significant bits must be set to 0.
The coding of the 16-bits value in the bias correction file is Least Significant Bit (LSB).

11.7.4. Flat correction file format

The flat correction file contains an array of fixed-point real values that are used to counterbalance the difference of sensitivity between the different pixels.

The bias correction file geometry must be identical to the actual sensor geometry.

Example :

For a geometry of 320x256, the flat correction file geometry is 320x256

The values are stored in left-to-right/top-to-bottom order, *e.g.* the same order as the pixels in a received frame from the sensor.

When flat correction is applied, the result of the bias correction of a pixel is multiplied by the value specified in the corresponding pixel entry in the flat correction file.

Values are stored using fixed-point representation.

For *Mono8* pixel format, the value of the multiplier is stored as an 8-bits value.
Bits 7-5 are used to store the integral part of the multiplication factor.
Bits 4-0 are used to store the decimal part of the multiplication factor.

Examples of values :

- 00100000b / 0x20 is the representation of value 1.0
- 01000000b / 0x40 is the representation of value 2.0
- 00010000b / 0x10 is the representation of value 0.5
- 00110000b / 0x30 is the representation of value 1.5

For *Mono10* and *Mono10Packed* pixel formats, the value of the multiplier is stored on the 10 least significant bits of a 16-bits value. The 6 most significant bits must be set to 0.

Examples of values :

- 0010000000b / 0x080 is the representation of value 1.0
- 0100000000b / 0x100 is the representation of value 2.0
- 0001000000b / 0x040 is the representation of value 0.5
- 0011000000b / 0x0C0 is the representation of value 1.5

For *Mono12* and *Mono12Packed* pixel formats, the value of the multiplier is stored on the 12 least significant bits of a 16-bits value. The 4 most significant bits must be set to 0.
The coding of the 16-bits value in the bias correction file is LSB.

Examples of values :

- 001000000000b / 0x200 is the representation of value 1.0
- 010000000000b / 0x400 is the representation of value 2.0
- 000100000000b / 0x100 is the representation of value 0.5
- 001100000000b / 0x300 is the representation of value 1.5

11.7.5. Transferring Bias and Flat corrections files

The transfer of bias or flat correction files is performed using the File Access Control registers defined in the SFNC.

To access the bias (respectively flat) correction file, the *FileSelector* register must be set to *Bias* (respectively *Flat*)

Then, the file must be opened:

Select the file open mode (*Read* or *Write*) using the *FileOpenMode* register.
Select the *Open* operation in the *FileOperationSelector*.
Use the *FileOperationExecute* command to perform the open operation.
The result of the open operation can be checked using the *FileOperationStatus* register.

Then, the file accesses can be performed using the *Read* and *Write* values of the *FileOperationSelector* register.

The file content will be accessed using the *FileAccessBuffer* register, which allows access to a maximum of 4096 bytes of the file. Full file access content typically requires several operations.

Use *FileAccessOffset* and *FileAccessLength* register to specify the part of the file accessible through the *FileAccessBuffer* register.

Note : *FileAccessLength* is limited by the size of the *FileAccessBuffer* register (4096 bytes).

The read or write operation is performed using the command *FileExecuteCommand*
The result of the operation can be checked using the *FileOperationStatus* register.
The actual number of bytes transferred is accessed through the *FileOperationResult* register.

Once the file transfer is complete, the file must be closed. This is done by selecting the *Close* operation in the *FileOperationSelector*, then executing the command *FileExecuteCommand*.

11.7.1. Median Filter

The camera integrates an optional built-in 3x3 median filter.
This feature allows to replace eligible pixels by the median of its adjacent pixels.

Two criteria of eligibility of pixels are supported

- Saturated pixels
- Pixels that are too far from the median of their adjacent pixels

The replacement of saturated pixels is controlled using the *MedianFilterSaturationEnable* register. When enabled, all saturated pixels are replaced. This mode is mainly useful when bias correction is enabled to avoid the black pixel artefact visible for pixels that have a limited dynamic due to their high dark level value.

The replacement of pixels that are too far from the median of their adjacent pixels is controlled using the *MedianFilterThresholdEnable* and *MedianFilterThreshold* registers.

When enabled the camera compares the value of each pixel with the median of the adjacent ones. If this difference is above *MedianFilterThreshold*, the pixel value is replaced.

