FIRST LIGHT
ADVANCED IMAGERY

OCAM²

User Manual

Thank you for choosing OCAM² !

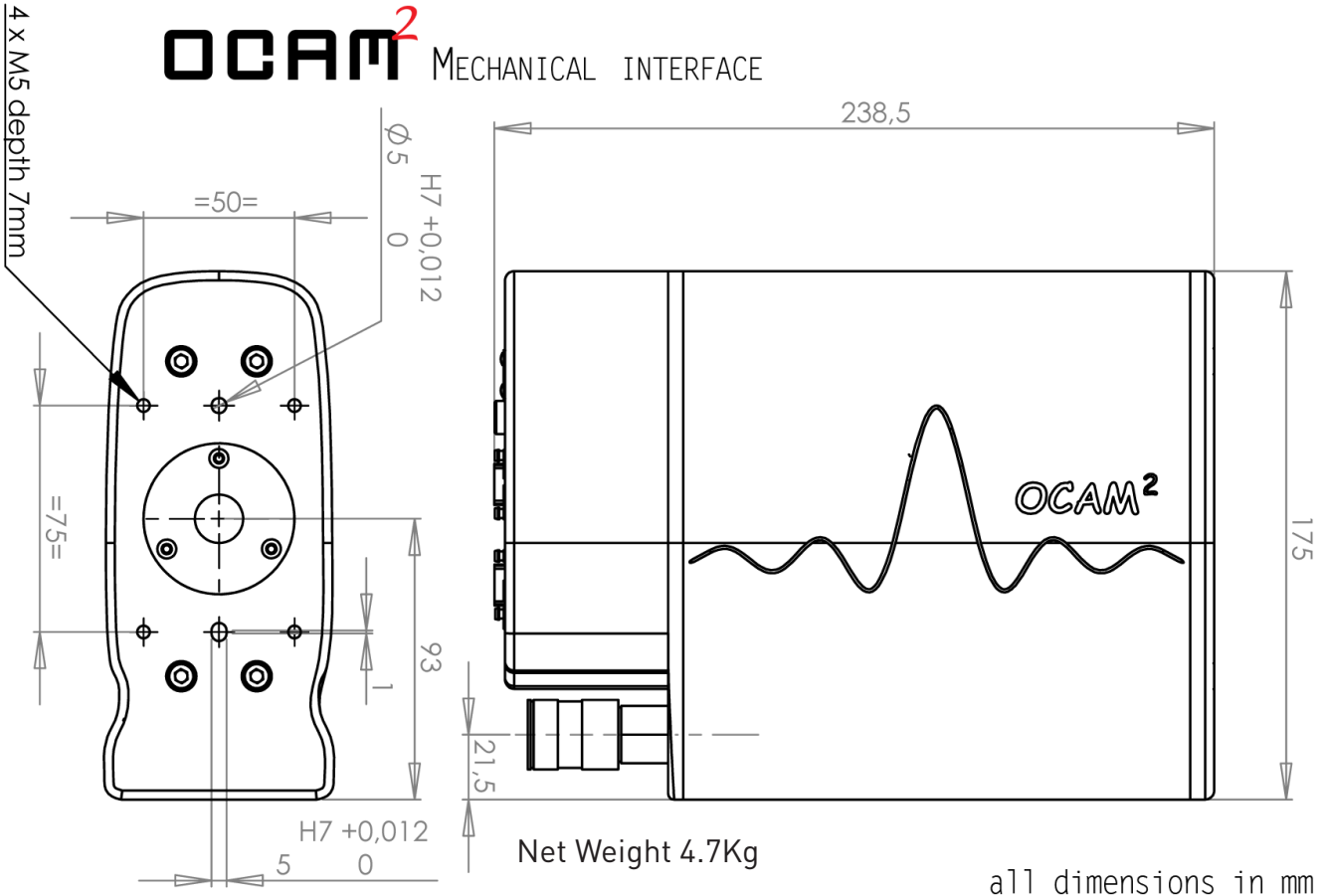
OCAM² is a state of the art liquid-cooled high-speed, high-sensitivity, ultra low noise camera for scientific applications.

