C-RED One
User Manual

Table:

1. INTRODUCTION

Thank you for choosing C-RED One!

C-RED One 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 C-RED One.

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, should you have any question, at support@first-light.fr.

1.1. Caution

⚠️ *Your C-RED One camera contains fragile components, especially the e-APD detector.*

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

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

1.2. Overview

C-RED One is a state of the art liquid-cooled high-speed, high-sensitivity, ultra-low noise camera for challenging scientific applications.

Equipped with an e-APD MCT (Avalanche Photo Diode Mercury Caldium Telluride) detector, C-RED One takes more than 3500 images per second at the full 320x256 resolution of its 24µm pixels.
It has a CameraLink Full connectivity for low-latency output and can achieve single photon detection with extremely low noise of less than 1e with gain.

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

⚠️ *Always follow the instructions for use.*

2. WARNINGS

2.1. Vacuum

Your camera is under vacuum. Do not open the camera valve without active pumping.

⚠️ *Opening your camera to atmospheric pressure may lead to permanent damage.*

2.2. 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.*

2.3. 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.*

2.4. Cooling water

Be sure that the cooling system is correctly connected before turning on the camera and check that no leaks are visible.

⚠️ *Any operation without water cooling can damage permanently the camera.*

3. CONTENTS OF PACKAGE

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

	C-RED One
Camera	1
Power Supply	1
User Manual printed	1
Staubli female connectors	2
LEMO Cables for external trigger	2
Vacuum pumping group including hoses and connectors	1
USB Key with User Manual + Demo software + Test report	1
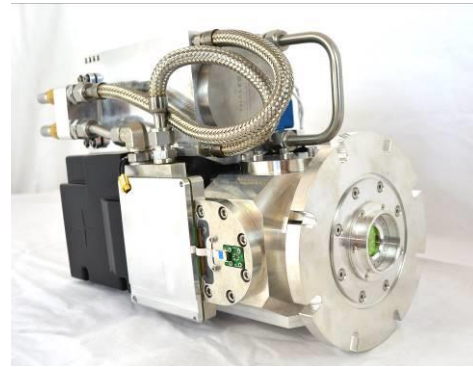
Note 1: The cooling unit and personal computer can be bought separately. Any reference is compatible with respect of the minimum requirements (see section 4).

Note 2: The softwares are downloadable on http://www.first-light.fr/category/downloads/softwares/ .

Note 3: Items may differ from pictures.

Note 4: If you bought your C-RED One system together with the cooling unit, please refer to the cooling unit instructions before handling the cooling unit (see section 4 for minimum requirements).

4. DESCRIPTION AND TECHNICAL SPECIFICATIONS

4.1. e-APD Sensor

4.1.1. Introduction to ME 1000 and main features.

Designed and fabricated by SELEX, the SAPHIRA detector is designed for high speed infrared applications and is the result of a development program alongside the European Southern Observatory on sensors for astronomical instruments. It delivers world leading photon sensitivity of <1 photon rms with Fowler sampling and high speed non-destructive readout (>10K frame/s). Saphira is an HgCdTe avalanche photodiode (APD) array incorporating a full custom ROIC for applications in the 1 to 2.5 µm range.

The SAPHIRA detector uses the HgCdTe APD properties, offering sub-electron noise with multiplication gain up to x400. The pixel format is 320x256 pixels with 15fF integration node capacitance (28fF with HgCdTe diode). The array has 32 parallel video outputs, organized as 32 sequential pixels in row. The 32 outputs are arranged in such a way that the full multiplex advantage is available also for small sub-windows. Non-destructive readout schemes with subpixel sampling are possible. This reduces the readout noise at high APD gain well below the sub-electron level at frame rates of 1 KHz. The growth technology used now is the metal organic vapour phase epitaxy (MOVPE). This growth technology provides more flexibility for the design of diode structures. It is possible to make heterojunctions with different bandgap properties between the absorption region and the multiplication region. The change to MOVPE resulted in a dramatic improvement in the cosmetic quality with 99.97 % operable pixels at an operating temperature of 85K. The avalanche gain is controlled by an external voltage. The digital and analog functions are controlled by a serial interface. The readout of SAPHIRA allows to read multiple windows, each independently resettable. Glow protection and APD protection circuit are also included.

4.1.2. Spectral response at 80K

Quantum efficiency for Mark 13 APD arrays
As a fn of antireflection coating thickness

4.2. Camera Specification and performances

4.2.1. C-RED One

Test Measurement	Unit	C-RED One
Mean Readout noise at 3500 fps and multiplication gain 100 with optimized filters	e	<0.5
Quantization	Bits	16
Dark Signal at 3500 fps at 80k	e/pixel/frame	0.6
Detector operating Temperature	°C	80K
Peak Quantum Efficiency at 1550 nm	%	70
Image full well capacity at gain X1	e	80 000
Latency between exposure and first pixel availability	µs	2

4.2.2. Mechanical and optical interfaces

The C-RED One camera is designed to deliver the best precision possible regarding the optical alignment of the sensor.

DÉTAIL A
ECHELLE 1 : 1

4.3. Description and Minimum Specifications for accessories

4.3.1. Power Input

C-RED One requires a single power supply.
Power supply should provide a stable 24V DC, with at least 18 A of current available. Thus a 24V, 600W power supply or above is adequate to power C-RED One.
The mating connector is a LEMO® FGG.1B.306 series. Cabling is shown Figure 1.

C-RED One Female power
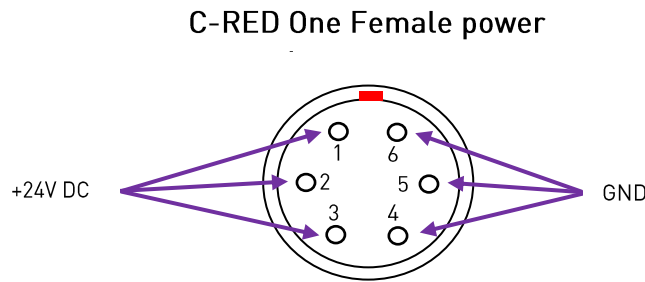
Fig. 1 :   C-RED One power connector cabling

⚠ *Always use the provided power supply.*

4.3.2. Cooling

To achieve its nominal performance, the C-RED One camera requires liquid cooling.
The camera has its own internal thermal regulation that cools the detector down to 80K.

Parameters	Value
Flow	3 liters per minute minimum
Pressure	10 bars maximum
Temperature	35°C maximum
Liquid	Ethylen Glycol aqueous solution (concentration max: 50%) Distilled water or deionized water if liquid temperature is > 5°C
Cooling capacity	400 W minimum

Heat is evacuated by circulating a cooling fluid through the two rear connectors Ref. Staubli CBI06.7151/IA, mating connectors are Ref. Staubli CBI06.1810/IA/VP.

⚠ *Be sure that the cooling system is correctly connected.*

4.3.3. Vacuum

Setup :
Connect the pumping system to the camera
Switch the pumping system ON
Let it run for 5 minutes
Open gently the camera vacuum valve, so that the camera is flushed.
Important:
Due to the pressure loss between internal assemblies, the vacuum and the back to atmospheric pressure must be achieved in more than 30 seconds.

⚠️ *Opening the valve too quickly may lead to huge differential pressures in the camera and permanent damage.*

This version of C-RED One camera requires an external pumping to achieve the cryogenic temperature of the sensor.
The pressure must be lower than 1.10-4 mbar to activate the pulse tube cryocooler.

4.3.4. Data

The C-RED One data connection uses the CameraLink standard to handle all communications.
The camera uses the Camera Link Full interface that requires two data cables.
The C-RED One connectors are 2 female SDR-26 Mini CameraLink.
Connectors are numbered 1 and 2. Connector 1 is the one at the top of the camera as shown.
If the cables are cross-connected 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 One firmware communicates with the user through the serial line embedded in the CameraLink cables. Usually the driver for the Frame grabber will expose the serial line of the CameraLink standard as a virtual COM port on the acquisition system.

