C-RED 2

User Manual

C-RED 2 User Manual_20180625

TABLE:

1. INTRODUCTION

Thank you for choosing C-RED 2!

C-RED 2 features and performances are described in detail within this User Manual.
It contains all information and advice needed to get the optimum performance from C-RED 2.

You can also find an up-to-date version of this User Manual on our website: www.first-light.fr/downloads/
Please contact our support for any question at: support@first-light.fr

1.1. Caution

⚠ *Your C-RED 2 camera contains fragile components.*

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

Please follow the instructions of use to take advantage of all C-RED 2 performances.
Please read carefully the warnings (section 2) and follow the safety precautions to avoid any personal injury or damage when using the camera.

1.2. Overview

C-RED 2 is a revolutionary ultra-high speed low noise camera designed for high resolution short wave infrared imaging.
It is equipped with an Indium Gallium Arsenide (InGaAs) (640 x 512) pixels sensor of 15 µm each.
Thanks to its advanced technology in electronics, software, and its innovative mechanics, C-RED 2 is capable of unprecedented performances: up to 600 images per second. C-RED 2 offers both Camera Link® or USB3 interface.

Your C-RED 2 camera contains fragile components, especially the detector. Please always handle your camera with care.

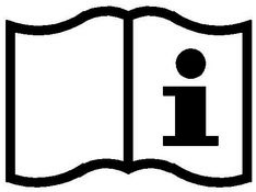
⚠ *Always follow the instructions of use.*

1.3. 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.

The CE marking indicates the conformity of the camera 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

1.4. Disposal - DEEE

C-RED 2's sensor contains specific material such as:

- InAs CAS n° 1303-11-3 / EC n° 215-115-3
- GaAs CAS n° 1303-00-0 / EC n° 215-114-8.

⚠ *In case of disposal, do not throw your camera in waste disposal and send it back to First Light Imaging*

2. WARNINGS

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.

Equipments connected 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.
Do not close the ventilation system to avoid any overheating.

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 UNPLUGGED before any technical intervention.

The security provided with this equipment is only guaranteed with a use in accordance with the specified purpose. Only use the provided (XPPower, model AJM90PS12) power supply.

The use of a Polymer Lithium battery involves fire hazard which can seriously harm goods and persons. The user fully agrees to accept the risks and responsibility.
The manufacturer and the distributor cannot be held responsible for any damage to goods and persons as they cannot control the proper use of the battery (charge, discharge, storage).

IMPORTANT NOTE: For Switzerland: the annex 4.10 of the SR 814.013 standard is applicable to batteries.

2.2. Sealed enclosure

The sensor of your camera is enclosed in neutral gas.

Opening your camera to ambient air may lead to permanent damage.

2.3. Never open your camera

Do not ever 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, your warranty will be void.

2.4. Power circuitry

Use the camera with the voltage indicated. Using a different voltage may damage your camera and lead to fire or electric shock.

Always use the supplied power unit.

3. TECHNICAL SPECIFICATIONS

Power supply	Voltage	100 – 240 VAC
	Frequency	50 – 60 Hz
	Current	1.5 A – 0.6A
Camera's dimensions	Length	143 mm
	Width	74.91 mm
	Height	55 mm
Operation conditions	Maximum temperature	35°C
	Humidity	80 %

4. CONTENTS OF PACKAGE

When you open the package, please check that all items described below are included.

Fig. 1 : *On the left, closed Pelicase®.*
On the right, opened Pelicase® with dedicated spaces.

	C-RED 2
Camera	1
Power supply	1
IEC / NEMA / XXX cable	1
USB3 cable	1
Quick Start Manual	1
USB key with User manual + Demo software + Test report	1

Fig. 2 : *Package items description.*

Note 1: The cooling unit and personal computer can be bought separately. Any reference is compatible with respect of the minimum requirements (see section 5.3).

Note 2: The latest release of software is available on demand at: support@first-light.fr.

Note 3: Items may differ from pictures.

5. DESCRIPTION AND TECHNICAL SPECIFICATIONS

5.1. SWIR CMOS sensor

5.1.1. SNAKE-SW introduction

Designed and fabricated by SOFRADIR, the SNAKE-SW sensor is dedicated for low flux imaging applications in the SWIR band. On the one hand, it is responding to night vision, airborne tracking, surveillance needs, and on the other hand, on various medical applications in preclinical and clinical such as real-time intra/per/postoperative, oncology, dentistry and neurosciences, for example.

SNAKE-SW includes a focal plane array (FPA) composed of a (640 x 512) pixels pitch of 15 µm each. It is made of photovoltaic (PV) Indium Gallium Arsenide (InGaAs) on Indium Phosphide (InP) substrate connected by bump bonding to a silicon readout integrated circuit (ROIC).

Standard InGaAs used in SNAKE-SW allows to detect wavelength ranges between 0.9 and 1.7 µm.

The digital and analog functions are controlled by a serial interface. The readout of SNAKE-SW allows to read windows in cropping mode.

5.1.2. Spectral response

Typical curve is represented on Fig. 3:

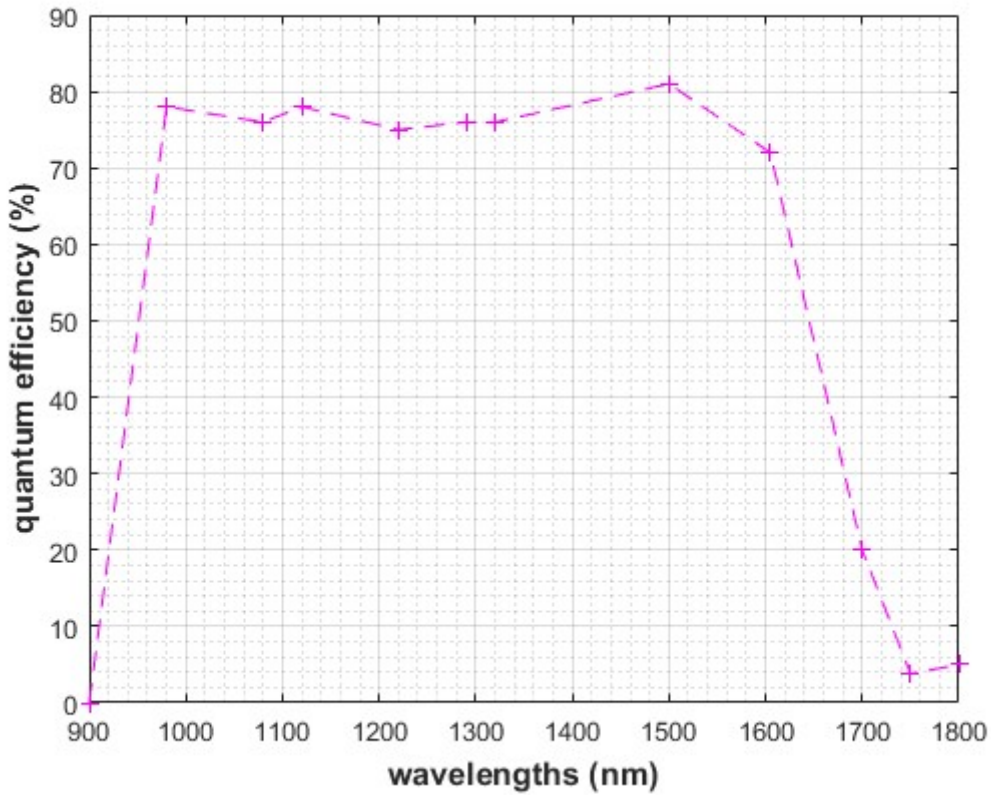
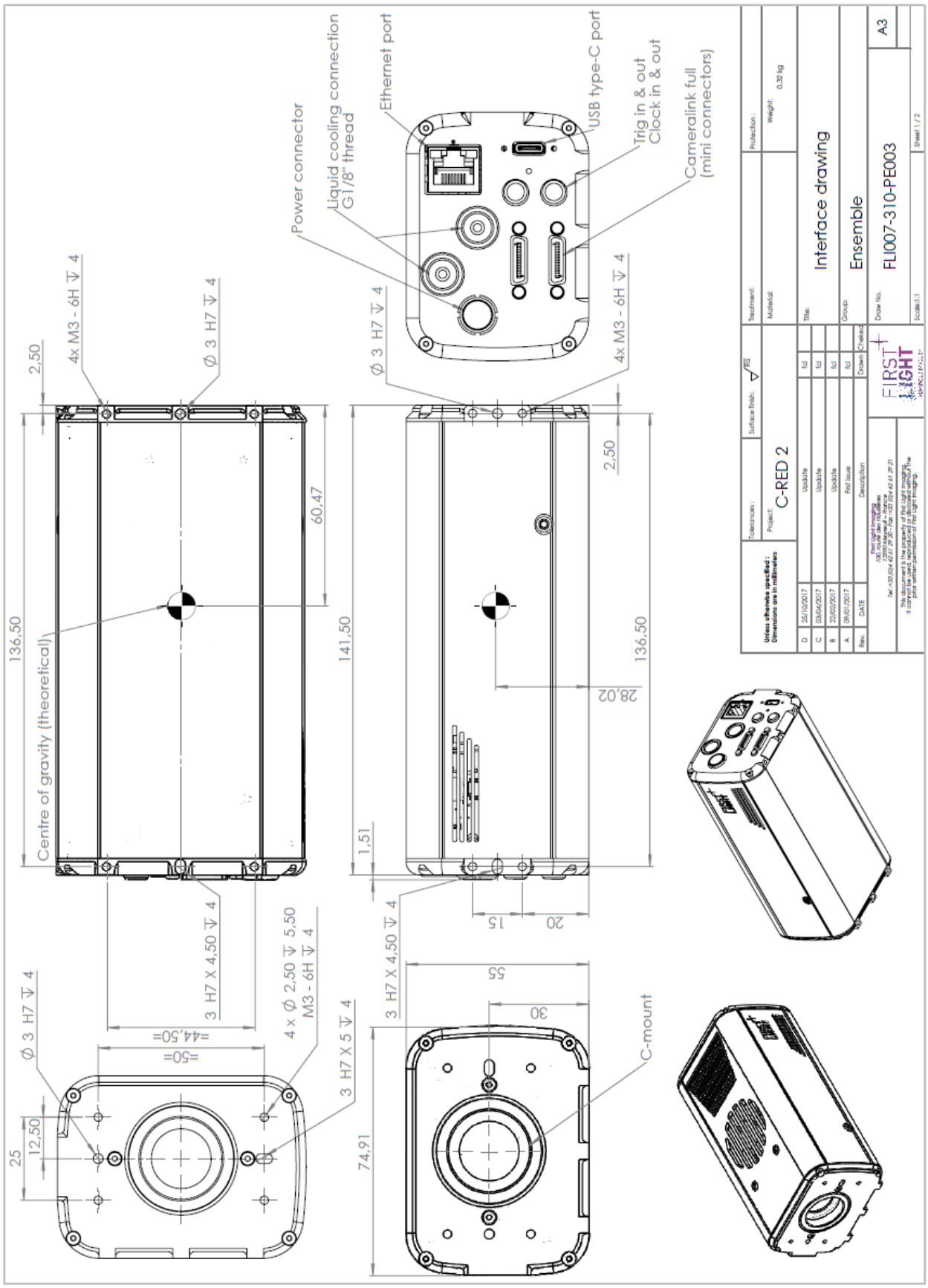