Equipped with an L3Vision™CCD from e2v Technologies, OCAM² takes more than 1500 images per second at the full 240x240 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 0.1e^{-} [1]

1 with L3Vision™ gain.

1 CONTENTS

OCAM² MECHANICAL INTERFACE



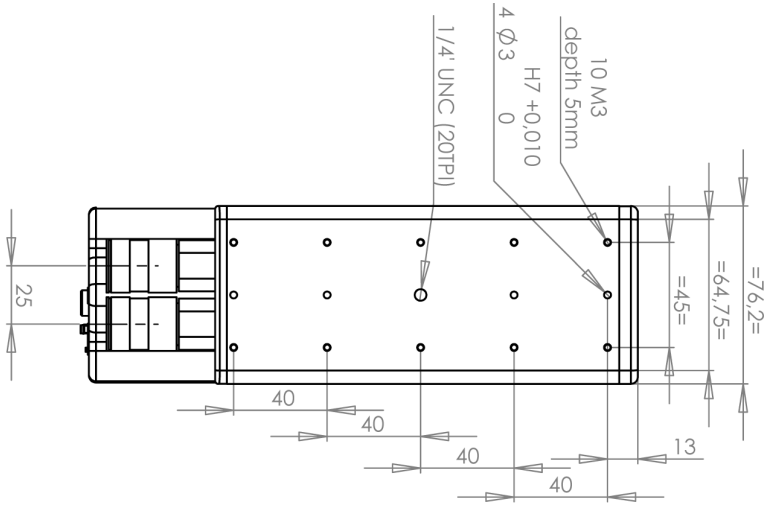
Net Weight 4.7Kg

all dimensions in mm

1 CAMERA INSTALLATION

1.1 MECHANICAL INTERFACE

The ² camera is designed to deliver the best precision possible with regard to the optical alignment of the CCD.



The reference side is the front face as it is mechanically indexed to the CCD package.

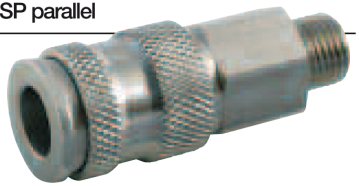
1.2 COOLANT SYSTEM

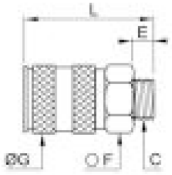
In order to achieve its nominal performance the OCAM² camera requires liquid cooling.

The camera has its own internal thermal regulation that cools the detector down to -45°C.

9201

Male body BSP parallel

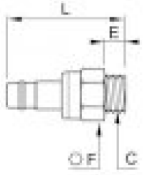




C	with shut-off	E	F	G	L
G1/4	9201X25 13	10,5	19	23	59
G3/8	9201X25 17	9	19	23	57,5
G1/2	9201X25 21	12	24	23	60,5

9287-9087

Male thread BSP parallel



C	with shut-off	E	F	L
G1/4	9287X25 13	9	19	56
G3/8	9287X25 17	9	19	56
G1/2	9287X25 21	12	24	59

C	without shut-off	E	F	L
G1/4	9087X25 13	9	17	33,5
G3/8	9087X25 17	9	19	33
G1/2	9087X25 21	12	24	38

Heat is evacuated by circulating a cooling fluid through the two rear connectors (Réf. Legris/Parker 9201x25, mating connectors are Réf. Legris/Parker 9287x25).

Cooling fluid Temperature should not exceed 35°C, flow rate should be no less than 1 litre/min. Pressure should be below 12 bars.

1.3 Power supply

OCAM² requires a single power supply.

Power supply should provide a stable 24V DC, with at least 6 A of current available. Thus a 24V, 150W power supply or above is adequate to power OCAM².

The mating connector is a Lemo® FGG.1B.304 series. Cabling is shown Figure 2.