Please note that our cameras have been developed and tested with specific grabbers, and that we highly recommend to use these grabbers. Any malfunctions related to the use of a non-certified grabber will not be supported by First Light Imaging.

Fig. 2 :   CameraLink Output

Fig. 3 :   *CameraLink COM port mapping*

In order to communicate both ways with the camera said COM port should be set to:
115200 Bauds, 8 bits, No parity, 1 Stop bit.

4.3.5. List of tested and recommended grabbers

-TELEDYNE DALSA PCX Xcelera-cl px8 full
-MATROX: Radient eV-cl full

5. INSTALLATION / CAMERA START UP

5.1. Connecting your camera

5.1.1. Cooling Hoses
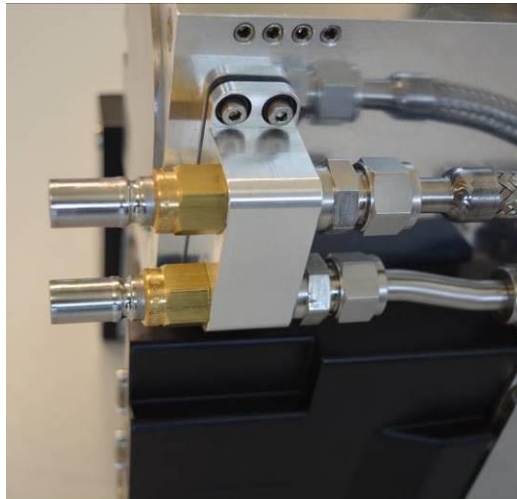
Fig. 4 :   C-RED One coolant connectors

Insert the male connector into the socket until it locks in place. There should be an audible 'click' and the connector should not move until released by pushing the ring on the female (camera) side.
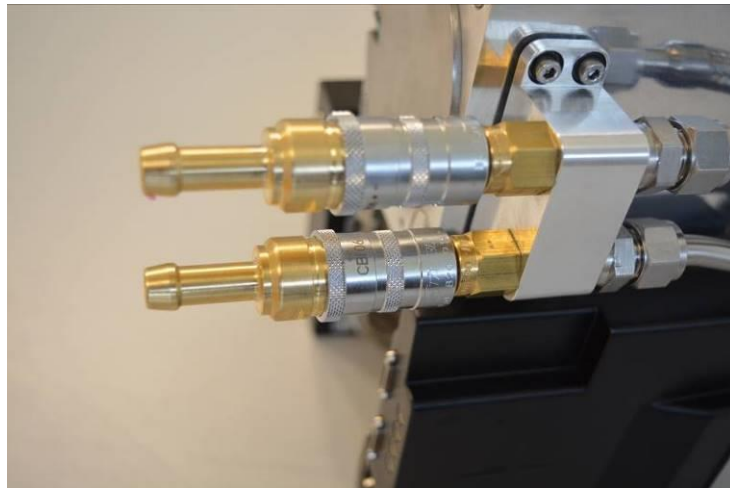
Fig. 5 :   Coolant connectors in place

Once cooling connectors have been correctly inserted, the coolant circulation can be turned on, and the user should check that no leaks are visible. Refer to the cooling unit user manual to ensure a proper operation.

Be sure that the cooling is on before turning on the camera.

⚠️ *Any operation without water cooling can damage permanently the camera.*

5.1.2. Camera Link cables

Once the camera is properly cooled the CameraLink connectors should be plugged and fastened.

The CameraLink connections should be plugged or unplugged camera off. It is recommended to turn the acquisition computer ON before the camera.

Note: Unlike the coolant connectors, the CameraLink cables <u>are</u> numbered. Connector 1 should go to the top of the camera, and connector 2 at the bottom.
Connectors can be plugged in any order, but reversing the order (i.e. plugging camera output 1 to grabber input 2 and vice-versa) will prevent camera operation.
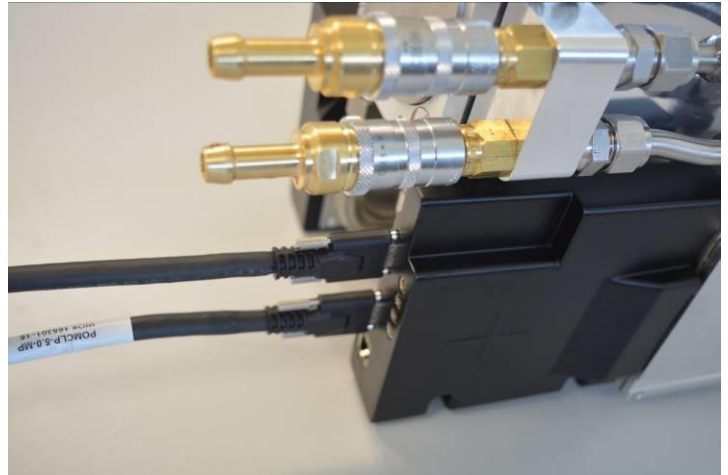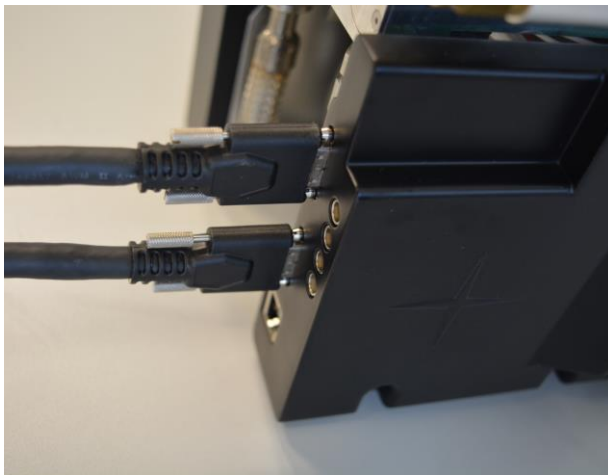
Fig. 6 :   CameraLink SDR-26 connector and cable

5.1.3. Power LEMO cable: powering up the camera

Once the camera has been connected to the cooling system and data acquisition, it is possible to power up the camera.

⚠️ *Plug firstly the LEMO power connector to the camera and then the power unit to the line plug.*

⚠️ *Before plugging the connectors to the power unit, it is important to check that the power is 24V, and that the electric current is maximum (turn the button clockwise to the maximum until there is a bump)*

Fig. 7 :   Setup Powering unit

The camera is on.
The camera power usage varies with regard to the cooling required. Without cooling the camera requires 24 Watts of power.
With cooling the figure can rise up to 240 Watts.
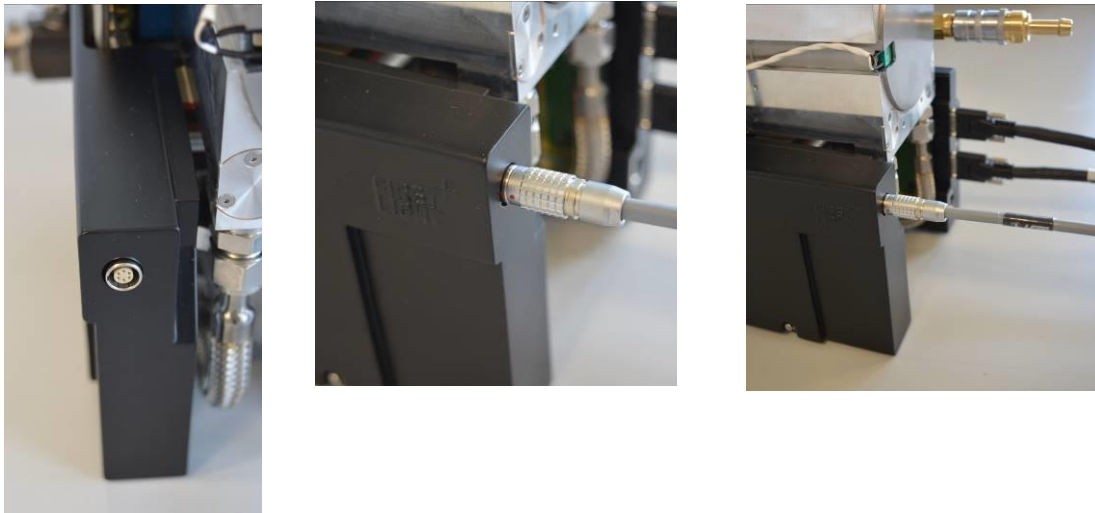
Fig. 8 :   Plugging the LEMO cable

5.2. Powering down

Turn the Pulse Tube off: command « set cooling off »
Turn the power off
Unplug the LEMO connector.