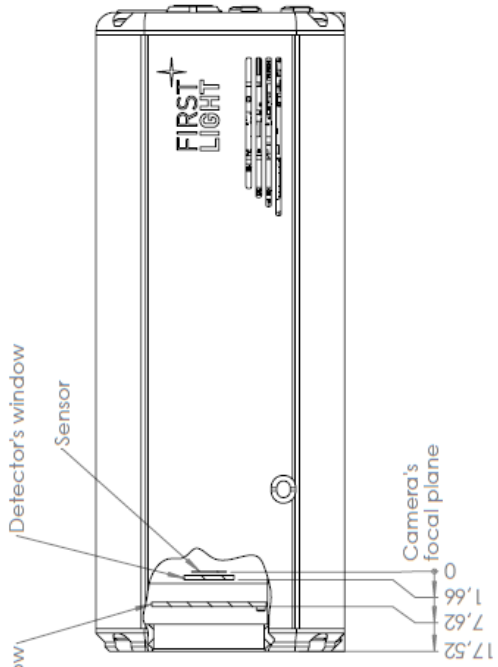
Fig. 3 : *InGaAs quantum efficiency between 900 and 1800 nm.*

5.2. C-RED 2 camera

5.2.1. Mechanical and optical interfaces

C-RED 2 integrates a SNAKE-SW sensor.
The camera is designed to deliver the best precision possible regarding the optical alignment of the sensor.


Power connector
Liquid cooling connection G1/8" thread
Ethernet port
USB type-C port
Trig in & out
Clock in & out
Cameralink full (mini connectors)
4x M3 - 6H ∓ 4
Ø 3 H7 ∓ 4
2,50
60,47
136,50
Centre of gravity (theoretical)
141,50
28,02
1,51
3 H7 X 4,50 ∓ 4
4 x Ø 2,50 ∓ 5,50 M3 - 6H ∓ 4
3 H7 X 5 ∓ 4
=50=
=44,50=
12,50
25
74,91
55
30
20
15
C-mount
Interface drawing
Ensemble
C-RED 2
FLI007-310-PE003
A3



Optical glass properties

	Thickness	Refractive index (@1,3 µm)	Material
Detector's window	1 mm	1.75	Optical grade Sapphire
Camera's window	1 mm	1.75	Optical grade Sapphire

Unless otherwise specified:
Dimensions are in millimeters
Tolerances :
Project: C-RED 2
Surface finish:
Treatment:
Material:
Protection :
Weight: 0.32 kg

Rev.	DATE	Description	Drawn	Checked
D	25/10/2017	Update	fcl	
C	03/04/2017	Update	fcl	
B	22/02/2017	Update	fcl	
A	09/01/2017	First issue	fcl	

Title: Interface drawing
Group: Ensemble
Drawn No. FLI007-310-PE003
A3
Scale: 1:1
Sheet 2 / 2

5.3. Description and minimum specification accessories

5.3.1. Power input

C-RED 2 requires a single power input, supplied in the package.
Power supply must provide a stable 12 V DC, with at least 7.5 A of current available (90 W) to properly power C-RED 2.
The mating connector is a LEMO® FGG.0B.304.CLAD52Z.

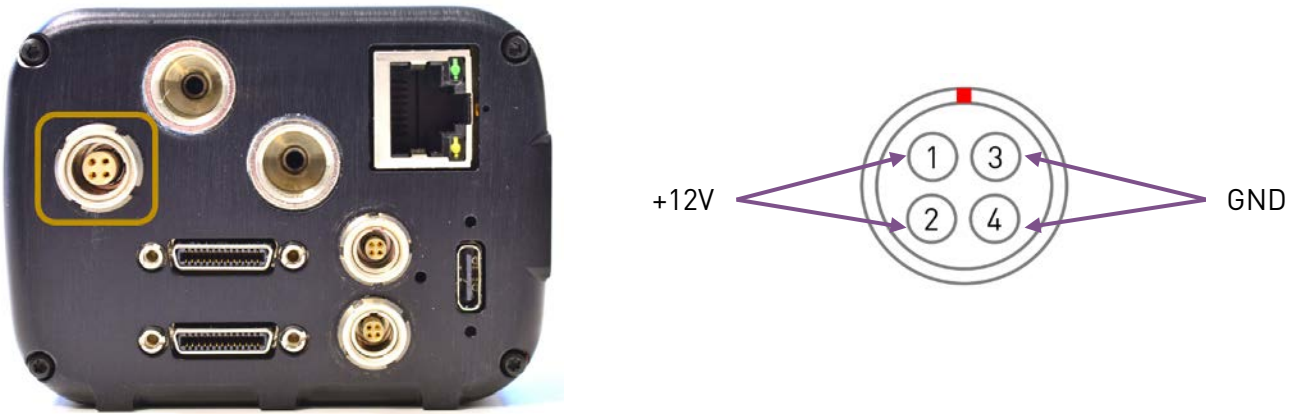


Fig. 4 : *On the left, C-RED 2 back view. The yellow box shows the female power connector cabling.*
On the right, the female power connector. 1 and 2 represents the +12 V power connectors. 3 and 4 represents the GND connectors.

Always use the provided power supply.

5.3.2. Cooling system

To cool down the detector, C-RED 2 can use air (fan) or liquid cooling system.
The camera has its own thermal regulation system to maintain the requested setpoint.

5.3.2.1. Air cooling

Air cooling allows to cool the detector down to nominal -15°C with a maximum room temperature of 35°C.

5.3.2.2. Liquid cooling

Liquid cooling allows to cool the detector down to nominal -40°C with the following conditions.

Parameters	Value
Flow	⩾ 0.5 L/min
Pressure	10 bar max
Temperature	35°C max
Liquid	Ethylen Glycol aqueous solution (max concentration : 50%) distilled water or deionized water if liquid temperature is > 5°C
Cooling capacity	100 W minimum

Fig. 5 : *Liquid cooling system parameters requirements.*

Heat is evacuated by circulating a cooling fluid through two ports (G1/8 thread).
First Light Imaging advises to use a chiller (active system) instead of a passive cooler.
For use with hot water, it is recommended to activate the automatic fan speed mode to vent hardware components.

⚠ ***Be sure that there are no fluid leaks between connectors and G1/8 thread.***

5.3.3. Communication protocol

Control and data acquisition are done either through Camera Link® or USB 3.0 connection.

5.3.3.1. CameraLink

The Camera Link® Full interface requires two data cables with male SDR-26 Mini Camera Link® connectors as shown in Fig. 6:

Fig. 6 : *On the left, C-RED 2 back view. The yellow box shows the female Camera Link® connectors. On the right, a picture of one male SDR-26 Mini Camera Link® connector.*

Note: The Camera Link® cables are numbered.

Connector 1 should be plugged on top, and connector 2 below.
If the cables are reversed the camera will fail to send data properly, but it doesn't have any harmful effect on the camera nor the grabber.

The C-RED 2 firmware communicates with the user through the serial line embedded in the Camera Link® cables. Usually the driver for the frame grabber will expose the serial line of the Camera Link® standard as a virtual COM port on the acquisition system. To communicate both ways with the camera, said COM port should be set to: 115200 Bauds, 8 bits, no parity, 1 stop bit, no flow control.

5.3.3.2. USB-C

The USB3 interface requires a standard USB-C connector.

Fig. 7 : *On the left, C-RED 2 back view. The yellow box shows the USB3 connector. On the right, a picture of the USB3 connector.*

Note 1: USB-C connector is reversible, so it can be plugged any way.

Note 2: C-RED 2 is compatible with USB-C screw locking cables

C-RED 2 is detected as a composite USB device (control interface + acquisition interface).
The control interface is exposed as a standard serial port whereas the data acquisition interface is exposed as a proprietary USB device.

The control interface (serial port) parameters must be set to 115200 bauds, 8 bits, no parity, 1 stop bit, no flow control.

5.3.4. Grabbers

The camera is compliant with Camera Link® standard.
However, please note that our cameras have been developed and tested with specific grabbers, and we highly recommend using these grabbers.

Any malfunctions related to the use of a non-certified grabber will not be supported by First Light Imaging.

5.3.4.1. List of tested and recommended grabber

- MATROX Radient eV-cl full (drivers available for linux and windows)
- DALSA/TELEDYNE X64 Xcelera-CL (drivers available for windows only)

6. SETTING UP AND START UP CAMERA

6.1. Connecting your camera

Each step below can be realized independently of one another in any order.

6.1.1. Power LEMO cable connection

The provided power supply/LEMO cable described in section 4.3.1 is connected to the back of the camera and connected to the line plug.

⚠ *First, plug the LEMO power connector to the camera, then plug the power unit to the line plug.*

Fig. 8 : *C-RED 2 with power supply connected thanks to the LEMO connector.*

6.1.2. Cooling hoses connection

First Light Imaging advises to use Loctite 577 thread sealant to fasten your connector on G1/8 threads.

Then, the coolant circulation can be turned ON and the user should check that no leaks are visible.
Please refer to the cooling unit user manual to ensure a proper operation.

First Light Imaging provides brass BSPP threaded hose-tail adapters. The connectors must be assembled to hoses with inner diameter of 6mm or ¼".

⚠ *First Light Imaging recommends turning on the cooling BEFORE turning on the camera.*

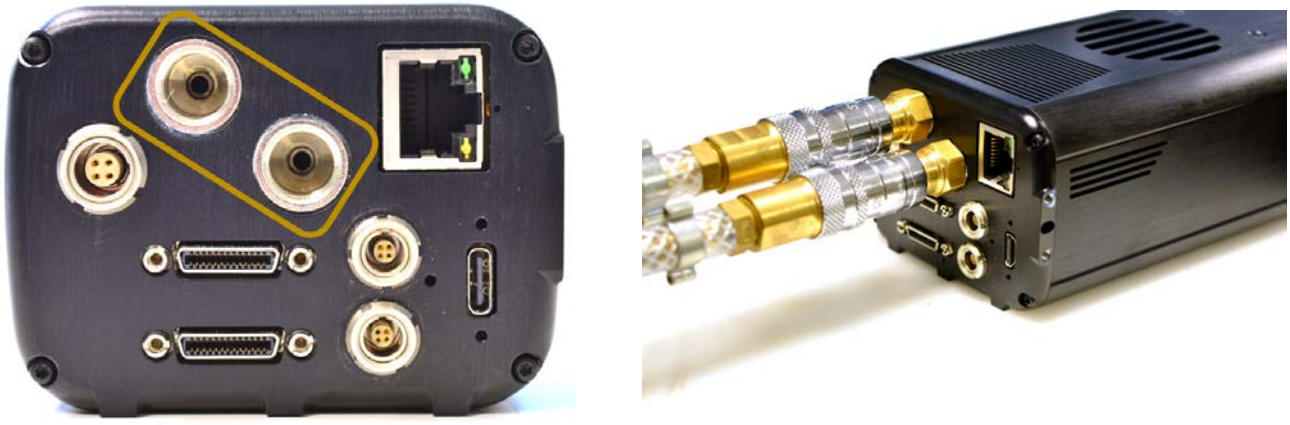


Fig. 9 : *On the left, C-RED 2 from the back. The yellow box shows the female coolant connectors. On the right, C-RED 2 coolant connectors connected to the camera.*

6.1.3. Camera Link® connection

The Camera Link® connectors can be plugged and fastened in any order but reversing the order will prevent camera operation. The Camera Link® connections can be plugged or unplugged either if the camera is ON or OFF.