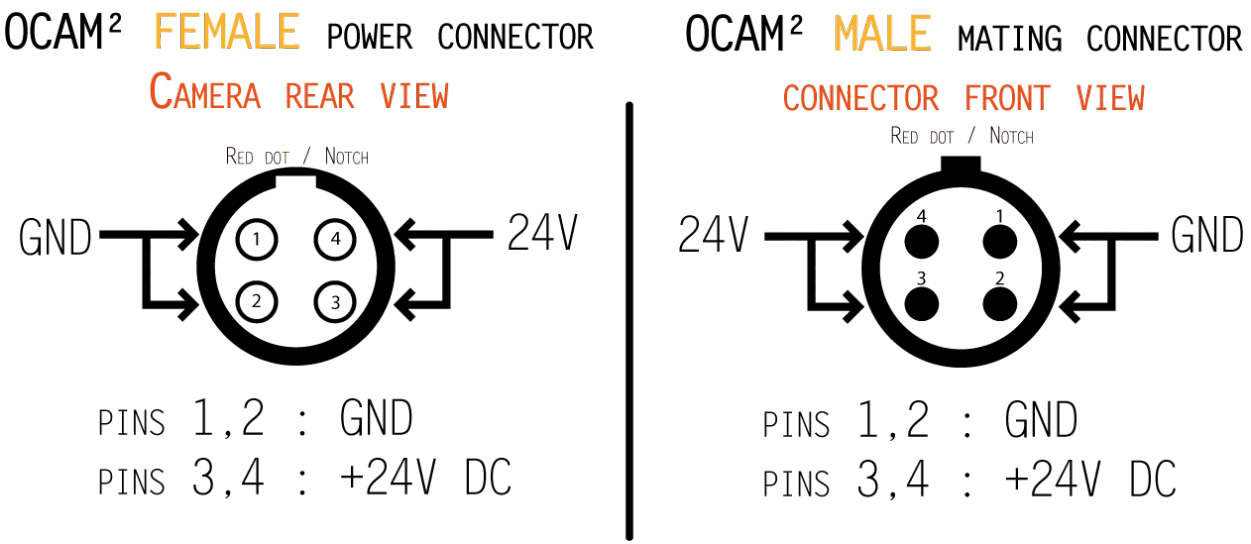


Figure 2: OCAM² power connector cabling.

WARNING : OCAM² power circuitry is protected against polarity errors, but not against short-circuits.

1.4 Data connection

OCAM² data connection uses the Camera Link™ standard to handle all communications.

The camera uses the Camera Link™ FULL interface that requires two data cables.

OCAM² connectors are 2 female SDR-26 Mini Camera Link™.

Connectors are numbered 1 and 2. Connector 1 is the one at the top of the camera as shown in Figure 3.

If the cables are cross-connected the camera will fail to send data properly but it doesn't have any ill effect on the camera nor the grabber. See *5.1 Image issues*.

OCAM² Camera Link™ connectors

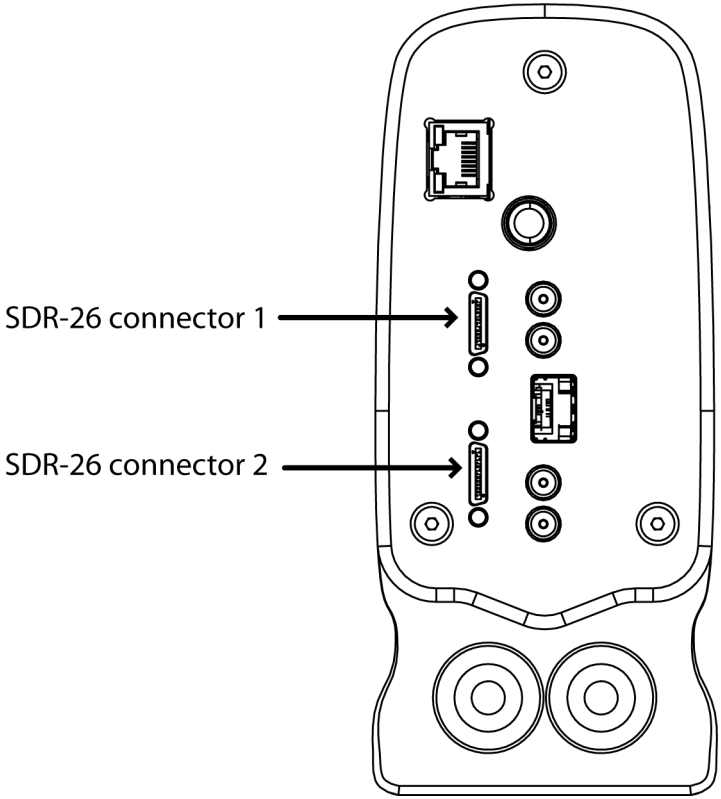


Figure 3: OCAM² Camera Link™ connectors

A mating cable for a grabber that uses MDR-26 connectors ('regular' size) would be for example ref. 1MF 26 L560 00 C 500 (Ref. Cable manufactured by 3M)