6. OPERATION

6.1. Powering up the camera.

You can see the diode signal through the synchro connectors holes

Once the camera is powered up, the system boots.
Once the diode blinks green, the camera is ready, type "set cooling on" to cool it down, or press the cooling button on the demo GUI software, wait for 60".
During the cooling process the diode blinks white.
When the requested temperature is reached, the camera begins to acquire images, the diode blinks in purple.

6.2. Acquiring images

At boot, the C-RED One camera self-checks and waits for command to cool down.
The boot procedure takes about 30 seconds.

When operating temperature is reached, C-RED One starts acquiring images in normal mode (Global Shutter Full Frame @3500FPS), with unity gain.
Then for further starts up, it begins in last selected mode and at full speed.
The C-RED One camera running in standalone mode, without external sync, continually acquires images at the set speed.
By default, speed is 3500 fps, corresponding to 285 µs exposure time.
The user can set the acquisition speed to any value between this speed and 1 fps (1 second exposure time).

6.3. Detector Geometry

The SAPHIRA sensor has a 320 x 256 Diode Array and 32 buffered analog outputs. The pixel clock of the sensor is set to 10MHz, which allows a read-out speed about 640Mpixels.s^{-1}.

32 adjacent pixels are sent every clock tick in such a way 10 pixel clock ticks are required to read one line of the sensor on full frame mode.
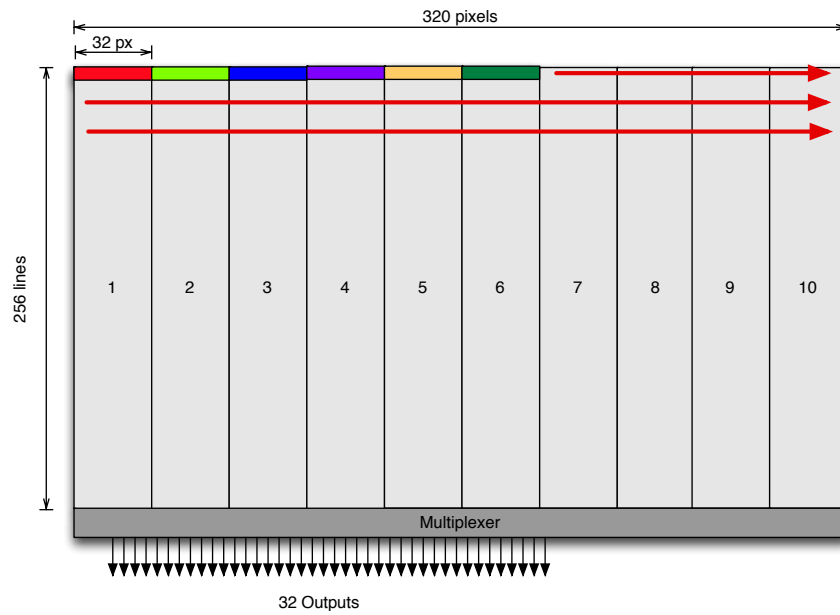
Fig. 9 :   Sensor Geometry
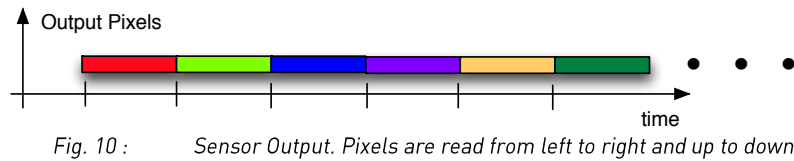
Fig. 10 :   Sensor Output. Pixels are read from left to right and up to down.

The sensor can finally be seen as an array of 10 x 256 blocks of 32 pixels.

6.3.1. Pixel format

C-RED One digitizes the signal from the sensor with 16-bit precision.
The pixel values are in unsigned format and range from 0 to 65535 ADUs.

6.3.2. Cropping mode

It is possible to select one or multiple regions of interest on the sensor.
Data are sent from left to right and up to down.
To select a region, a line and a column must be selected. The intersection of both of them will be readout.
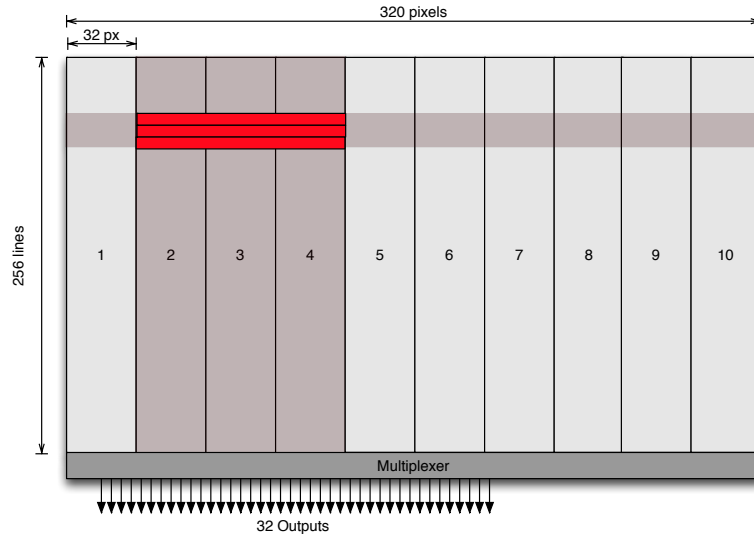
Fig. 11 :   Cropping example
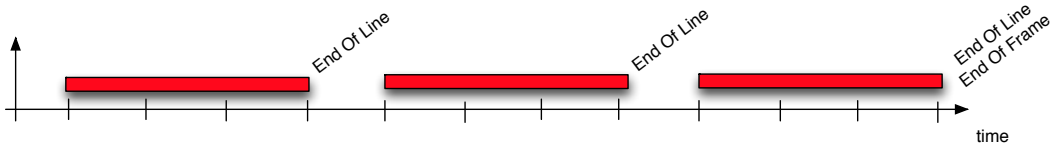
Fig. 12 :   Sensor Output. Pixels are read from left to right and from up to down.

This selection method implies that if the user needs to select a second region, 4 regions will be finally readout
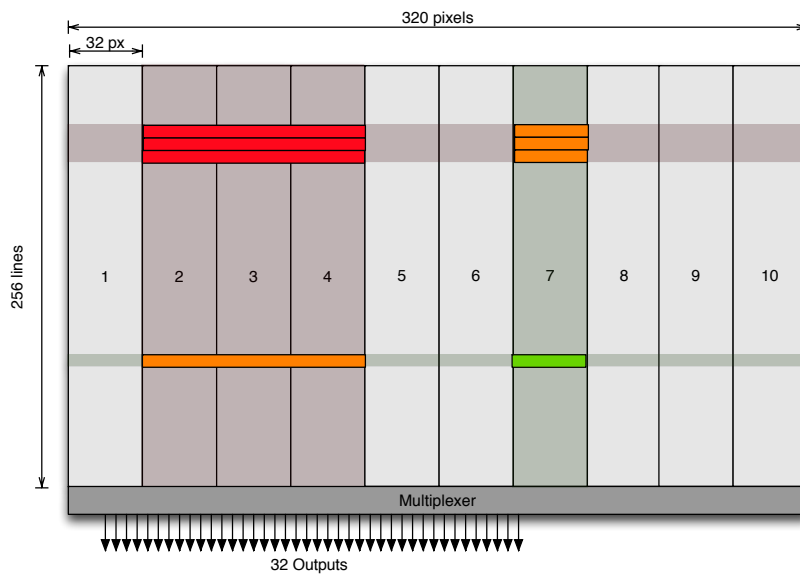
Fig. 13 :   Red and green parts are initially selected. Orange parts will also be readout.
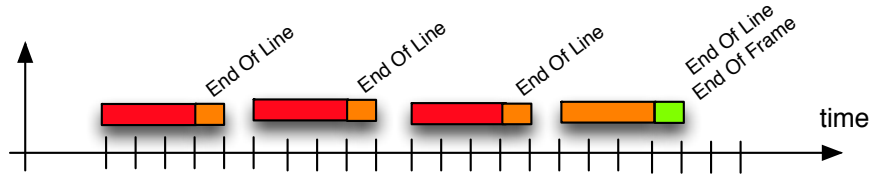
Fig. 14 :   Sensor output.