Fig. 10 : *SDR-26 Mini Camera Link® connectors plugged in the camera.*

6.1.4. USB connection

The USB connection is done using a USB-C connector located on the rear side of the camera.
The camera only supports USB 3.0 connection.

The connection can be done using either a USB-A – USB-C or USB-C – USB-C cables.
Note that USB-A 3.0 compliant connectors are typically blue on standard PC.

Fig. 11 : *USB3 cable connected plugged in the camera*

To use the camera USB connection, it is strongly recommended to use a windows 10 PC.
For convenience, drivers for windows 7 OS are provided, but this OS is not officially supported by First Light Imaging.

Since windows 7 does not support USB 3.0 natively, USB 3.0 support is heterogeneous, and performance is hardly predictable. Please note that First Light Imaging will not provide any support for issues regarding the use of Windows 7.

Also, before using USB3 connection, the C-RED 2 USB3 drivers must be installed on the PC.
The drivers are included in the USB SDK library. By default, this library is installed with the GUI demo software. Please simply install the demo software and the drivers will be installed.

6.2. Demo GUI software

The Graphical User Interface (GUI) demo software is provided in the USB key supplied with C-RED 2, or available on demand at support@first-light.fr.
It is a dedicated interface developed by First Light Imaging which allows to control almost all the parameters of the camera. This demo software has its own manual.

6.3. Powering up/down

6.3.1. Power ON:

When the power LEMO is connected to the camera, and the power supply to the line plug, the camera is ON.

6.3.2. Power OFF:

Please use the CLI command "shutdown" from a simple terminal before turning off the camera. First unplug the power supply from the line plug, then unplug the LEMO cable from the camera.

6.4. Camera status

Once the camera is properly powered up by following the steps of section 5, the system boots and C-RED 2 is ready to operate.
A white or purple diode signal, visible through the camera's body holes, confirms the operability.

The color depends on the cooling status:
- White diode: Target temperature not reached yet.
- Purple diode: Target temperature reached.

Camera status	Camera's led color	Description
Starting	Blue	Camera starting
Configuring	Green	Camera configuration is applied
Operational (cooling)	White	Camera is cooling down
Operational (cold)	Purple	Camera has reached target temperature
Operational (throttling)	Purple double blink	Because of temperature environment, the camera can't reach the set point and is limiting itself to the lower possible temperature
Safe	Red double blink	The camera detects an error. The detector is turned off. To be able to reuse the camera, you must restart it.
Prevsafe	Yellow	When you restart the camera after a safe state, the camera will be stopped in prevsafe state. You have to use continue command to resume the camera starting.
Locked	Red	The camera detects a critical error. The camera is unusable, please contact First Light Imaging for support.
Safe (rescue FW)	Orange double blink	The camera detects a critical error. The camera is unusable, please contact First Light Imaging for support.

Note: turned off led does not necessary mean that there is an issue with the camera. Indeed, the camera can be configured to switch off the led automatically once boot is completed.

6.5. Cooling down the camera

Acquiring data is possible at any temperature between room temperature and -40°C.

6.5.1. First powering up:

For the first powering up, the camera will operate at 20°C by default. To change this default setting, please use the CLI command "`set temperature snake`" from a simple terminal. This action changes the camera running configuration only.
If you want this new setting to be non-volatile (to get it at the next reboot), you must save the current setting.

6.5.2. Next powering up:

C-RED 2 automatically goes to the last temperature saved.

6.5.3. Cooling regulation behavior:

If the camera is not able to reach the target temperature due to environment constraints (air / water too hot…), the camera will automatically increase the target temperature to avoid overheating.

In this case, the status LED blinks twice in purple (if led is enabled).

The camera will not automatically exit this throttling mode, even if the camera's environment becomes more favorable. The user must change the target temperature to exit this mode.

For example, if the user has set target temperature to -40°C, the user shall set target temperature to a different value, for example -39°C to allow the camera to restart its cooling cycle.

⚠ *C-RED 2 has an automatic system of regulation to limit the operation temperature if the cooling conditions are out of recommended conditions. If the target is not achieved, please check cooling conditions.*

6.5.4. Fan control:

Fan speed can be controlled in automatic mode or manual mode.
The automatic mode adapts the fan speed according to the camera's temperature.
In manual mode, the user can set the fan speed between 0% and 100%.

7. READOUT MODES

7.1. Integration/readout function

The acquisition speed can be set to any value from 0.001 to 400 or 600 fps.
The integration time can also be set. The integration time range is [50µs - ~1/fps] *

*For integration time below 50µs, please contact First Light Imaging at support@first-light.fr.

7.1.1. Integrate while read (IWR)

For maximum integration time, the camera integrates the signal in IWR mode.

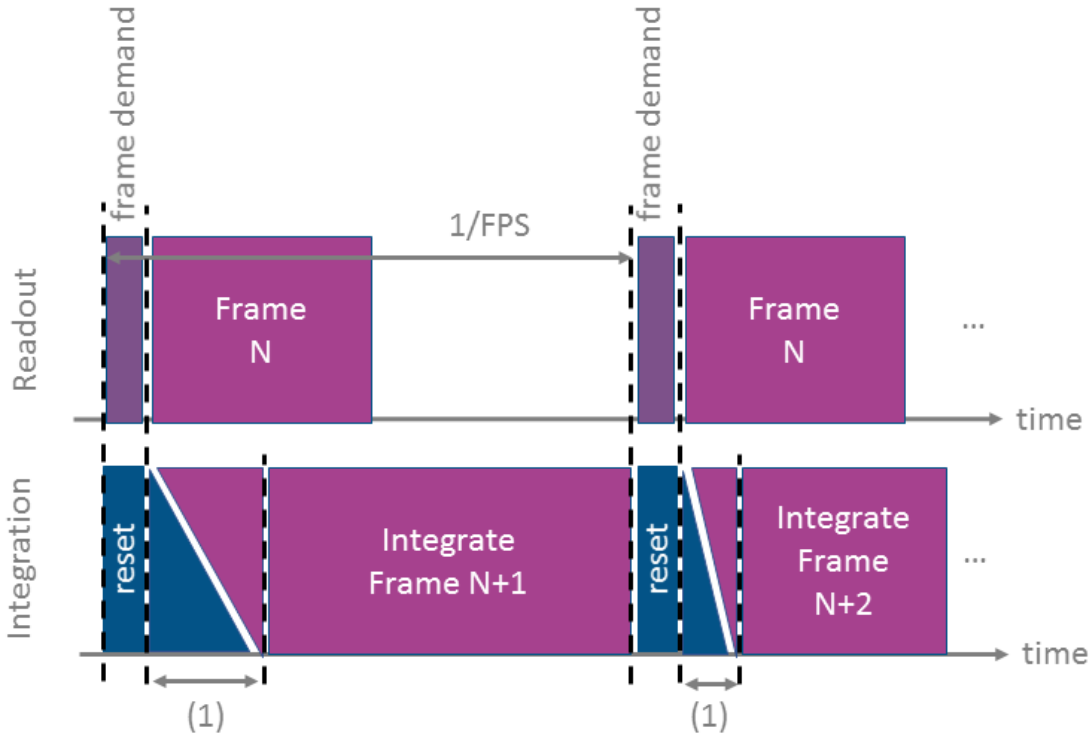


Fig. 12 : *IWR mode overview.*

(1) **Variable time:** This time (1) is either reset time, or integration time, depending of the FPS and Tint set by the user.

7.1.2. Integrate then read (ITR)

In this mode, the integration of the next image is done when the readout of the current image is fully completed. Light integration is lost for the frame readout time. So for an identical fps, the integration time is always shorter than in IWR mode.

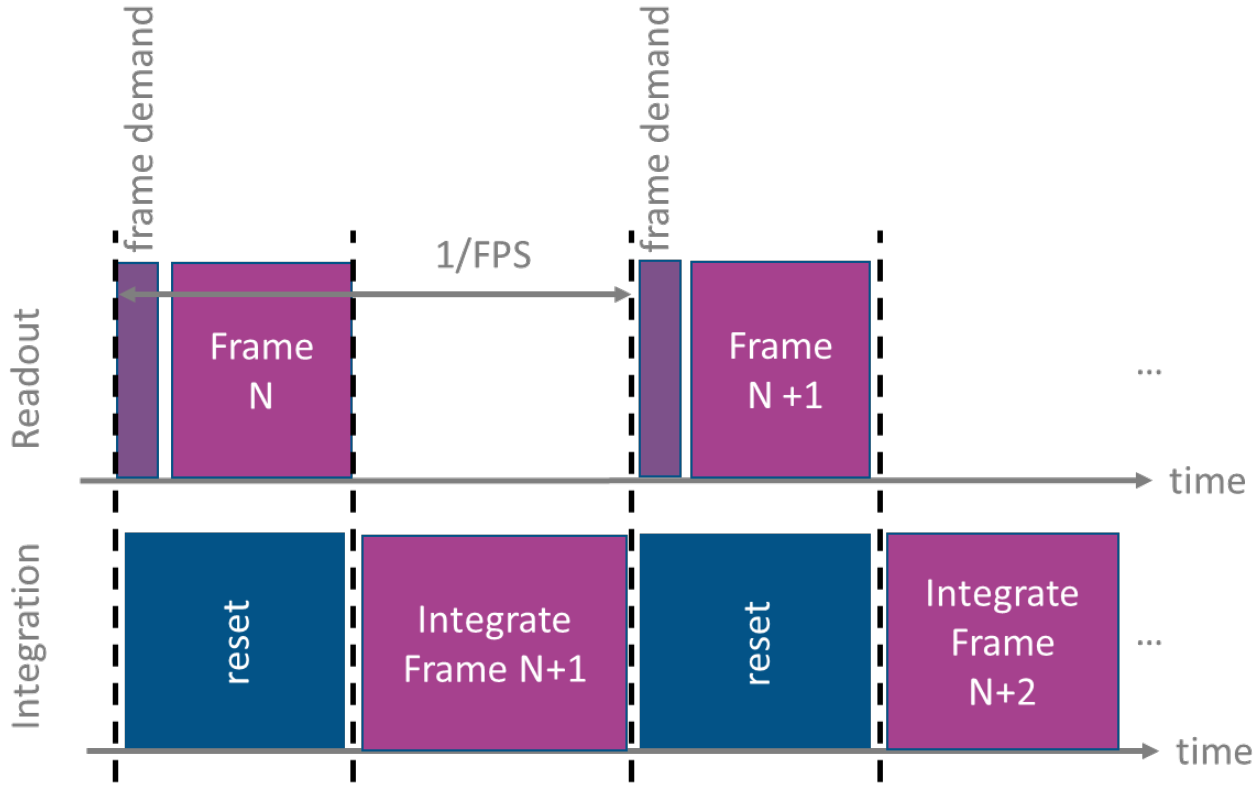


Fig. 13 : *ITR mode overview.*

7.2. Readout mode

7.2.1. Single Read

The entire frame is read once before a reset period.
The particularity of C-RED 2 readout mode allows to adjust the integration time (Tint) independently of the frame rate.
Depending of these two parameters, the camera will run in ITR or IWR mode, please refer to Fig. 12 : and Fig. 13 : for further information.
By default, in single read readout, the images are acquired in correlated double sampling (CDS) mode.
An internal CDS is done directly on the sensor.