OCAM² firmware communicates with the user through the serial line embedded in the Camera Link cables. Usually the driver for the Framegrabber will expose the serial line of the Camera Link standard as a virtual COM port on the acquisition system.

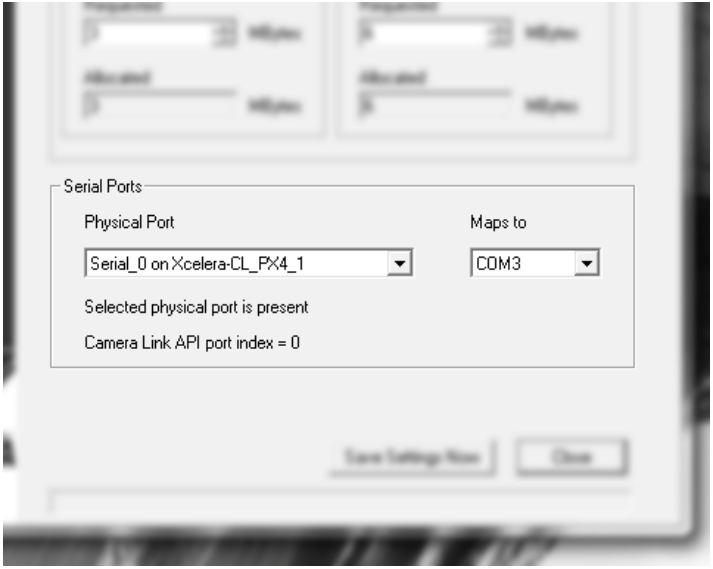


Figure 4Camera Link COM port mapping

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.