The reset region selection method is the same as the interest region selection.
But eventually, the Reset Region can be different from the Read Out region.
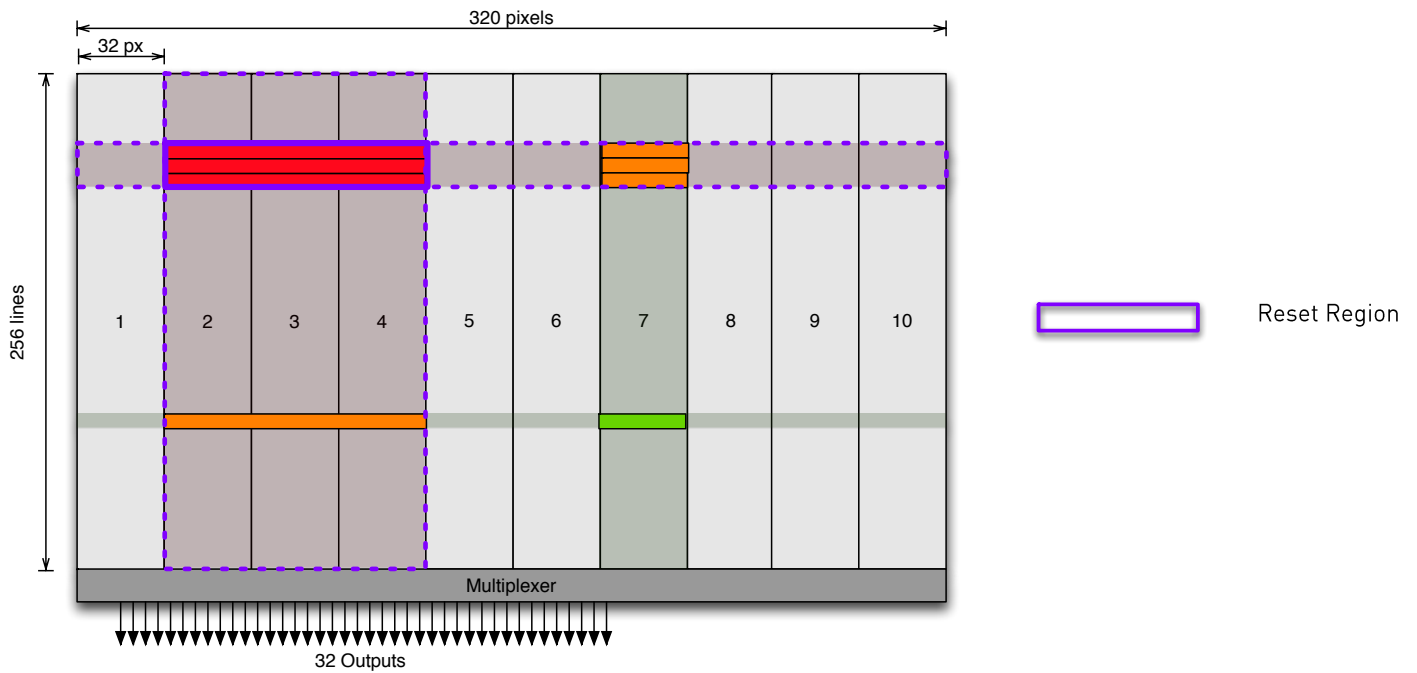
Fig. 15 :   Two different regions are defined. Only the first one is reset.

6.4. CameraLink data format

C-RED One uses the CameraLink FULL interface that 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 CameraLink and the CameraLink Pixel Clock will be at 80MHz.
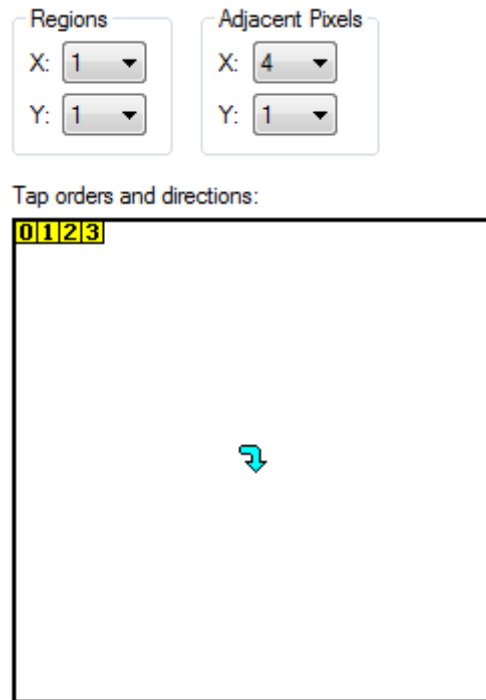
Fig. 16 :   Print Screen of Intellicam software from Matrox

6.4.1. ROI transmission.

As seen earlier, it is possible to choose a specific region of interest on the sensor.

6.4.1.1.   Single region of interest.

If only one region is selected, it is possible to immediately fit the CameraLink standard by choosing the right resolution. The third-party frame grabber will be able to automatically handle the video stream.
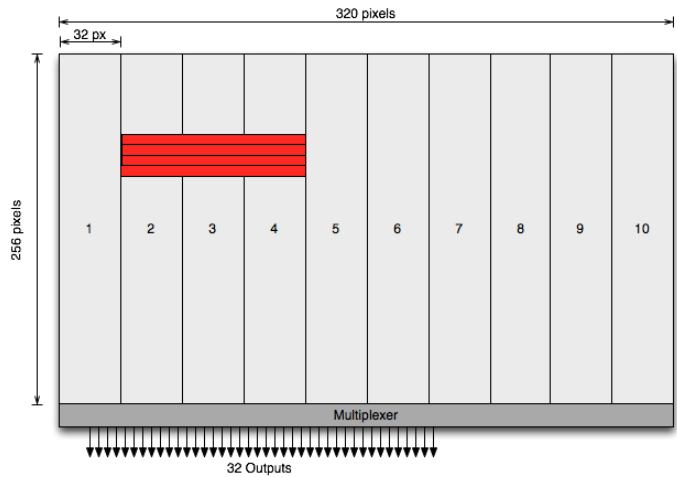
Fig. 17 :   Only one region is selected. The Frame Grabber has to be set to a resolution of 96x4 pixels

Note: Using Matrox acquisition board, you actually need to set x to 24(=96/4) because pixels are sent 4 by 4