Example :

Assuming a pixel value of 1200 and the median of the surrounding pixels of 1000

If *MedianFilterThreshold* is set to 0.1, the pixel is replaced: |1200 – 1000 | > 0.1 * 1000
If *MedianFilterThreshold* is set to 0.3, the pixel is not replaced: |1200 – 1000 | < 0.3 * 1000

Note: a convenient way to apply the median filter to the whole image is to set *MedianFilterThreshold* to 0.

The median filter is a convenient way to automatically replace camera hot pixels (*e.g.* pixels with high dark level values) without the need to compute a bias correction. This is especially useful for long exposures where bias computation would be excessively tedious.

11.7.2. Binning

The IMX530 sensor supports 2 x 2 horizontal and vertical Floating Diffusion binning in 8-, 10- and 12-bits quantization.

Floating diffusion binning (or charge-domain binning) refers to a binning operation happening directly to the electrons stored in the charge capacitors before any other processing is done on the signal.

Binning is not supported in HDR mode

The binning is controlled using the SNFC *BinningHorizontalMode*, *BinningHorizontal*, *BinningVerticalMode* and *BinningVertical* registers.

The only supported value for *BinningHorizontalMode* and *BinningVerticalMode* is *Sum*, meaning the sensor adds the response of the combined cells, resulting in increased sensitivity.

The *BinningHorizontal* and *BinningVertical* registers contain the number of pixels combined horizontally and vertically. Since the sensor only supports 2 x 2 binning, this means that

BinningHorizontal and *BinningVertical* registers are always equal (modifying one automatically impacts the other) and can only be set to 1 or 2.

When *BinningHorizontal* and *BinningVertical* are set to 1, binning is disabled. When the registers are set to 2, a 2 x 2 binning is implemented.

Table 55: Description of the binning registers

Name	Access	Values	Description
BinningHorizontalMode *BinningVerticalMode*	RW	*Sum* *Average*	Type of binning. Only *Sum* is supported.
BinnningHorizontal	RW	1, 2	Number of pixels combined horizontally.
BinningVertical	RW	1, 2	Number of pixels combined vertically.

12. CAMERA MAINTENANCE

12.1. Troubleshooting

Information useful for troubleshooting is available in several SNFC registers. The table below lists the related parameters.

Table 56: Description of the parameters useful to troubleshoot.

Value	Access		Description
`DeviceIndicatorMode`	RW	`Active`	Device's indicators are active showing their respective status.
		`Inactive`	Device's indicators are inactive (Off). This is the default state, unless an error occurs.
		`ErrorStatus`	Device's indicators are inactive unless an error occurs.
`DeviceStatus`	RO	*Starting* *Configuring* *Configured* *Operational* *Safe*	Status of the device.
`DeviceStatusDetailed`	RO	*No cooling* *Cooling* *Cold* *Throttling* *Safemode* *diagnostic* Empty	Detailed status of the device.
`LogHistoryDepth`	RW	Integer	Specifies the log history depth in days.
`LogCollect`	WO	Command	Collects the logs.
`LogCollectAbort`	WO	Command	Abord collecting of the logs.
`LogCollectStatus`	RO	`Idle`	No log collect operation has been requested.
		`InProgress`	Log collect operation in progress.
		`Done`	Log collects succeeded. The logs can now be served.
		`Failed`	Log collects failed.
`LogCollectRefresh`	WO	Command	Forces reload of log collecting status. This is only needed for implementation that do not handle *IsSelfClearing* properly.
`LogServe`	WO	Command	Serves the logs previously collected.
`LogServeAbort`	WO	Command	Aborts serving of the logs.
`LogServeUri`	RO	String	Specifies location of firmware update.

The table below provides a troubleshooting shortlist :