7.2.2. Integrated Multiple Readout (IMRO)

IMRO mode is a specific readout mode in which sensor reset is done every N (N>1) read operations.
The number of non-destructive reads (NDR) is configurable by the user.

The IMRO burst starts with a reset period, followed by the chosen number of NDR reads. The NDR reads are performed at the current frame per second rate.

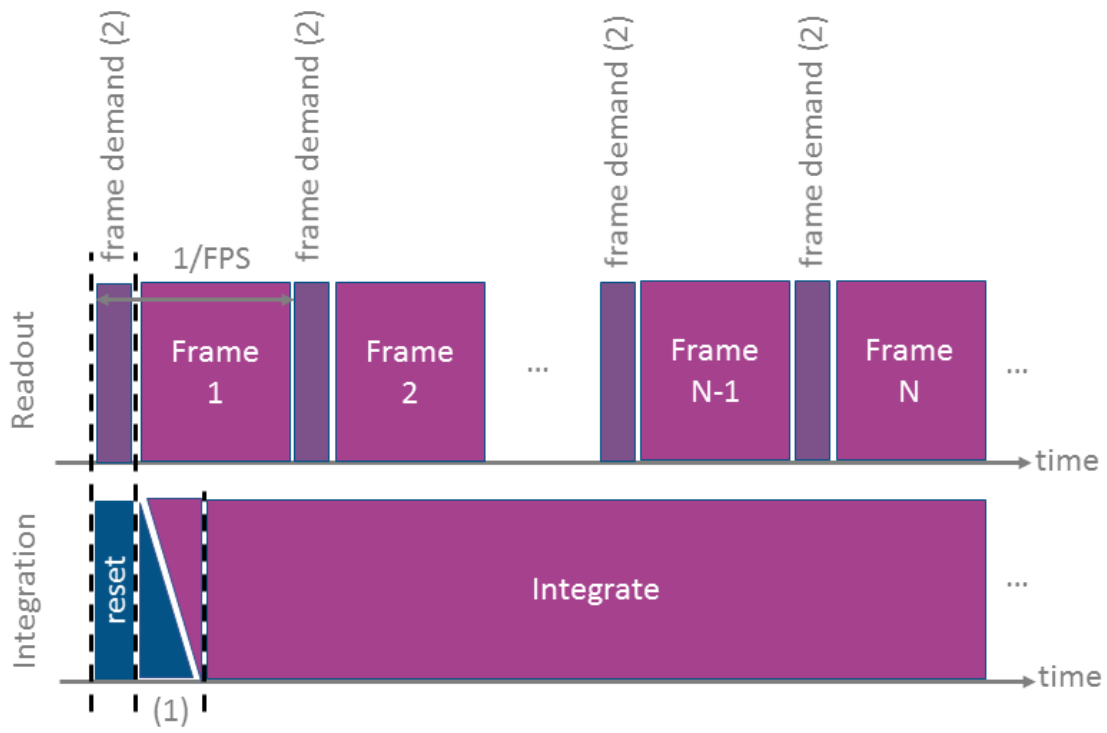


Fig. 14 : *IMRO mode overview.*

(1) Variable time:
This time (1) is either reset time, or integration time, depending of the FPS and Tint set by the user.
First Light Imaging recommends setting the maximum integration time allowable for a given FPS.

(2) Frame demand:
The camera can do an **embedded processing of IMRO bursts**.
This embedded processing can be enabled or disabled. When enabled, the camera processes internally all the frames of an IMRO burst and sends the resulting image. When disabled, the camera sends all the acquired frames.

The first frame of an IMRO burst, e.g. the frame read just after sensor reset is acquired in correlating double sampling (CDS) mode. For the following frames, acquired without sensor reset, acquired images are directly the additional light integration on the capacitor.

The integration time of the first frame is configurable, but for next reads the integration time is always 1/fps. If the user sets an integration time different from 1/fps, please note that he will get a different integration time between the first and the following frames.

When processing of IMRO frames is enabled in the camera, the following limitations applies:

- When enabled, cropping area (see 6.3.4) cannot be smaller than 1/4 of the sensor full resolution.
- The number of NDR reads is limited to 255 in raw mode. When the embedded slope computation is used the limit is 64.

7.3. Data acquisition mode

7.3.1. Detector geometry

The SNAKE-SW sensor has a (640 x 512) diode array and 8 buffered analog outputs (see Fig. 15 :).

For 400 fps variant, the pixel clock of the sensor is set to 12.2 MHz, which allows a read-out speed about 195 Mpix/s.
For 600 fps variant, the pixel clock of the sensor is set to 18.2 MHz, which allows a read-out speed about 292 Mpix/s.

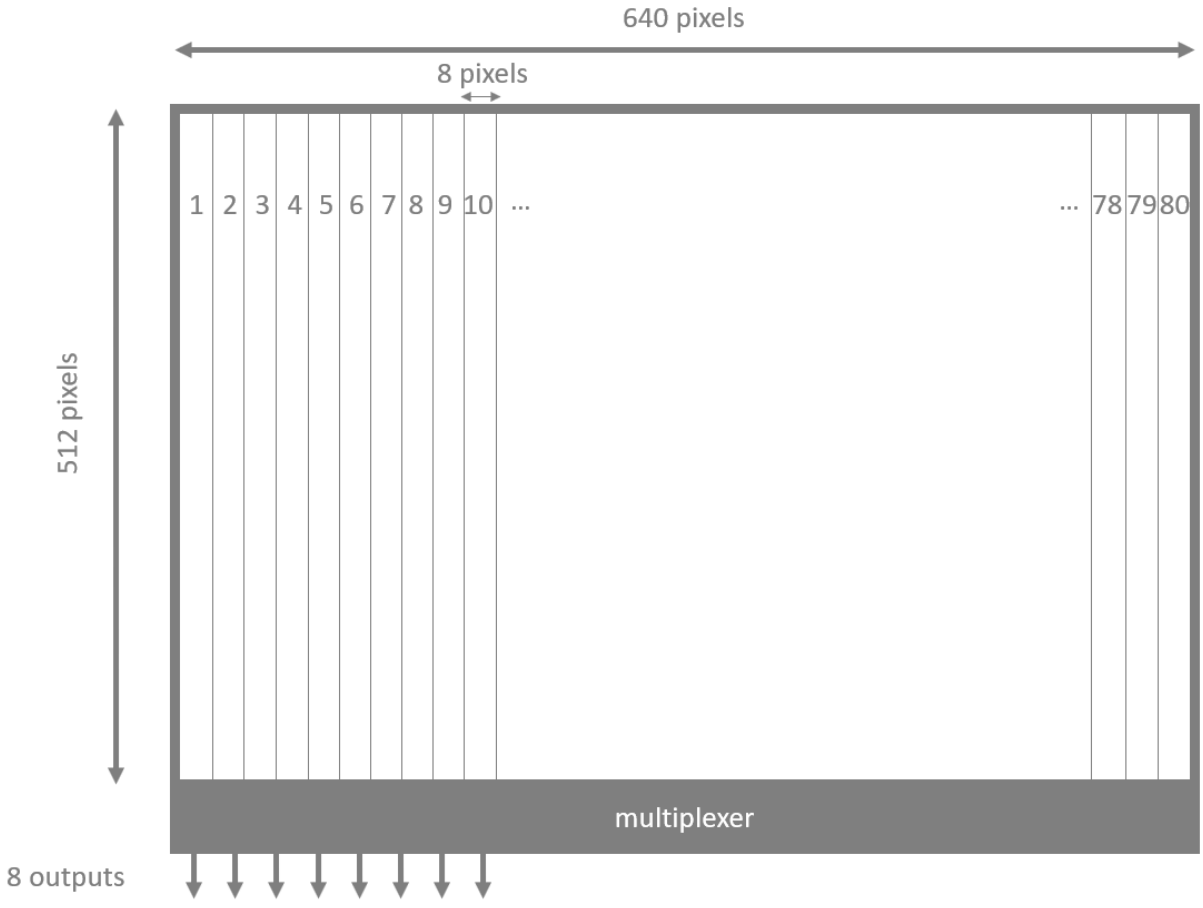


Fig. 15 : *Sensor geometry*

7.3.2. Pixel format (ADU)

C-RED 2 digitizes the signal from the sensor with 14-bits precision. However, the pixel values are sent as 16 bits signed format. Indeed, after embedded bias subtraction, some pixels may have negative value.

7.3.3. Full frame mode

Pixels are read from left to right and up to down (see Fig. 16 : and Fig. 17 :) starting from the left top corner.