6.4.1.2.   Multiple regions of interest.

If two or more regions are selected, they are concatenated in a single square and the third-party frame grabber will still handle the video stream easily.
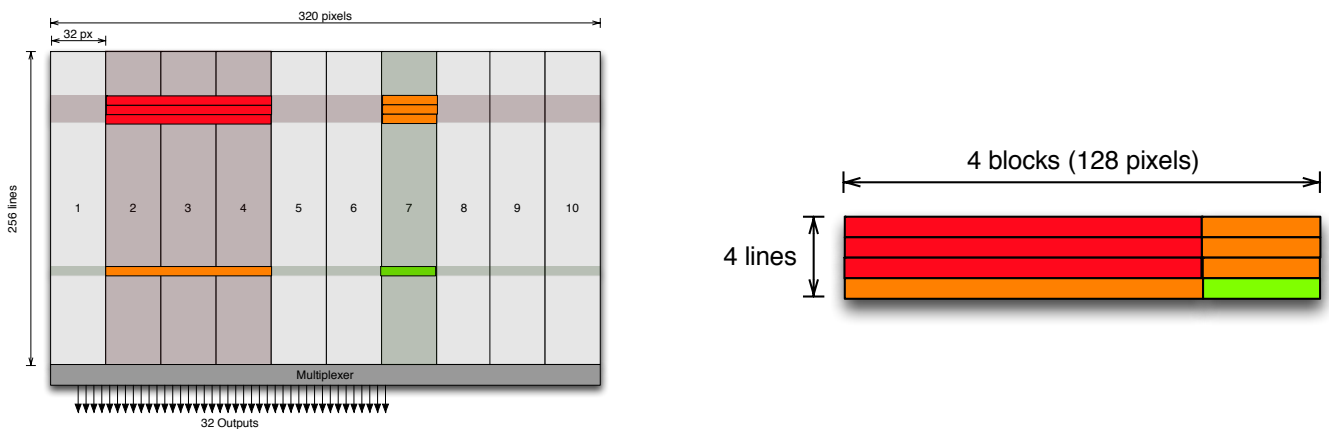
Fig. 18 :   4 regions on the sensor will be seen as a single image.

6.4.2. Issuing commands to the camera – How to

C-RED One firmware communicates with the user through the serial line embedded in the CameraLink cables. Usually the driver for the frame grabber will expose the serial line of the CameraLink standard as a virtual COM port on the acquisition system. See below an example for Dalsa Teledyne Xcelera-CL PX4 board.

Fig. 19 :   CameraLink COM port mapping for Xcelera PX4 board

Please note that our cameras have been developed and tested with specific grabbers, and that we highly recommend to use these grabbers. Any malfunctions related to the use of a non-certified grabber will not be supported by First Light Imaging.

List of tested and recommended grabbers:
-TELEDYNE DALSA PCX Xcelera-cl px8 full
-MATROX: Radient eV-cl full

In order to communicate both ways, the serial line must be configured with the following settings:
115200 Bauds, 8 bits, No parity, 1 Stop bit

The commands of the camera are sent as ascii characters sequence ended with '\n' (Carriage Return).

This is why the FLI "CRED1 DEMO" software can be used to send commands but also any terminal software, like putty for example.

However, in addition of commands, bias/flat images can be sent to the camera too.
These images are sent through the serial link and Ethernet.
To send these images, the FLI "CRED1 DEMO" software must be used.

There is more information about First Light's software in **CRED1DEMO_usermanual.pdf.**

6.5. Basic parameters

This section covers adjusting fundamental image parameters such as gain and frame rate.

6.5.1. Sensor Cooling

At first type "set cooling on" to start the cooling of sensor.
Type "temperature" to know what is the temperature of the sensor.
Type "set cooling off" to stop the cooling process.

temperature	Gives the current temperatures of the camera
set cooling on	Turns the cooling down of the camera on,
set cooling off	Turns the cooling of the camera off

⚠️ *« set cooling on » does not activate the external water cooling system. It is the responsibility to the user to provide sufficient water cooling to the camera. Failing to provide external water cooling may damage permanently the camera.*

6.5.2. Adjusting Frame rate / Exposure

To change the rate at which C-RED One acquires images, the camera must be issued an 'fps' command.
Syntax is 'set fps *nnn*' where *nnn* is the requested speed in frames per second.
Accepted range is 1 to 3500 Hz.

6.5.3. Adjusting e-APD gain

The e-APD gain on the C-RED One camera is factory calibrated for operation at temperature of 80K.

The requested gain can be adjusted by issuing the 'set gain nnn' command.

The gain can be freely adjusted by the user in the range from 1 (unity gain) to 500 by steps of 1.

At powerup the camera operates at unity gain.

7. CAMERA OPERATING MODES

7.1.1. Global Shutter

The global Shutter mode allows the user to select a reset width from 8 to 64 clock periods. A delay time between the end of the reset and the first frame demand can be adjusted.
For each mode, it is possible to select a sub-window of the array to increase the frame rate.

7.1.1.1. Single Read

The entire frame is read once then reset immediately. The integration time is the time between two frames demands. It is limited by the Read Out time of the frame.
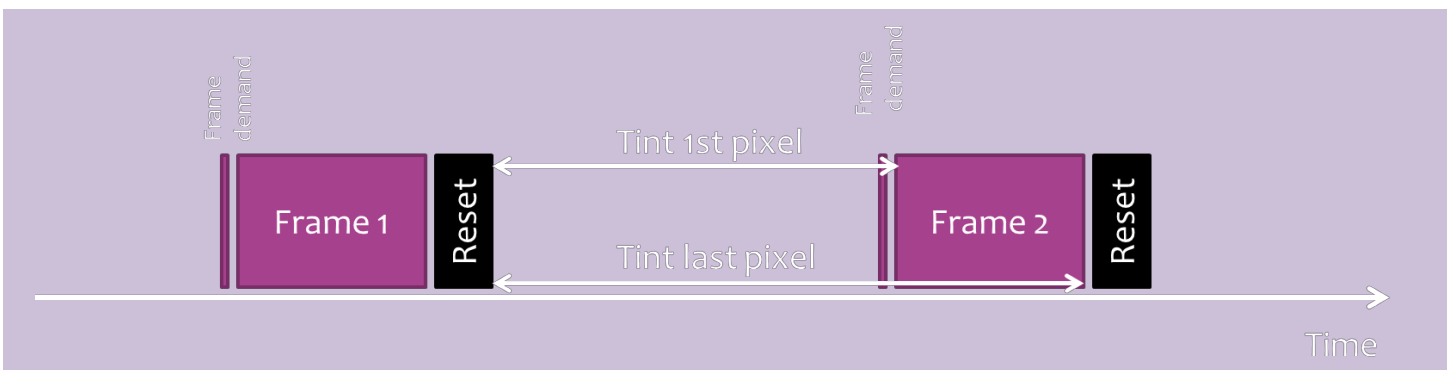
Fig. 20 :   Global Reset Single read operation

7.1.1.2. Correlated Double Sampling

The entire frame is read immediately after a frame demand then reset and automatically read again. The result of the CDS processing is the difference between those two frames and gives a flow in e-/frame.
The maximum speed is twice lower than the maximum frame rate in single read mode.
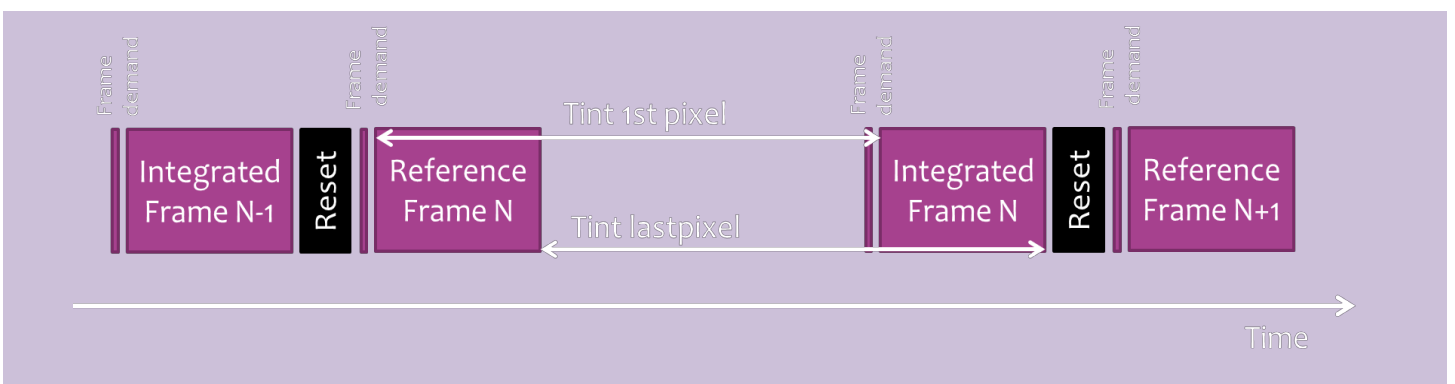
Fig. 21 :   Correlated Double Sampling mode

C-RED One can deliver raw frames or the processed one every two frames by selecting the parameter "Raw" or not.