Table 57: Common issues and troubleshooting procedures

Issue	Possible cause	Troubleshooting
Cooling does not reach the set point	▪ The cooling plate is not in good thermal contact. ▪ The cooling system is off or defective.	▪ Check in Section 5 that the set points are within the reach of the system. ▪ Make sure the camera's fan is not blocked. ▪ Make sure the cooling system is switched on, filled with liquid fluid and that the liquid is flowing.
The camera has shut down automatically	▪ The camera has overheated.	▪ Reboot the camera by unplugging/ replugging the power cord.
No signal on the status LED	▪ The camera is not powered ▪ The LEDs may have been turned off	▪ Check that the camera is correctly powered ▪ Make sure the LEDs have not been turned off
The camera does not make images	▪ The camera is not properly connected ▪ The CoaXPress® cable are inverted ▪ Acquisition triggers are active, but no trigger is received	Check that: ▪ Cables are connected properly. ▪ CoaXPress® cables are in good position. ▪ Graphical User Interface software is running properly ▪ Camera responds to software commands (i.e. thermal reading, monitoring functions) ▪ Trigger signals Then: ▪ Restart the camera ▪ Restart the computer
The camera is not detected	▪ The CoaXPress® cable are not in a correct position.	▪ Check that the camera is powered properly. ▪ Check the CoaXPress® connectors are well connected. ▪ Invert the CoaXPress® cables.

12.2. Pattern Generation

The sensor can be configured to send a fixed pattern. The pattern generation is configurable through the SFNC *TestPattern* register.

Table 58: Descriptions of the control for pattern generation

Name	Access	Values	Description
TestPattern	RW	*Off*	Sensor normal operation, the image is coming from the sensor
		Black	Generate frames with fixed pixels values 0x00 (8 bits) or 0x000 (12 bits)
		White	Generate frames with fixed pixels values 0xFF (8 bits) or 0x3FF (12 bits)
		GreyHorizontalRamp	Generate frames with pixels values from 0x00 to 0xFF in 8 bits and from 0x000 to 0x3FF in 12 bits mode
		SimulatorGreyHorizontalRamp	Same as *GreyHorizontalRamp*, but generated by the camera FPGA
		SimulatorGreyHorizontalRampMoving	*GreyHorizontalRamp* moving horizontally from left to right at each frame, generated by the camera FPGA

The test pattern is *OFF* by default.

The *Black*, *White* and *GreyHorizontalRamp* patterns are generated in the sensor. They can be useful when developing software to control the camera or to troubleshoot the CoaXPress links.

The *SimulatorGreyHorizontalRamp* and *SimulatorGreyHorizontalRampMoving* are generated in the camera FPGA.

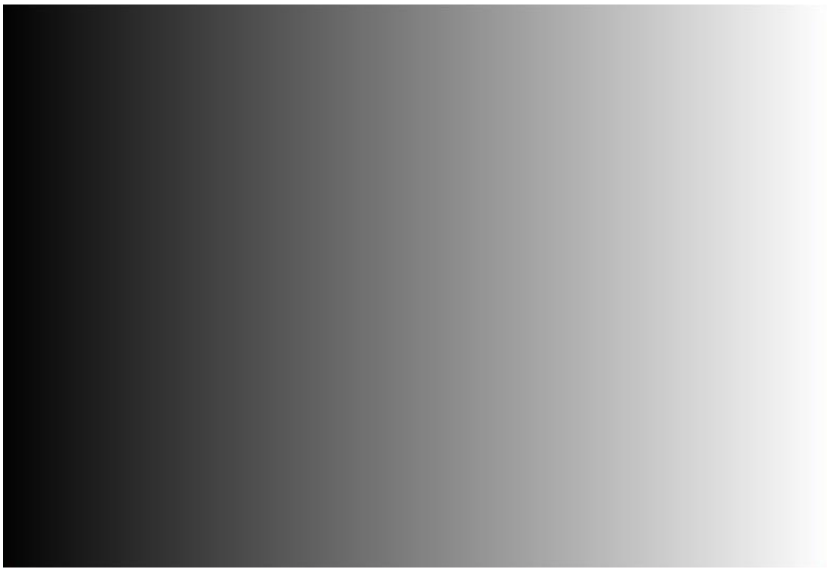


Figure 37: Grey horizontal ramp

12.3. Firmware update

The firmware update control command is sent through CoaXPress® or GigE Vision interface, then firmware is downloaded by the camera using the Ethernet interface.

The Ethernet cable is not provided in the Andor CB2 camera package. It is strongly advised to use shielded cable to respect Electromagnetic Compatibility (EMC) recommendations.

Please refer to Section 7.6.

12.4. Cleaning of the window

The camera is cleaned in a controlled environment before shipping.
To avoid having to clean the window, make sure you protect the camera from dirt and finger marks. Always cover the camera with a cap.

The window can be cleaned with a dry and soft cloth. Please avoid touching the glass window.
You can also use a clean cloth dampened with ethanol and gently wipe the window.
Never use an unclean cloth to wipe the window of the camera.