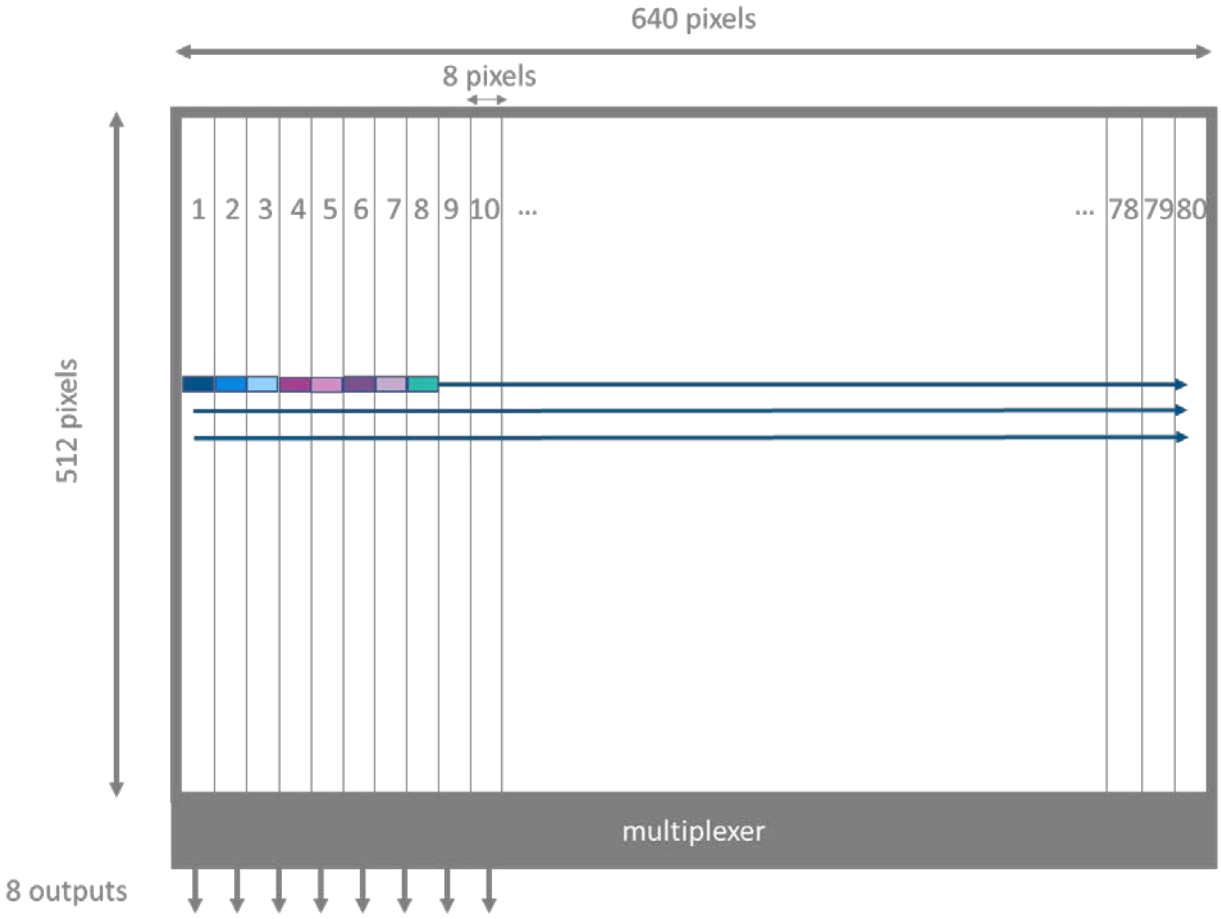


Fig. 16 : *Detector geometry and read out pixels scheme.*

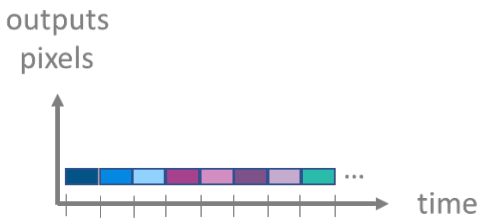


Fig. 17 : *Sensor outputs. Pixels are read from left to right and up to down.*

7.3.4. Cropping mode

On the sensor, it is possible to select one region of interest and acquire data from this selected window only.
Column granularity is 32 and line granularity is 4.
So, the starting column and line must be a multiple of 32 and 4 pixels, respectively.
In the same way, the width and the height of the window must also be a multiple of 32 and 4 (see Fig. 18 :).
The intersection of both lines and columns forms the readout window.
Pixels are sent like in full frame mode, from left to right and up to down (see Fig. 20 :).

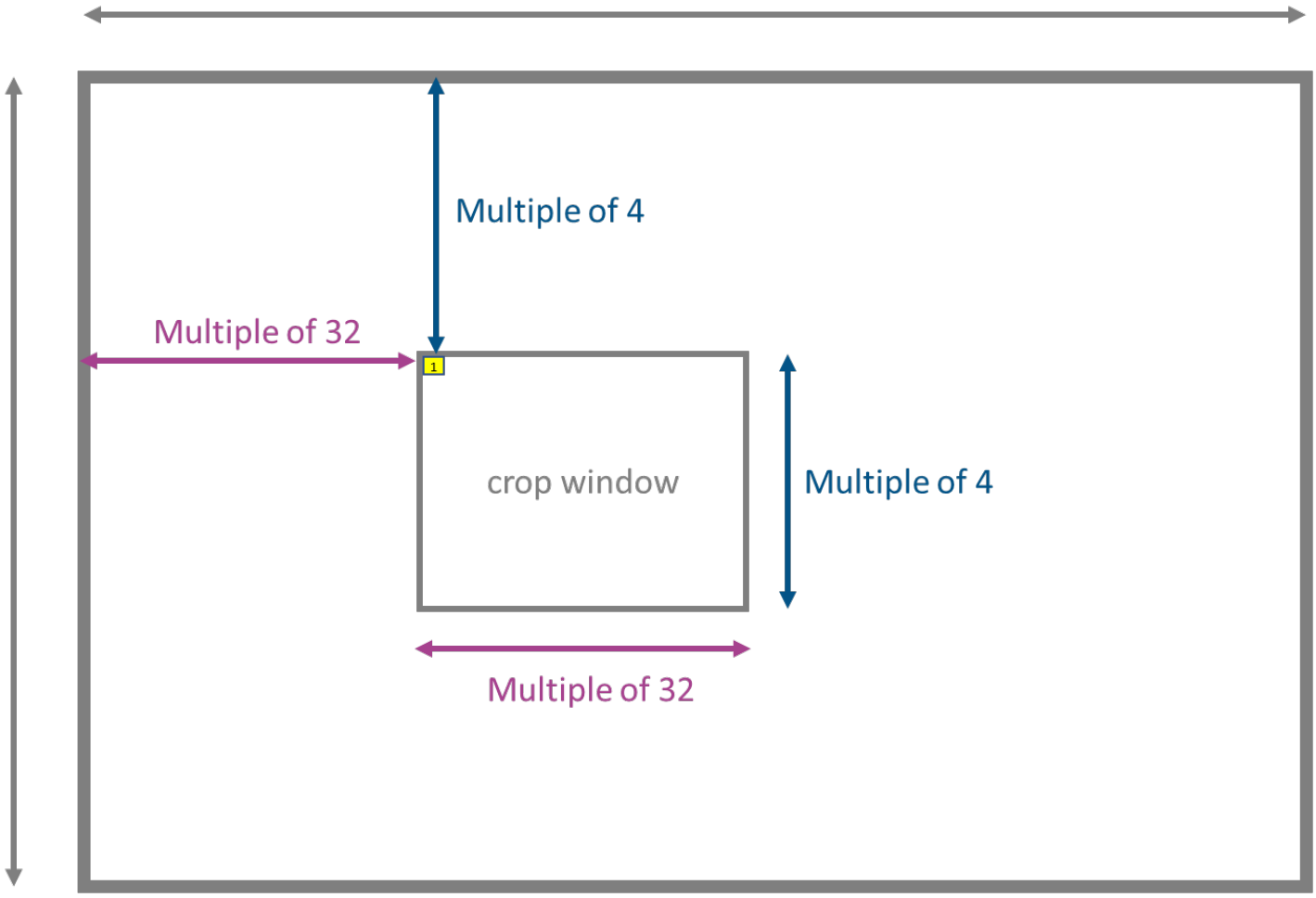


Fig. 18 : *Descriptive scheme of a cropping window.*

Note : To set a cropping window using the command line interpreter, the user must indicate the starting column, the ending column, the starting row and the ending row. Please refer to camera commands for more detail.

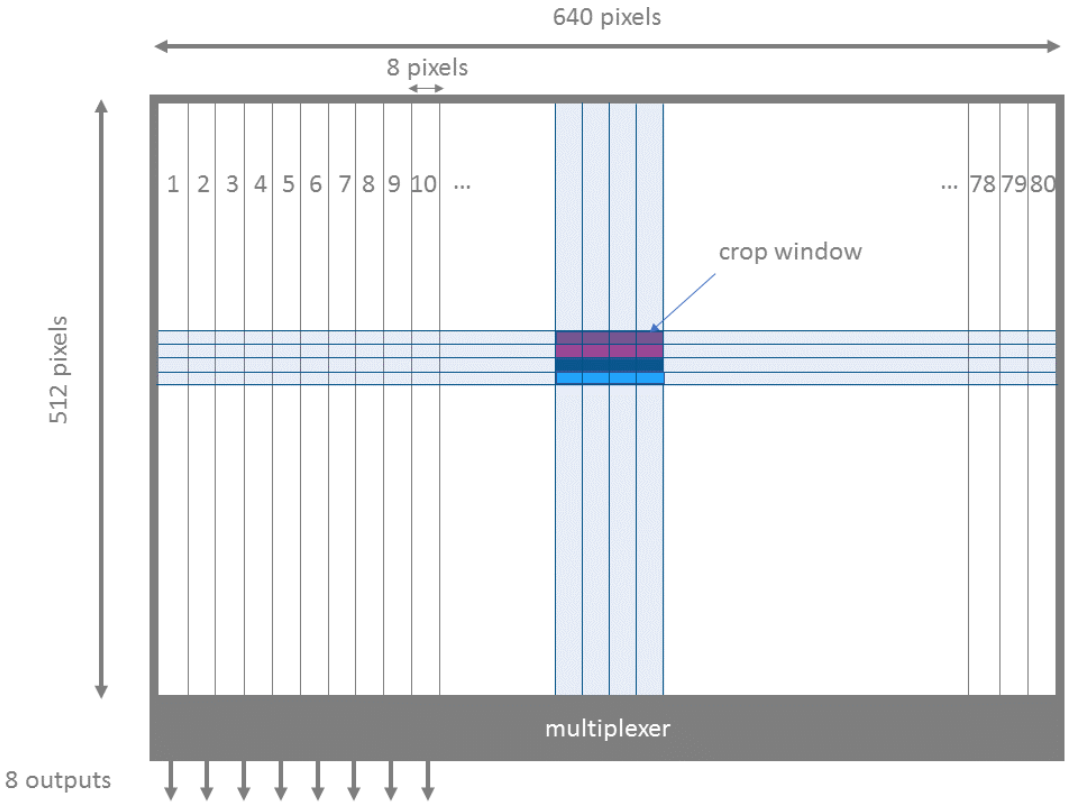


Fig. 19 : *Cropping example on geometry detector.*

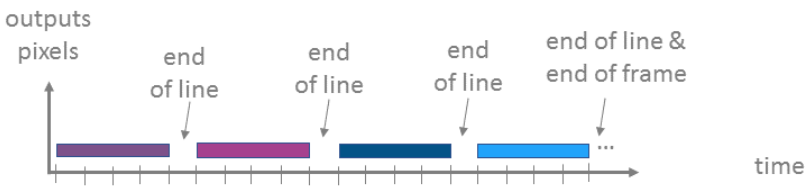


Fig. 20 : *Sensor Output in cropping mode. Pixels are read from left to right and up to down.*

7.4. Sensibility scale mode

Signal can be integrated in low, medium or high gain corresponding to high, medium and small integration capacity, respectively. The modification of the integration capacity impacts the dynamic of the signal and thus implies a change of the noise level.
It is possible to modify the integration capacity using "`set sensibility low`", "`set sensibility medium`" or "`set sensibility high`" commands in the command line interpreter.