7.1.1.3. Multiple Non-destructive reads

The multiple non-destructive mode starts with a reset period and then a user specified number of frames are read and delivered at maximum speed. It's a burst mode.
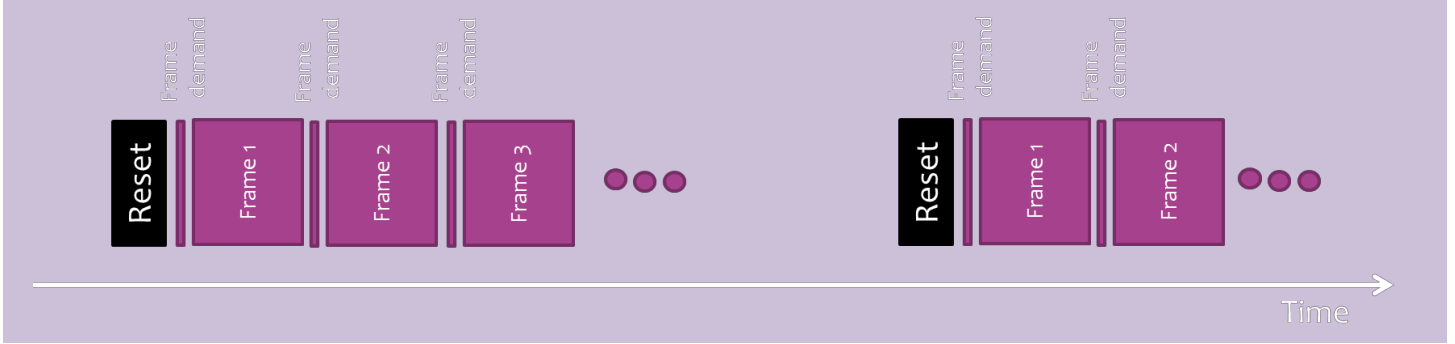
Fig. 22 : Correlated Double Sampling mode.

C-RED One can deliver raw frames or the result of the substract of the last frame minus the second one by selecting the parameter "Raw" or not.

7.2. Synchronization

7.2.1. Cable Assembly

Together with the C-RED One Camera with synchronization option are supplied 2 LEMO cables (FGG.00. 304.CLAD35).
These cables will allow you to use all the functionalities of the Synchro card.

Wiring is detailed below:
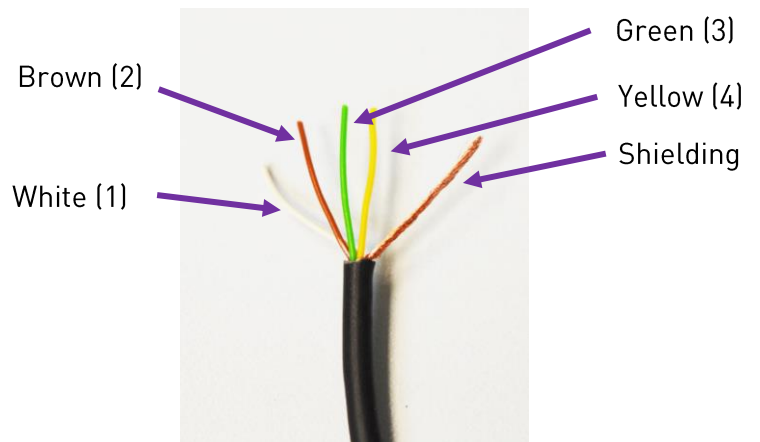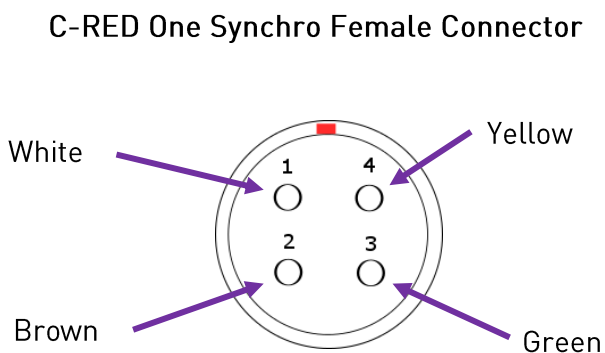
Fig. 23 : Cabling

7.2.2. Synchro connection

C-RED One with Synchro Mode offers the possibility to drive the frame readout with an external trigger and can provide timing information through a 4-pin LEMO connector (Mating LEMO male connector reference is FGG.00.304. series connectors).
Both input and outputs are **LVDS** and require two wires, ground reference is the connector body.
Here is the Sync connector layout of the rear panel (from up to down):
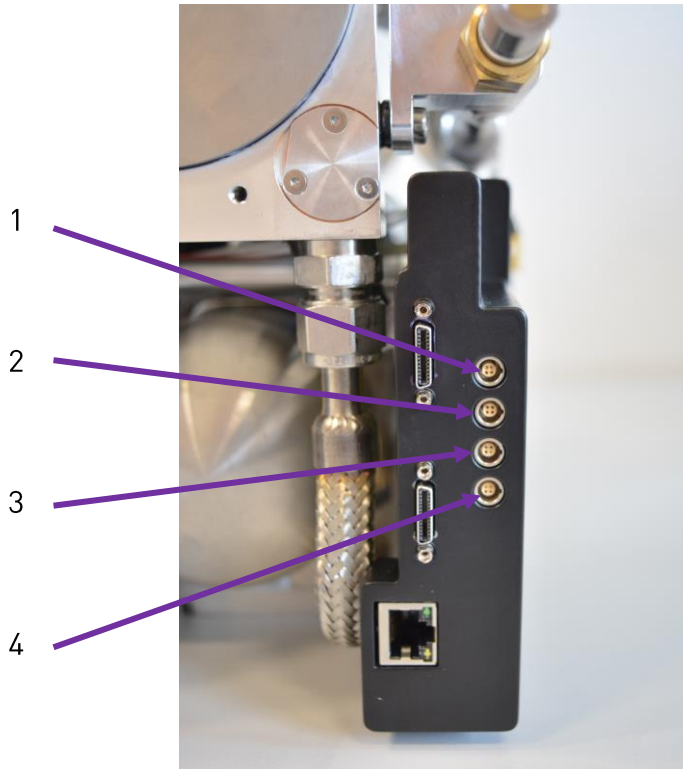
Fig. 24 :   Sync connectors on the rear panel.

⚠️ *The input port is only 2.5V tolerant.*

7.2.3. Input: FPS In

The frame rate of C-RED One can be driven by an external source plugged on connector 1.
C-RED One allows values between 0 and 3500 fps. The camera stays in integration mode while the synchro-in signal is high. When this signal goes low, it triggers the readout.
Valid data is present on the CameraLink bus 2 μs after this trigger (which corresponds to the camera latency). While the camera readout is initiated, the status of synchro-in is ignored, the next exposure starts in parallel. Once the sensor has been read out, the camera stays in integration if the synchro-in signal toggled too high in the meantime. If the synchro-in is still low, then another sensor readout is issued immediately, and another image is sent on the CameraLink bus.

Cabling is shown in Figure 25:

C-RED One Synchro Female Connector #3
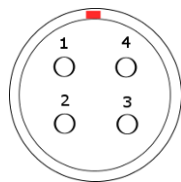
Pin White (1): FPS_IN_P
Pin Brown (2): FPS_IN_N
Pins 2 & 3: NC

FPS_IN_N
FPS_IN_P
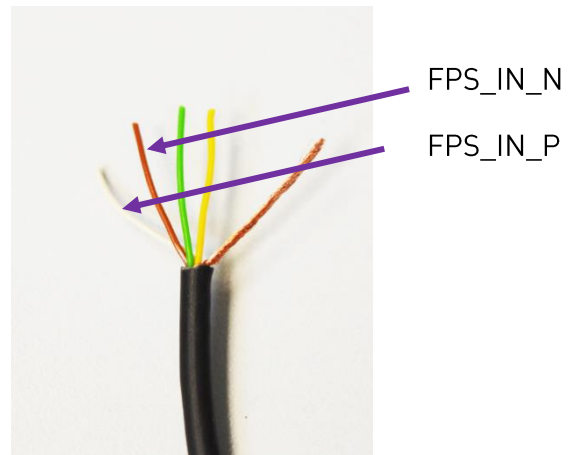
Fig. 25 :   Cabling.