Please contact us at fli-support@oxinst.com before cleaning the camera.

12.5. Support requests

For any support request please indicate the serial number of your camera. The camera serial number is available at the bottom of the camera. You can also check the SFNC register `DeviceSerialNumber` to retrieve the information.

Please send your requests at: fli-support@oxinst.com

Figure 38: Camera serial number can be read underneath the camera

Note : The P/N (Part Number) depends on the sensor model in the camera.

13. PRECAUTIONS & PRODUCT SAFETY

13.1. Precaution of use

Your Andor CB2 is a high-end scientific instrument, if this equipment is used in a manner not specified by the manufacturer the protection provided by the equipment may be impaired and the warranty will not be applicable.

Your Andor CB2 camera is an expensive and fragile product, handle it with care!

13.1.1. Environmental conditions

Like any scientific instrument, your Andor CB2 camera is fragile and should not be exposed to shocks, extreme temperatures, humidity and dusty environment.

13.1.2. Static & electric shocks

Your Andor CB2 is an electronic equipment that requires precaution regarding static shocks. Electrostatic Discharge (ESD) is dangerous for the camera. We recommend you follow these rules:

- Any electronic equipment that must be connected to Andor CB2 should be fitted with appropriate protection on all power lines.
- Any connected equipment should be powered off before removing any connection between the computer and Andor CB2.

13.1.3. Never open the camera

There are no user-serviceable parts inside your camera, do not ever attempt to open it. There are some indicators inside the camera, if you try to open it your warranty will be void.

Do not open the camera, your warranty will be void.

14. WARRANTY AND LIABILITY

14.1. For the USA

14.1.1. Limited Warranty

Subject to the limitations set forth herein, FLI represents and warrants that the Products (including the Sensor, if applicable) will correspond, at the time of delivery, to the specifications provided to FLI by Purchaser, and shall be free from defects in material and workmanship (the "Limited Warranty"). Such Limited Warranty shall remain in effect for a period of two (2) years from the date Purchaser takes delivery of such Products; provided, however, that such Limited Warranty as it relates exclusively to the Sensor (which shall be supplied by a third party manufacturer), if and as included in a Product, shall remain in effect for such length of time as the original manufacturer's warranty shall be in effect. Therefore, for example purposes only, if there shall be eight months remaining on the original manufacturer's warranty for the Sensor at the time Purchaser takes delivery of a Product which incorporates such Sensor, then the Limited Warranty hereunder as it relates exclusively to the Sensor shall be in effect for eight months. FLI shall inform Purchaser of the length of time remaining on the original manufacturer warranty for the Sensor at the time the applicable Product is delivered to Purchaser.

14.1.2. Conditions

The Limited Warranty specified above is subject to the following conditions:

- FLI shall be under no liability with respect to defects arising in the Products as a result of any incorrect drawing, design, or specification supplied by Purchaser;
- FLI shall have no liability with respect to any defect which arises from wear and tear, willful damage, negligent or abnormal use of the Product, mishandling of the Product, Force Majeure Events, or failure to comply with FLI's instructions regarding the use and maintenance of the Product, including, but not limited to, all written instructions, and all instructions contained in the Documentation;
- the Limited Warranty shall be limited to the Products themselves, and FLI shall have no liability with respect to any damages whatsoever which are caused to, or by, third party (or Purchaser's) parts, materials, or systems, as a result of or in connection with the integration or use of the Products.

14.1.3. Warranty Enforcement

To avail itself of the rights provided under the Limited Warranty, the Purchaser must submit, in writing, a detailed report regarding the defect exhibited by the particular Product (a "Defect Report"). Such Defect Report shall be submitted to FLI at fli-sales@oxinst.com, with a copy of such Defect Report furnished to FLI by certified mail, or regular mail with return receipt requested, at the address listed below.

Purchaser shall have the burden of proving the defect is covered by the Limited Warranty. FLI shall have sole discretion to determine whether the Limited Warranty applies to any defect reported by Purchaser.

14.1.4. Returns

In the event the Limited Warranty applies, Purchaser shall return the Product to FLI within thirty (30) days of receiving written authorization from FLI to do so, in the same condition as the Product was originally delivered to Purchaser. Purchaser shall assume all costs, risk and liability in connection with the shipment and return of the Product. In the event the Product is not returned within the requisite time period, the Limited Warranty shall be void and of no further effect.