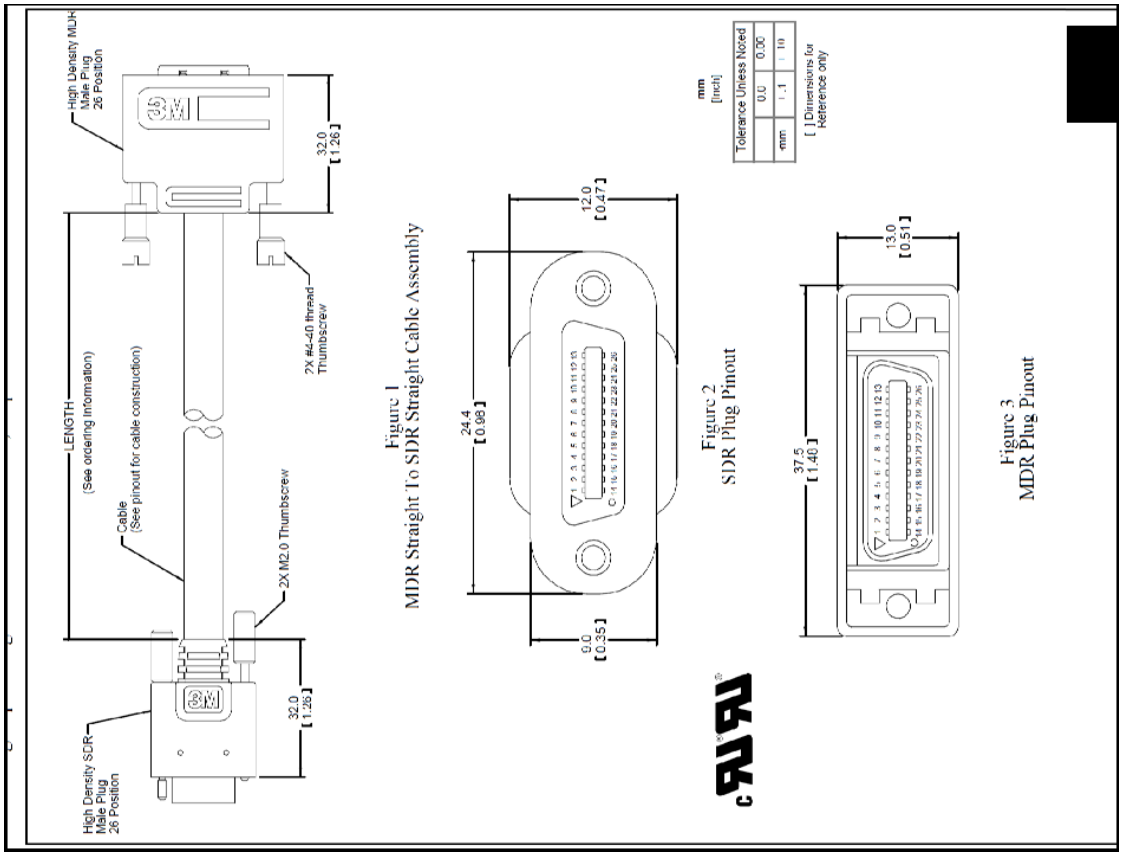


Figure 5 : OCAM² Camera Link™ mating cable for MDR26-equipped grabber

2 CAMERA STARTUP

This section describes the actions required to set up OCAM² for operation.

2.1 CONNECTING THE CAMERA

2.1.1 Fluid connectors

The first step is to connect the cooling fluids and make sure there is no leak.

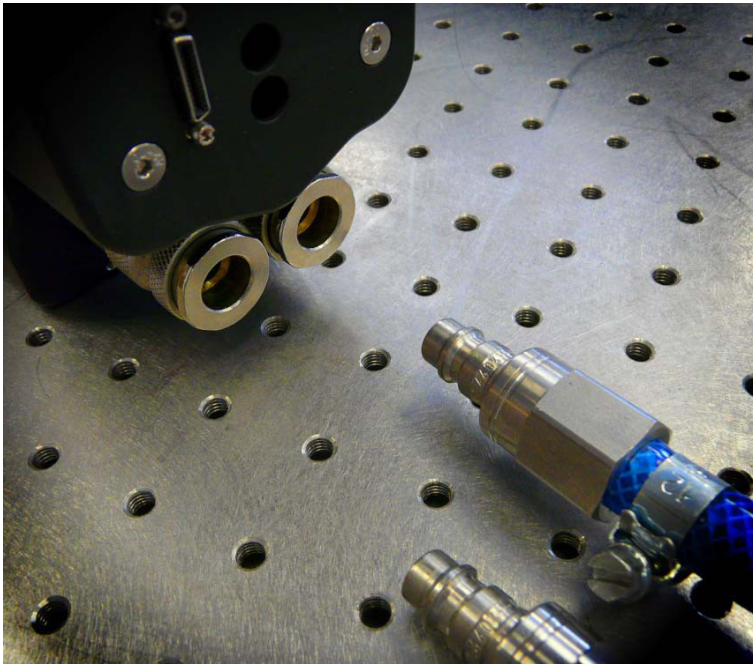


Figure 14 : OCAM² coolant connectors

The preferred connection is to put .the water IN connector to the left-side connector. This ensures a slightly better thermal performance. Connect the "Out" inlet of the cooling unit to the "in" inlet of the camera.

Insert the male connector into the socket until it locks in place. There should be an audible 'click' and the connector shouldn't move until released by pushing the ring on the female (camera) side.