7.2.4. Output : FVAL

This output delivers a signal synchronized with each new image delivered by C-RED One. The sync out is the mirroring of the FVAL (frame valid) CameraLink signal. It indicates when data is available on the bus and reflects the camera frame rate. It might be used to sync some equipment (tip tilt for example) using the camera as the timing master.
It goes low when readout since the falling edge of this signal gives the exposure start of the new frame as well as the start of the readout.
It goes high once the readout is finished, indicating that the camera would be ready for the next readout.
It should have the same frequency as the input FPS sync when "Synchro Mode" is on.

Cabling is shown in Figure 26:

C-RED One Synchro Female Connector #1
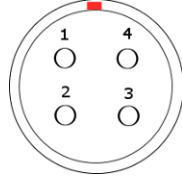
Pin White (1): FVAL_P
Pin Brown (2): FVAL_N
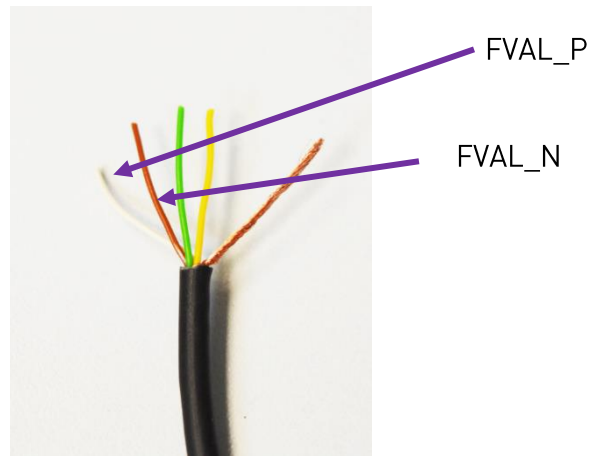
Fig. 26 :   Cabling of the Synchro-out connector

7.2.5. Output: LVAL

Cabling of this port is shown in Figure 27**Erreur ! Source du renvoi introuvable.**:

C-RED One Synchro Female Connector #2
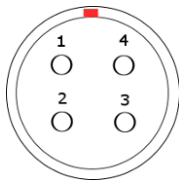
Pin White (1): LVAL_P
Pin Brown (4): LVAL_N
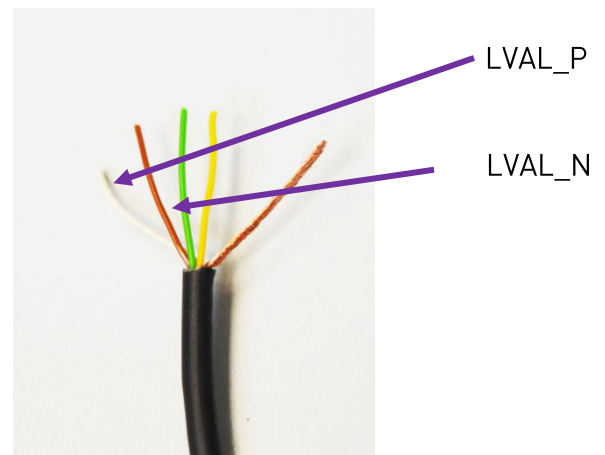
Fig. 27 :   Cabling of the Output LVAL

7.3. Bias Correction

Bias correction can be done on the fly by the camera.
To do so, a bias image must be loaded in the camera.

For use of personal images, *please follow software user manual.*

8. DESCRIPTION OF VARIOUS FONCTIONS

The list of available commands on the camera can be displayed using 'help' command
The list of command is printed below.
There are 3 kinds of commands: get, set and exec commands.
To get a parameter value, just type this parameter.
For example, type 'fps' and you will get "Frames per second: 3447".
To set a parameter put the keyword 'set' before the parameter.
For example, type 'set fps 1000' and you will get "Result:OK".
By default, the commands are verbose. But to get only the parameter value, you can add the keyword 'raw' at the end of the command.
For example, type 'fps raw' and you will get "3447".
Commands used to ask the camera to do a task follow the keyword 'exec'
For example, type 'exec buildbias' to ask the camera to compute a bias file. You will get "Compute bias image........Done".

COMMANDS	DESCRIPTION
all raw	Display, colon separated, camera parameters
powers	Get all camera powers
powers raw	raw printing
powers getter	Get getter power
powers getter raw	raw printing
powers pulsetube	Get pulsetube power
powers pulsetube raw	raw printing
temperatures	Get all camera temperatures
temperatures raw	raw printing
temperatures motherboard	Get mother board temperature
temperatures motherboard raw	raw printing
temperatures frontend	Get front end temperature
temperatures frontend raw	raw printing
temperatures powerboard	Get power board temperature
temperatures powerboard raw	raw printing
temperatures water	Get water temperature
temperatures water raw	raw printing
temperatures ptmcu	Get pulsetube MCU temperature
temperatures ptmcu raw	raw printing
temperatures cryostat diode	Get cryostat temperature from diode
temperatures cryostat diode raw	raw printing
temperatures cryostat ptcontroller	Get cryostat temperature from pulsetube controller
temperatures cryostat ptcontroller raw	raw printing
temperatures cryostat setpoint	Get cryostat temperature setpoint
temperatures cryostat setpoint raw	raw printing
fps	Get frame per second

fps raw	raw printing
maxfps	Get the number max of frame per second regarding current camera configuration
maxfps raw	raw printing
peltiermaxcurrent	Get peltiermaxcurrent
peltiermaxcurrent raw	raw printing
ptready	Get pulsetube ready information
ptready raw	raw printing
pressure	Get cryostat pressure
pressure raw	raw printing
gain	Get gain
gain raw	raw printing
bias	Get bias correction status
bias raw	raw printing
flat	Get flat correction status
flat raw	raw printing
imagetags	Get tags in image status
imagetags raw	raw printing
led	Get LED status
led raw	raw printing
sendfile bias <bias image file size> <file MD5>	After this command, the interpreter is disabled and the camera waits for bias image binary bytes. If no bytes are sent, after a timeout, the interpreter is restarted.
sendfile flat <flat image file size> <fileMD5>	After this command, the interpreter is disabled and the camera waits for flat image binary bytes.
getflat <url>	Getting a flat image file from URL.
getbias <url>	Getting a biasimage file from URL.
gettestpattern <url>	Getting a pattern images tar.gz file from an URL. The file contains the image that will be sent by the camera in testpattern mode. These files must be named 00, 01, 02, 03, …,31
testpattern	Gets the testpattern mode status.
testpattern raw	raw printing
events	Camera events sending status
events raw	raw printing
extsynchro	Get usage of external synchro status
extsynchro raw	raw printing
rawimages	Get raw images (no embedded computation) status
rawimages raw	raw printing
getter nbregeneration	Get number of getter regeneration
getter nbregeneration raw	raw printing
getter regeremainingtime	Get the remaining time before the end of the getter regeneration