8. OPERATION

8.1. Data format

8.1.1. Camera Link®

C-RED 2 uses the Camera Link® Full interface which requires two data cables. Data are transmitted with a standard protocol using 4 taps of 16 bits width. With this configuration, pixels are sent 4 by 4 through the Camera Link®, and the Camera Link® Pixel Clock is 48.8 MHz for 400 fps configuration and 72.9 MHz for 600 fps configuration.

Fig. 21 : *Print screen of Intellicam software from Matrox*

Note: When a Matrox acquisition board is used, the user needs to set x to 160(=640/4).

8.1.1.1. Camera Link® frame grabber

The camera is compliant with Camera Link® standard.
However, please note that our cameras have been developed and tested with specific grabbers, and we highly recommend using these grabbers.

The C-RED 2 firmware communicates with the user through the serial line embedded in the Camera Link® cables. Usually the frame grabber driver exposes the Camera Link® serial line as a virtual COM port on the acquisition system.

To communicate both ways, the serial line must be configured with the following settings:
115200 Bauds, 8 bits, No parity, 1 Stop bit, no flow control

8.1.2. USB

In addition to Camera Link®, C-RED 2 provides USB 3.0 interface. The connector type is USB-C.

As for Camera Link®, both image and configuration interfaces are available.
The configuration interface is also a pseudo COM port.
Before using USB interface, it is required to install C-RED 2 USB driver on the acquisition computer.
(cf. doc install C-RED 2 demo software).
When the camera is detected on the USB 3.0 port, windows automatically installs the C-RED 2 drivers.

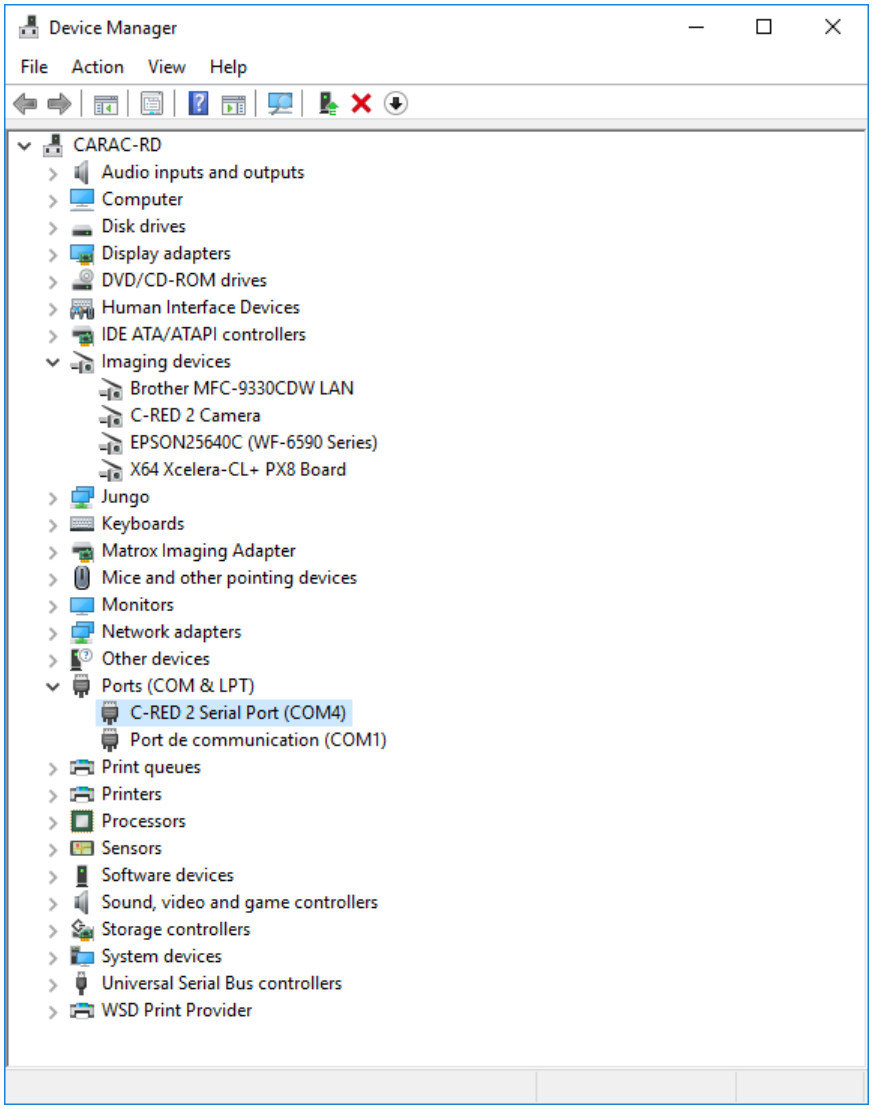


Fig. 22 : *Windows device manager illustration*

The COM port settings are the same as Camera Link® serial port interface:
115200 Bauds, 8 bits, No parity, 1 Stop bit, no flow control

A USB SDK is provided in both binary and source forms to perform frame grabbing.

Proper operation of the camera has been tested when using common one-meter long USB 3.0 cables, and with up to five-meters industrial grade USB 3.0 cables.

8.2.Synchronization

Synchronization is possible with C-RED 2. The camera is equipped with two sync connectors on its rear side (see Fig. 23 :).

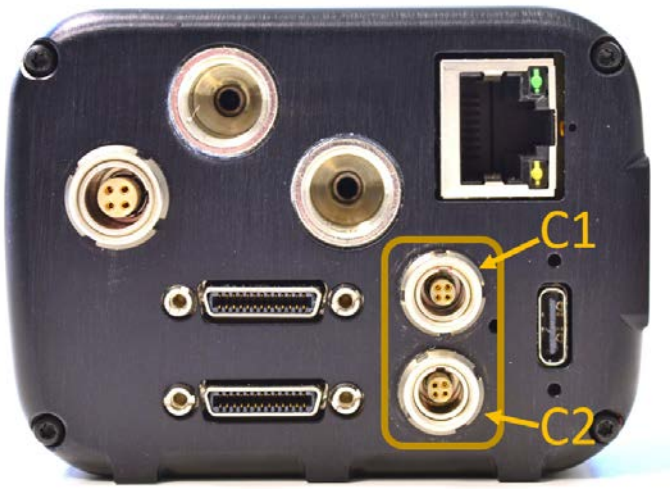


Fig. 23 : *C-RED 2 from the back. The yellow box shows the sync connectors C1 et C2.*

To be connected on the external synchronization, use the command "`set extsynchro on`" in the command line interpreter. If not, you will stay connected to the internal synchronization.

You can check if external synchro is on or off using the "`extsynchro`" command.

Note: Proper connection of external synchronization signals must be done before issuing the "`set extsynchro on`" signal.

8.2.1. Cable assembly

Synchronization requires two cables assemblies.

You can make your own synchronization cables using FGG.00. 304.CLAD35 LEMO Male connectors in association with a four-wire cable.

It is strongly advised to use shielded cable to respect Electromagnetic Compatibility (EMC) recommendations.

These cables will allow you to use all the functionalities of the external synchro.

Wiring is detailed in Fig. 24 :

Fig. 24 : *On the left, a C-RED 2 synchro female connector.*
On the right, wire cables corresponding to connector.

The C-RED 2 camera supports two configurations for synchronization signals.

First variant, available on all C-RED 2 camera firmware releases allow to control the frame acquisition using LVDS signaling. Second variant, available since FW version 2.9.1 allows to control the frame acquisition using CMOS signaling.

For firmware versions 2.9.1 and above, the selection between the two variants is done using the "`set synchronization`" command. Active configuration can be read using the "`synchronization`" command. For older configuration, the camera always uses LVDS signaling.

Note: prior to **downgrading** firmware from firmware version 2.9.1 or above to a previous version, ple ase ensure that synchronization configuration has been restored to LVDS.

8.2.2. Synchro connection when using LVDS signals

When using LVDS signaling, the C-RED 2 external synchro mode offers the ability to drive the frame readout with an external trigger.

It can provide timing information through a 4-pins LEMO connector (Mating LEMO male connector reference is FGG.00.304. series connectors).

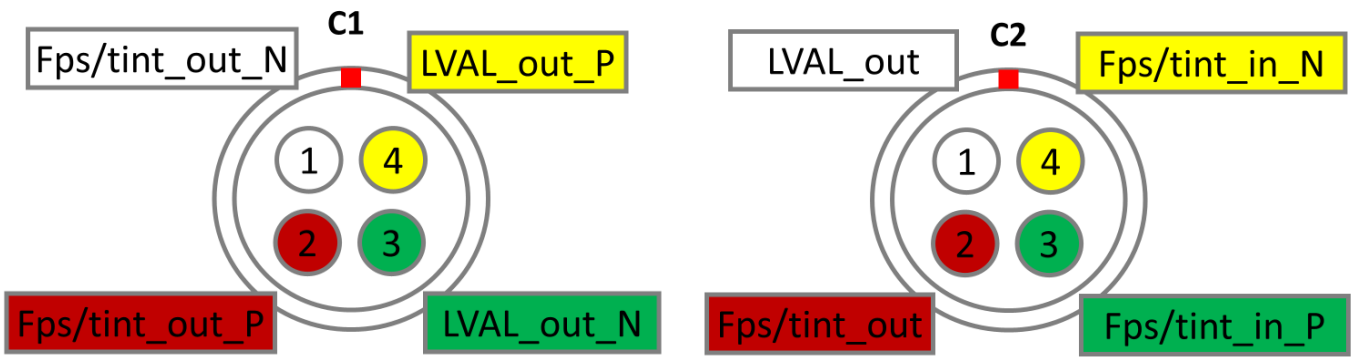


Fig. 25 : *LVDS Synchro connection scheme*

8.2.2.1. Input: fps/tint

The frame rate and integration time of C-RED 2 can be driven by an external source plugged on **C2.**
C-RED 2 allows values between 0.001 and 400 or 600 fps depending on the camera configuration.

The camera stays in integration mode while the synchro-in signal is low. When this signal goes high, it triggers the readout.

8.2.2.2. Output: fps/tint

The frame rate and integration time of C-RED 2 are available on connector C1 as LVDS output and on connector C2 as single ended LVCMOS3.3V.