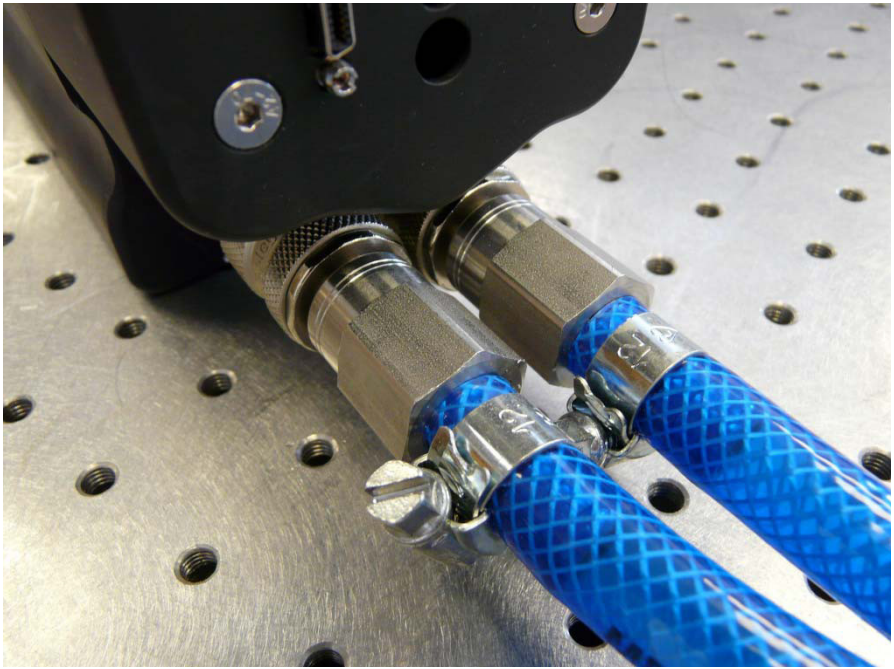


Figure 15 : Coolant connectors in place

Figure 15 shows the camera with both 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 and a flow of 1l/min. Be sure that the cooling is on before turning on the camera. Any operation without water cooling can damage permanently the camera.

2.1.2 Camera Link™ connectors

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

The CameraLink connections are hot-pluggable and can be swapped and/or unplugged at any time without issues. It is recommended to turn the acquisition computer ON before the camera.

Note that unlike the coolant connectors, the CameraLink cables are 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.

Figure 16: Camera Link™ SDR-26 connector and cable

Once the connector is in place, the user should fasten the screws to ensure good contact and correct data transmission.

2.1.3 Power connector

The last step is to connect the 24VDC power connector to the camera.

Connector is a LEMO® FGG.1B.304.

Figure 17: OCAM² power connector

2.2 Powering up the camera

Once the camera has been connected has explained in 3.1 it is possible to turn on the power.

The camera power usage varies with regard to the cooling required. Without cooling the camera requires 65 Watts of power.

With cooling the figure can rise up to 140Watts.

Typical power usage with CCD at -45°C and cooling fluid at 25°C will be about 90Watts.

2.3 Powering down the camera

Before powering down the camera, it is very important to warm the detector back to ambient temperature to prevent thermal shock. This is done by sending the 'cooling' command to the camera with a positive temperature. Example : 'cooling 20' will warm the detector back to 20°C at a pace of 6°C per minute.

2.4 Acquiring Images

At boot, the OCAM² camera self-checks and automatically starts acquiring images.

The boot procedure takes about 1 second, after which the grabber should start receiving images.

Contrarily to OCAM 1, there is no user action required to start image acquisition.

By default, OCAM² starts in normal mode (66x121x8outputs @ 1503Hz), with

UNITY GAIN AND DETECTOR COOLING SYSTEM OFF.

The telemetry data is made available as it is gathered by the on-board monitoring system and may take a few seconds to stabilize.

2.5 ADJUSTING BASIC IMAGE PARAMETERS

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

2.5.1 Adjusting Frame rate / Exposure

To change the rate at which OCAM² acquires images the camera must be issued an 'fps' command.

Syntax is 'fps *nnn*' where *nnn* is the requested speed in frames per second. Accepted range is 1..1503 Hz.

The special value 0 (as in 'fps 0') instructs the camera to operate at full speed (1503.25Hz for OCAM² 1500).

See section 4 for a detailed explanation on how to issue commands to the camera

2.5.2 Adjusting L3Vision gain

The L3Vision gain on the OCAM² camera is factory calibrated for operation at CCD temperature of -45°C. The requested gain can be adjusted by issuing the 'gain' command as described in paragraph *4.5.3 Gain command*.

The gain can be freely adjusted by the user in the range from 1 (unity gain) to 1000 by steps of 1. Note that operating the camera with gain and intense lighting can trigger the integrated overillumination protection and cause the camera to revert to a safe level of unity gain.