	Title: C-RED One USER MANUAL Document: C-RED One User Manual_20170116v0.2 Issue: 002 Classification: PUBLIC	Page : 35 Date : 16/01/2017

getter regeremainingtime raw	raw printing
cooling	Get cooling satus
cooling raw	raw printing
standby	Get standby mode satus
standby raw	raw printing
mode	Get readout mode
mode raw	raw printing
resetwidth	Get reset width
resetwidth raw	raw printing
nbreadworeset	Get number of read without reset
nbreadworeset raw	raw printing
cropping	Get cropping status (active/inactive)
cropping raw	raw printing
cropping columns	Get cropping columns configuration
cropping columns raw	raw printing
cropping rows	Get cropping rows configuration
cropping rows raw	raw printing
aduoffset	Get adu offset
aduoffset raw	raw printing
version	Get all product versions
version raw	raw printing
version firmware	Get firmware version
version firmware raw	raw printing
version firmware detailed	Get version details
version firmware detailed raw	raw printing
version firmware build	Get version build date
version firmware build raw	raw printing
version fpga	Get fpga version
version fpga raw	raw printing
version hardware	Get hardware version
version hardware raw	raw printing
status	Get camera status.The different possible status are : - starting: Just after power on. - configuring: The camera is reading the configuration - poorvacuum: Vacuum between 10-3 and 10-4 during startup. - faultyvacuum: Vacuum above 10-3 - vacuumrege: Getter regeneration - ready: Camera ready to be cooled - isbeingcooled: Camera is being cooled - standby: Camera cooled but the sensor is off - operational: Camera is cooled and is doing valid images - prevsafe: During previous camera usage an error occurred

First Light Imaging SAS | 100, route des Houillères | 13590 MEYREUIL | FRANCE | +33 (0)4 42 61 29 20
First Light Imaging SAS au Capital de 85 000 euros | 533 716 817 RCS Aix-en-Provence | TVA : FR78 533 716 817

	- safe: An error occurred, the camera is in safe mode. The sensor is switched off, the cooling stopped. To use the camera again, you must restart the camera. - locked: A critical error occurred, the camera s in safe mode and locked. It means you can't use it anymore. You have to contact First Light support to restart the camera.
status raw	raw printing
status detailed	Get last status change reason (if available)
status detailed raw	raw printing
continue	Continue camera starting. Can be used if at the last use, the camera was in error or if the camera is in poor vacuum state.
save	Save current camera settings. The cooling state and the gain are never saved.
save raw	raw printing
ipaddress	Display the camera IP settings
cameratype	Display camera information
exec upgradefirmware <url>	Upgrade the firmware with the new release at the specified URL
exec buildbias	Build the bias image
exec buildbias raw	raw printing
exec buildflat	Build the flat image
exec buildflat raw	raw printing
exec redovacuum	Start vacuum regeneration
set testpattern on	Enable the testpattern mode. In this mode the camera send a loop of 32 images instead of images fetch from the sensor.
set testpattern on raw	raw printing
set testpattern off	Disable the testpattern mode
set testpattern off raw	raw printing
set fps <fpsValue>	Set the framerate
set fps <fpsValue> raw	raw printing
set gain <gainValue>	Set the gain
set gain <gainValue> raw	raw printing
set bias on	Enable bias correction
set bias on raw	raw printing
set bias off	Disable bias correction
set bias off raw	raw printing
set flat on	Enable flat correction
set flat on raw	raw printing
set flat off	Disable flat correction
set flat off raw	raw printing
set imagetags on	Enable tags in image When enabled the 3 first pixels are used to send a frame

	counter and a position number for multiple nondestructive readout. The two fist pixels must read as a little endian 32 bit framecounter. The third pixel as a little endian 16 bits multiple read position.
set imagetags on raw	raw printing
set imagetags off	Disable tags in image
set imagetags off raw	raw printing
set led on	Switch on the LED. The LED is a multi-color led. The camera states are mapped to different colors. When the camera is operational, the led blinks purple. If the LED doesn't blink, it means the camera have an issue. Since there is a watchdog, the camera will restart.
set led on raw	raw printing
set led off	Switch off the LED
set led off raw	raw printing
set events on	Enable camera events sending If an error occurs the camera can send asynchronously error messages on the serial interface. If you want to disable these spurious messages disable the event sending;
set events on raw	raw printing
set events off	Disable camera events sending
set events off raw	raw printing
set extsynchro on	Enable usage of external synchronization
set extsynchro on raw	raw printing
set extsynchro off	Disable usage of external synchronization
set extsynchro off raw	raw printing
set rawimages on	Enable embedded computation on the images. For example, in CDS mode the subtraction is done by the camera.
set rawimages on raw	raw printing
set rawimages off	Disable embedded computation, all the images fetched from the sensor are sent to the camera link interface.
set rawimages off raw	raw printing
set cooling on	Enable cooling
set cooling on raw	raw printing
set cooling off	Disable cooling
set cooling off raw	raw printing
set standby on	Enable standby mode Standby mode can be used to keep the camera cooled with the sensor off
set standby on raw	raw printing
set standby off	Disable standby mode
set standby off raw	raw printing

set mode globalreset	Same as globalresetsingle, keep for compatibility
set mode globalresetsingle	Set global reset mode
set mode globalresetcds	Set global reset correlated double sampling mode
set mode globalresetbursts	Set global reset multiple non-destructive readout mode
set mode rollingresetsingle	Set rolling reset single mode
set mode rollingresetcds	Same as rollingresetnro, keep for compatibility
set mode rollingresetnro	Set rolling reset multiple non destructive readout mode
set resetwidth <resetwidthValue>	Set reset width
set resetwidth <resetwidthValue> raw	raw printing
set nbreadworeset <nbreadworesetValue>	Set number of read without reset
set nbreadworeset <nbreadworesetValue> raw	raw printing
set cropping on	Enable cropping
set cropping on raw	raw printing
set cropping off	Disable cropping
set cropping off raw	raw printing
set cropping columns <columnsValue>	Set cropping columns selection The columns granularity is 32. So, the range is 1-10 to select 32 to 320 columns. The format for row and column selection is like the one used for printer page selection. Each column number is separated with a comma and range can be selected using hyphen. For example, to select columns, 1 3 9 10, use the following syntax: 1,3,9-10
set cropping columns <columnsValue> raw	raw printing
set cropping rows <rowsValue>	Set cropping rows selection The rows granularity is 1. The range is 1-256. For example, to select rows, 1 3 9 10 11 12 50 use the following syntax: 1,3,9,10-12,50
set cropping rows <rowsValue> raw	raw printing
set aduoffset <aduoffsetValue>	Set adu offset
set aduoffset <aduoffsetValue> raw	raw printing

9. PRECAUTIONS AND MAINTENANCE

9.1. Precaution of use

Your C-RED One 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 One is an electronic equipment that requires precaution regarding static shocks, it contains an e-APD MCT detector that requires illumination and cooling precaution.
As any scientific instrument, your C-RED One camera is fragile and should not be exposed to shocks, extreme temperatures and humidity.

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

9.1.1. Static / electric shocks:

Any electronic equipment that has to be connected to C-RED One should be fitted with appropriate protection on all power lines.
The power of connected equipment should be switched off before moving any connection between computer and C-RED One.

9.1.2. Heating / cooling:

Your C-RED One camera has been built to work with liquid cooling system: never use your camera without such a system connected to the camera via the liquid connectors, filled with cooling fluid and switched on.
Please use your cooling system in accordance to the cooling system instructions.
Dew point: even if C-RED One is hermetically sealed and not subject to dew issue, please use cooling fluid at a temperature not below the dew point, do not use a coolant fluid temperature below the ambient temperature.

9.2. Operational environment

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

9.3. Maintenance

9.3.1. Never open the camera.

There is 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.

9.3.2. 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.

9.3.3. Storage.

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

10. WARRANTY AND LIABILITY

10.1. For the USA

10.1.1. 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.

10.1.2. 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.

10.1.3. 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 one 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.

10.1.4. 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:

10.1.4.1. 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.

10.1.4.2. 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.

10.1.4.3. 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.

10.1.4.4. 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.

10.1.5. 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.

10.1.6. 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.

10.2. For the rest of the World

10.2.1. 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.

10.2.2. 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.

10.2.3. 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.

11. CONTACTS

11.1. For the USA:

FIRST LIGHT IMAGING Corp.
2415 Third Street, Suite 231
San Francisco, CA 94107
USA

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

11.2. For the rest of the world:

FIRST LIGHT IMAGING SAS
100 route des Houillères
13590 Meyreuil
France

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