8.2.2.3. Output: LVAL

Line valid (LVAL) signal is available on connector C1 as LVDS output and on connector C2 as single ended LVCMOS3.3V.
When this signal is high, a line is being transmitted.

8.2.3. Synchro connection when using CMOS signals

When using CMOS signaling, the C-RED 2 external synchro mode also offers the ability to drive the frame readout with an external trigger. A supplemental input signal allows to tag interesting images in the captured flow.

It can provide timing information through a 4-pins LEMO connector (Mating LEMO male connector reference is FGG.00.304. series connectors).

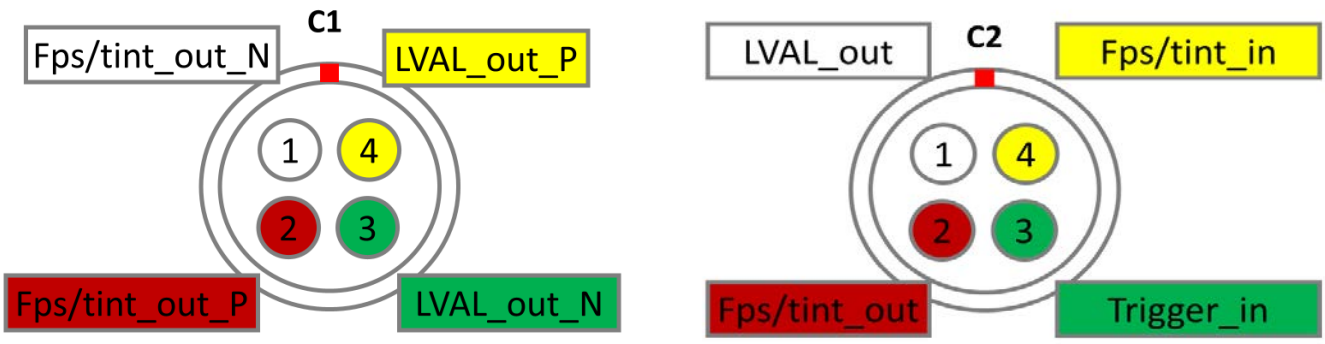


Fig. 26 : *CMOS Synchro connection scheme*

8.2.3.1. Input: fps/tint

The frame rate and integration time of C-RED 2 can be driven by an external source plugged on **C2.**
C-RED 2 allows values between 0.001 and 400 or 600 fps depending on camera configuration.

The camera stays in integration mode while the synchro-in signal is low. When this signal goes high, it triggers the readout.

8.2.3.2. Output: fps/tint

The frame rate and integration time of C-RED 2 are available on connector C1 as LVDS output and on connector C2 as single ended LVCMOS3.3V.

8.2.3.3. Output: LVAL

Line valid (LVAL) signal is available on connector C1 as LVDS output and on connector C2 as single ended LVCMOS3.3V.
When this signal is high, a line is being transmitted.

8.2.3.4. Input: Trigger_in

Trigger_in signal allows to mark specific frames during their acquisition. The camera does not interpret this signal, but only set the corresponding bit in the image tags (LSB bit of 4th image pixel). The image tags can be then used during acquisition by the acquisition software of later during image post processing.

Note: when CMOS signaling is used, Trigger_in signal is always used by the camera to mark acquired frames, independently of the usage of internal or external synchronization. This allows to use this signal without the need to drive image acquisition itself.

8.2.4. Latency

Camera latency is the delay between the rising edge of fps/int signal and the first valid data on camera link. This delay depends on camera configuration (400/600 fps configuration, tlsydel value, acquisition mode …)

The table below contains typical camera latency in normal (CDS) readout mode.

	400 fps	600 fps option
Latency for tlsydel = 324 (default)	33 µs	22.2 µs
Latency for tlsydel = 54 (min)	10.9 µs	7.4 µs

8.3. Bad Pixel Correction

Bad pixel correction can be done on the fly by the camera.

Enabling bad pixel correction requires that the bad pixel map has been loaded into the camera. This is done by First Light Imaging during the production/characterization of the camera. For cameras produced before the availability of the bad pixels correction, the bad pixel correction file is not present on the camera.
Please contact First Light Imaging support (support@first-light.fr) for a possible upgrade of the camera.

When enabled, bad pixel correction is the first correction applied on pixel values received from the sensor.

8.4. Bias/Flat Correction

Bias/Flat correction can be done on the fly by the camera.

Flat and Bias correction files can be computed automatically by the camera (operation triggered using "`exec buildbias`" or "`exec buildflat`" on the command line interpreter).
Alternatively, custom correction files can be uploaded to the camera using serial connection (either USB or CL) or using TCP/IP connection.

The use of bias/flat correction is more detailed in the software demo user manual, notably the use of custom correction files.

The bias correction is the second correction applied on pixel values read from the sensor.
The flat correction is the third correction applied on pixel values read from the sensor.

Even if it is possible to activate the different corrections independently from each other, it is important to understand that the correction will depend from all previous corrections applied.

For example, a bias correction file generated with bad pixels correction enabled will not be valid if bad pixels correction is disabled.

Flat correction should always be used with bias correction enabled.

Bias and flat corrections also depend from the acquisition parameters (frame rate, integration time, sensor temperature…). It is highly recommended to rebuild them when acquisition parameters are modified.

8.4.1. Bias correction file format

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

Bias correction file geometry must match the actual sensor geometry and must contain pixels values in the range [0-16383].

Pixels must be stored in left-to-right/top-to bottom order (the same order than the pixels in a received frame from the sensor). Each pixel value is stored on 16-bits, as for frames received from the sensor.

8.4.2. Flat correction file format

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

Flat correction file geometry must match the actual sensor geometry. Values are stored in left-to-right/top-to-bottom order (the same order than the pixels in a received frame from the sensor).

When flat correction is active, pixel values read from the sensor are multiplied by the corresponding value in the flat correction file.

Values are stored using fixed-point representation.
Bits 15-13 are used to store the integral part of the multiplication factor.
Bits 12-0 are used to store the decimal part of the multiplication factor.

Examples of values:

- 0010000000000000b / 0x02000000 is the representation of value 1.0
- 0100000000000000b / 0x04000000 is the representation of value 2.0
- 0001000000000000b / 0x01000000 is the representation of value 0.5
- 0011000000000000b / 0x01000000 is the representation of value 1.5

8.5. Tag generation

The C-RED 2 camera offers the possibility to replace the first 4 pixels of acquired images by information generated by the camera.

This function is controlled by the "`set imagetags on`" and "`set imagetags off`" commands.

When enabled, the first and second pixels of the camera are used to store a frame counter that increments by one for each frame acquired from the sensor. This counter can be used to check if some frames are lost during acquisition.

The third pixel value depends on the current readout mode of the camera.

In CDS mode, it is set to 0x0000.

In IMRO mode, the value depends on the activation of the image processing in the camera.

If IMRO frame processing is enabled, the pixel contains the number of frames in an IMRO burst, e.g. the number of frames between two sensor resets.

If IMRO frame processing is disabled, the pixel contains the index of the frame within an IMRO burst, starting from N-1 to 0 (N being the number of frames within an IMRO burst). N-1 corresponds to the first frame acquired after sensor reset, whereas 0 corresponds to the last frame acquired within a burst; e.g. the last one before the sensor is reset.

This counter is mainly useful in raw IMRO mode to allow the user to implement its own IMRO processing algorithms.

The forth pixel of the image is used to reflect the Trigger_in signal value, described in 8.2.3.4.
The pixel value is set to 0x3FFE when trigger_in signal is low and set to 0x3FFF when trigger_in signal is high.

8.6. Camera presets

C-RED 2 allows to store up to ten different user configurations, called presets.

Presets contain all parameters settable by user, plus corresponding bias and file correction files.
Using presets allow to switch easily from one configuration to another, without need to rebuild correction files.

A specific preset is selected using the "`preset <n>`" command. After loading a preset, the user is free to change any parameter. Changes can then be saved in the current present using the "`save`" command.
At any time, the current preset can be reloaded by using the "`preset`" command. All changes in the running configuration not previously saved will then be lost.

Factory camera presets can be restored using the "`restorefactory`" command.

8.7. Camera optional features.

C-RED 2 camera are provided with various optional features. These extra features are enabled through license files uploaded into the camera during the production or later by the customer.

An example of optional feature is the possibility to grab full sensor images at 600 frames per second.

The transfer of a license file into the camera is done using serial link connection, using either "`sendfile license`" or "`xsendfile license`" command.

A license file previously uploaded into a camera can be removed using the "`exec dellicense`" command.

For convenience, it is possible to enable/disable optional features without removing the corresponding license file.

Disabling of a license is done using the "`exec disablelicense`" command. Reenabling is done using the "`exec enablelicense`" command.

Note: When a license file is uploaded into the camera, it is enabled by default.

List of the currently installed licenses files and their status can be retrieved using the '`licenses`' command.

Note: uploading, enabling, disabling or removing a license require a camera reboot to be effective.

Below some examples of license management commands.

```
fli-cli>licenses
600fps.lic
OK

fli-cli>exec disablelicense 600fps.lic
OK

fli-cli>licenses
600fps.lic.disabled
OK

fli-cli>exec enablelicense 600fps.lic
OK

fli-cli>licenses
600fps.lic
OK
fli-cli>
```

9. DESCRIPTION OF VARIOUS FONCTIONS

The list of available commands of the camera can be displayed using 'help' command in the terminal of the demo GUI software. The available commands are listed below.