Purchaser agrees to the following limitations on FLI's liability in connection with the Products:

14.1.4.1. Liability Upon Delivery

Except as otherwise provided herein, FLI disclaims any and all liability in connection with purchaser's use of any products, including without limitation liability to third parties, to the fullest extent permitted by law, as of the date such product is delivered to purchaser.

14.1.4.2. Products Offered "As Is"

Except as provided in these terms, FLI provides the products "as is" and on an "as available" basis. Accordingly, and to the maximum extent permitted by applicable law, FLI makes no warranties, express or implied, that the products will be uninterrupted, error-free or free of harmful components.

14.1.4.3. No Other Warranties

Except as expressly set forth in these terms, and to the fullest extent permitted by applicable law, FLI does not make any warranty regarding the products or any other subject matter of these terms. Any implied warranty, including without limitation any implied warranty of merchantability and fitness for a particular purpose, shall be limited in scope to the extent permitted by applicable law, and shall be limited in duration to the duration of the limited warranty set forth above, or to such period of time as permitted by applicable law, whichever shall be shorter.

14.1.4.4. Limitation of Liability

To the fullest extent permitted by law, in no event will FLI, its affiliates, suppliers or distributors be liable for (a) any indirect, special, incidental, punitive, exemplary or consequential damages however caused, on any theory of liability, including but not limited to loss of use, loss of actual or anticipated profits or benefits, or the cost of procuring a replacement product, whether or not FLI has been advised of the possibility of such damages, arising in any way out of these terms or in connection with the products, or any undertaking or performance that may be promised, performed, or executed to implement these terms.

14.1.5. Purchaser Warranties

In addition to the other warranties, representations and covenants set forth in these terms, by using the products or placing an order, purchaser warrants and represents that purchaser has the right and authority to agree to these terms and to use the products, that purchaser's use of the products shall not violate the rights of any third party or any contract with any third party, and that purchaser's use of the products, FLI's fulfillment of any orders, and the delivery of any products, shall not violate any applicable laws.

14.1.6. Purchaser Indemnification

Purchaser agrees to defend, indemnify and hold FLI harmless from and against any and all claims, liabilities, damages, penalties, forfeitures, and associated costs and expenses (including attorneys' fees) that FLI may incur as a result of any breach by purchaser of any warranty, representation or covenant set forth in these terms.

14.2. For the rest of the World

14.2.1. FLI's legal guarantee and limit to the guarantee

FLI hereby exclusively guarantees the Product's compliance with the specifications agreed to within the limits of the legally applicable provisions.

FLI's guarantee is exclusively limited to repairs or replacement of any parts that are not in compliance. If after reasonable efforts, FLI is not able to replace the non-compliant Product, the guarantee will be limited exclusively to the reduction of the purchase price or reimbursement of the price (after deduction of depreciation for wear and tear), after the Product is returned by the Purchaser.

FLI will not be liable for any indemnification of the Purchaser for specific or indirect damage, opportunity cost, loss of income, loss of enjoyment, damage to individuals or goods not related to the purpose of the contract.

For parts or supplies that are not manufactured by FLI, the guarantee is limited to those to which FLI is entitled from its own suppliers.

This guarantee does not cover the defects of the Product resulting from any cause external to the Product, such as:

- Failure to comply with FLI's recommendations;
- Mishandling by the Purchaser;
- Intervention by a third party involving the Product;
- Poor maintenance or misuse of the Product;
- Wear and tear;
- Damage caused by elements external to the Product or attributable to a case of *force majeure*: fire, lightning, water damage, external accident, etc.

14.2.2. FLI's liability

The Products are sold by FLI in compliance with French laws in effect. FLI cannot be held liable for any failure to comply with the laws in the countries where the Product will be used.

In the event where FLI is held liable due to its failure to satisfy any of its contractual obligations, the Purchaser may not seek any indemnification for loss of income or opportunity cost, loss of enjoyment, specific, accessory or indirect damage to individuals or to goods or assets, caused by any failure in the performance of its obligations. The total amount of the indemnities that FLI may be required to pay to the Purchaser in remedy for the prejudice it suffers may not exceed the amounts paid by the Purchaser for such Product, regardless of the legal grounds for the claim and the procedure employed to resolve it.

14.2.3. Liability in connection with defective products

FLI's liability in connection with defective products excludes remedy for any damage caused to the products through commercial use.

15. CONTACT US

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15.2. For the rest of the world

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