9.1. List of available commands

COMMANDS	DESCRIPTION
voltage vref	Get VREF voltage
temperatures	Get temperatures
temperatures motherboard	Get motherboard temperature
temperatures frontend	Get front-end temperature
temperatures powerboard	Get power-board temperature
temperatures snake	Get sensor temperature
temperatures snake setpoint	Get sensor temperature setpoint
temperatures peltier	Get external TEC temperature
temperatures heatsink	Get heatsink temperature
power	Get powers consumed by the sensor internal's TEC and external TEC
power snake	Get power consumed by sensor's internal TEC
power peltier	Get power consumed by external TEC
tlsydel	Get tlsydel delay
fps	Get acquisition frame rate (fps)
minfps	Get the minimum acquisition frame rate according to current camera configuration
maxfps	Get the maximum acquisition frame rate according to current camera configuration (Camera Link)
maxfpsusb	Get the maximum acquisition frame rate according to current camera configuration (USB)
tint	Get integration time
mintint	Get minimum integration time according to current camera configuration
maxtint	Get the maximum integration time regarding current camera configuration
maxtintitr	Get the maximum integration time without integration/read overlap regarding current camera configuration
tintgranularity	Get the integration time granularity status when operating in IWR mode
tcdsadjust	Get TCDS automatic adjustment status for low integration times
vrefadjust	Get VREF automatic adjustment status
bias	Get bias correction status
flat	Get flat correction status
badpixel	Get bad pixel correction status
imagetags	Get tag generation status

led	Get current LED status
sendfile bias <sendfileSize> <sendfileMD5>	Upload a bias file into camera through serial link
sendfile flat <sendfileSize> <sendfileMD5>	Upload a flat file into camera through serial link.
sendfile license <sendfileName> <sendfileSize> <sendfileMD5>	Upload a license file into the camera through serial link.
xsendfile bias <sendfileSize> <sendfileMD5>	Upload a bias file into camera through serial link using X-MODEM protocol
xsendfile flat <sendfileSize> <sendfileMD5>	Upload a flat file into camera through serial link using X-MODEM protocol
xsendfile license <sendfileName> <sendfileSize> <sendfileMD5>	Upload a license file into the camera through serial link using X-MODEM protocol.
getflat <url>	Download a flat correction file from URL
getbias <url>	Download a bias correction file from URL
events	Get camera events sending activation status
extsynchro	Get usage of external synchronization status
rawimages	Get transmission of raw images in IMRO mode status.
nbreadworeset	Get number of frames read between reset in IMRO mode
cropping	Get cropping status
cropping columns	Get cropping columns
cropping rows	Get cropping rows
version	Get product versions
version firmware	Get firmware version
version firmware detailed	Get detailed firmware version
version firmware build	Get build version
version fpga	Get FPGA version
version hardware	Get hardware version
status	Get camera status
status detailed	Get last status change reason
continue	Continue camera starting even if at the last use, the camera was in error
save	Save current camera settings into the current active preset
restorefactory	Restore factory parameters and reboot the camera
preset	Get current preset id
ipaddress	Get IP address of the camera
telnet	Get telnet status
cameratype	Display camera information
shutdown	Shutdown the camera
remotemaintenance	Get remote maintenance status
password	Get current password for telnet/ssh connections
fan mode	Get fan speed control mode
fan speed	Get fan speed in manual mode
sensibility	Get camera sensibility value

snake <parameter>	Get snake configuration parameter
hwuid	Get camera unique identifier
synchronization	Get current signaling for external synchronization
licenses	Get currently configured license list
exec upgradefirmware <url>	Upgrade the firmware with a new release located at the specified URL
exec buildbias	Build the bias correction image
exec buildflat	Build the flat correction image
exec enablelicense <license>	Delete a license file. Will be active on next reboot
exec enablelicense <license>	Activates a license file. Will be active on next reboot
exec disablelicense <licence>	Deactivates a license file. Will be active on next reboot
exec logs	Collect and serve logs through http
exec logs <from>	Collect and serve logs through http
set voltage vref <vrefValue>	Set VREF voltage
set temperatures snake <snakeValue>	Set sensor temperature setpoint
set fps <fpsValue>	Set acquisition framerate
set tint <intValue>	Set integration time
set tintgranularity on	Enable exposure time granularity in IWR mode
set tintgranularity off	Disable exposure time granularity in IWR mode
set tcdsadjust on	Enable TCDS value adjustment for small integration times
set tcdsadjust off	Disable TCDS value adjustment for small integration times
set vrefadjust on	Enable VREF value adjustment
set vrefadjust off	Disable VREF value adjustment
set bias on	Enable bias correction
set bias off	Disable bias correction
set flat on	Enable flat correction
set flat off	Disable flat correction
set badpixel on	Enable bad pixel correction
set badpixel off	Disable bad pixel correction
set imagetags on	Enable tags generation
set imagetags off	Disable tags generation
set led on	Turn on the status led
set led off	Turn off the status led
set events on	Enable camera events
set events off	Disable camera events
set extsynchro on	Enable external synchronization
set extsynchro off	Disable external synchronization
set rawimages on	Disable IMRO processing – All IMRO frames are sent
set rawimages off	Enable IMRO processing. Only processed image is sent.
set nbreadworeset <nbreadworesetValue>	Set number of frame reads between two resets in IMRO mode
set cropping on	Enable cropping
set cropping off	Disable cropping

set cropping columns <columnsValue>	Set cropping columns (0-639, granularity 32)
set cropping rows <rowsValue>	Set cropping rows (0-511, granularity 4)
set password <password>	Change password for telnet/ssh connections
set ip mode manual	Select manual network configuration
set ip mode automatic	Select dynamic network configuration using DHCP
set ip address <ip>	Set camera's IPv4 address
set ip netmask <mask>	Set camera's IPv4 netmask
set ip gateway <gateway>	Set camera's IPv4 gateway address
set ip dns <dns>	Set primary DNS IPv4 address
set ip alternate-dns <dns>	Set alternate DNS IPv4 address
set telnet enable	Enable control of the camera through telnet connection
set telnet disable	Disable control of the camera through telnet connection
set remotemaintenance on	Enable remote maintenance
set remotemaintenance off	Disable remote maintenance
Set tlsydel <value>	Change tlsydel value
set fan mode automatic	Set automatic fan speed control
set fan mode manual	Set manual fan speed control
set fan speed <value>	Set fan speed in manual mode
set sensibility low	Select lowest camera sensibility
set sensibility medium	Select medium camera sensibility
set sensibility high	Set highest sensibility
set snake <parameter> <value>	Set snake config parameter
set preset	Reload currently active camera settings preset
set preset 0	Load camera settings preset #0
set preset 1	Load camera settings preset #1
set preset 2	Load camera settings preset #2
set preset 3	Load camera settings preset #3
set preset 4	Load camera settings preset #4
set preset 5	Load camera settings preset #5
set preset 6	Load camera settings preset #6
set preset 7	Load camera settings preset #7
set preset 8	Load camera settings preset #8
set preset 9	Load camera settings preset #9
set synchronization lvds	Select LVDS signaling for external synchronization
set synchronization cmos	Select CMOS signaling for external synchronization

Basically, there are three kinds of commands: 'get', 'set' and 'exec'.
The 'get' commands can be used to retrieve some values from the camera, 'set' to set parameters and 'exec' to ask the camera to do a task.

For example:
type '`fps`' to get in return '`Frames per second: 400`'.
'`set fps 100`' gives '`Result: OK`' when the request is implemented.

By default, commands are verbose. However, it is possible to get the parameter value only.
To do so, you can add the keyword '`raw`' at the end of the command.

For example:
'`fps raw`' gives '`400`'.

Another example:
Type '`exec buildbias`' to ask the camera to compute a bias file.
You will get '`Compute bias image.....Done`' when the operation is completed.

Note: the camera must be rebooted after using the command '`set password`', and after using every command '`set IP`'.

For details on some advanced commands like "`snake command`", please contact First Light Imaging at support@first-light.fr.

9.2. Commands format detail

C-RED 2's command line interpreter (aka CLI) on the CL or USB serial link is simple:

Commands are only composed of ascii characters.
Each command must be ended with line feed character: '\n'
There is no echo of character.
There is no escape sequence, only simple ascii characters.
After each answer of the camera, you get the following additional sequence of character: CR LF "fli-cli>"
('\r' '\n' 'f' 'l' 'i' '-' 'c' 'l' 'i' '>')

For example:
With the command "`temperatures motherboard raw`", you could get the following sequence of hexadecimal characters:

00000000 33 33 2e 35 30 0d 0a 66 6c 69 2d 63 6c 69 3e |33.50..fli-cli>|

Note: Since the configuration of the camera is done using serial interface, not only the "CRED2 DEMO" software can be used to communicate with the camera but also any terminal software like putty for example.

9.3. SSH configuration

The configuration of the camera can also be done using a ssh connection.
To be more human friendly, on ssh, the camera interpreter can behave differently. It can manage character echo and escape sequences. To use this improved mode, the ssh login is '`adminnc`'.
The same behavior as on the serial link is also available using the login '`admin`'.
The default password is "`flicred1`", it can be changed using the '`set password`' command.

Note: There is no authentication on the serial links. So, an interpreter running on this kind of interface can be used to run the command '`password`' and retrieve the password.

10. PRECAUTIONS AND MAINTENANCE

10.1. Precaution of use

Your C-RED 2 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 C-RED 2 is an electronic equipment that requires precaution regarding static shocks.
As any scientific instrument, your C-RED 2 camera is fragile and should not be exposed to shocks, extreme temperatures, humidity and dusty environment.

Your C-RED 2 camera is an expensive and fragile product, handle it with care!

10.1.1. Static / electric shocks:

Any electronic equipment that has to be connected to C-RED 2 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 C-RED 2.

10.1.2. Heating / cooling:

Your C-RED 2 camera can work with a liquid cooling system.
If used, please use your cooling system in accordance to the cooling system instructions.

Dew point:
Please use the cooling fluid at a temperature above the dew point. If the dew point is unknown, use a cooling fluid at a temperature which is not below the room temperature.

10.2. Operational environment

Maximum cooling fluid temperature:	35°C
Minimum cooling fluid temperature:	Dew point of the room (recommended)

Maximum Use / Storage temperature:	45°C
Minimum Use / Storage temperature:	10°C

Maximum Relative Humidity:	0% to 80%*
**If the camera uses liquid cooling, be careful to the dew point*	

Absolute pressure:	500 mbar* to 2 bar
** First Light Imaging recommends using liquid cooling for pressure lower than 1 bar*	

10.3. Maintenance

10.3.1. 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.*

10.3.2. Cleaning of window.

Never use an unclean cloth to wipe the window of the camera.
The window should be cleaned with a dry and soft cloth, you can use water or ethanol and gently wipe the window.
Please avoid touching the glass window.

10.3.3. Storage.

When not in use, please store your camera in a dry place, in its box.

10.3.4. Ethernet connection

Maintenance can be done using Ethernet connection, to upgrade the embedded firmware or for remote assistance.

The Ethernet cable is not provided in the C-RED 2 camera package. It is strongly advised to use shielded cable to respect Electromagnetic Compatibility (EMC) recommendations.

11. WARRANTY AND LIABILITY

11.1. For the USA

11.1.1. 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.

11.1.2. 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.

11.1.3. 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 contact@first-light.fr, 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.

11.1.4. 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:

11.1.4.1. 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.

11.1.4.2. 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.

11.1.4.3. 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.

11.1.4.4. 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.

11.1.5. 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.

11.1.6. 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.

11.2. For the rest of the World

11.2.1. 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.

11.2.2. 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.

11.2.3. 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.

12. CONTACTS

12.1. For the USA:

FIRST LIGHT IMAGING Corp.
185 Alewife Brook Parkway, Ste 210
Cambridge, MA 02138
USA

Tel.: + 33 4 42 61 29 20
E-mail: support@first-light.fr
Website: www.first-light.us

12.2. For the rest of the world:

FIRST LIGHT IMAGING SAS
Europarc Sainte Victoire, Bât. 6
Route de Valbrillant, Le Canet
13590 Meyreuil
France

Tel.: + 33 4 42 61 29 20
E-mail: support@first-light.fr
Website: www.first-light.fr