When triggered, the overillumination protection prevents any Gain elevation above normal until the error has been acknowledged.

See *4.5.4 Overillumination protection* for details on how the protection operates.

At powerup the camera operates without unity gain, and the overillumination protection is active.

2.6 Camera Startup

There are no specific operations required at camera powerup.

When plugged to an adequate power source, the OCAM² camera will go through its booting and autotest procedure. It will then proceed to load the previous mode (mode at power off) and start producing images.

At camera reset the following applies :

- Camera starts in previous mode (ie. Normal, overscan lines, overscan columns).

- Cooling is OFF, there is no active cooling of the CCD.
- Overillumination protection is SET and requires manual resetting before gain can be applied.
- Default voltages are loaded for all values.

2.7 Acquiring Images

The OCAM² camera running in standalone mode, without external sync, continually acquires images at the set speed. By default speed is 1503.25 fps, corresponding to 664µs exposure time.

The user can set the acquisition speed to any value between this speed and 25 fps (40ms exposure time).

2.8 Image Format

This section describes the image format used by OCAM², from its analogic source to unscrambling digital image data.

2.8.1 Detector geometry

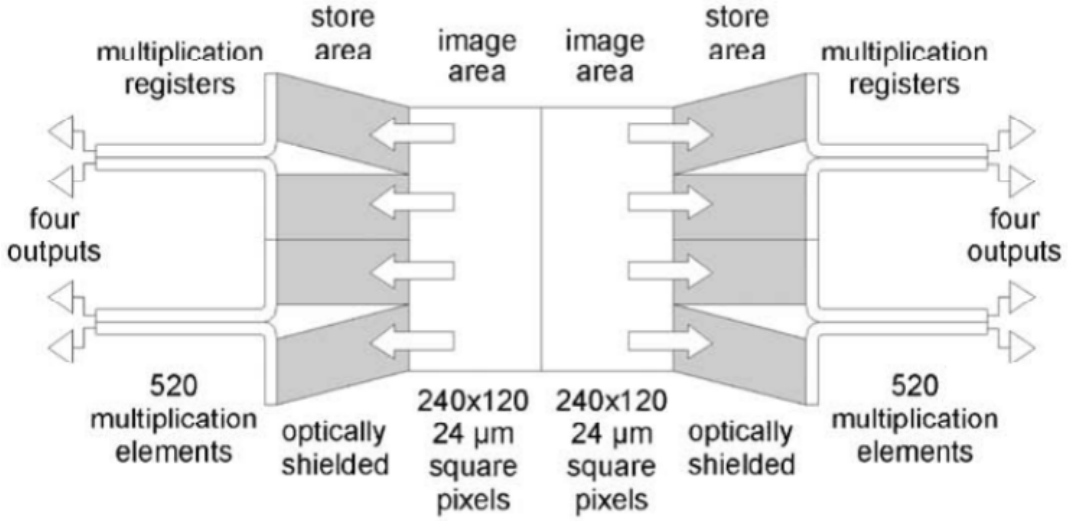


Figure 6 : The CCD220 geometry

The CCD220 is a 24µm square 240x240 pixels split frame-transfer back illuminated L3Vision™ CCD. The image and store area (store is optically shielded) are built with two- phase metal-buttressed parallel clock structures to enable fast lines shifts in excess of 7MLines.s^{-1} allowing for a total transfer time from image to store of 18µs, as well as a low smearing of about 1% at 1500fps.

Eight electron-multiplying registers operating at a greater than 3MPixels.s^{-1} speed enable sub- electron noise at frame rates of 1500Hz.

The CCD220 is encapsulated in a 64-pin package with a custom-designed integral Peltier

cooler that cools the CCD down to -45°C to achieve the required total dark current.

OCAM² adds an external third stage of Peltier coolers that help in maintaining the CCD220 at optimal temperature even with relatively warm cooling fluid temperatures.

The package is sealed and back-filled with 0.9 bar of krypton gas to minimize heat transfer to the outside.

2.8.2 Pixel format

OCAM² digitizes the signal from its CCD220 with 14-bit precision.

The pixel values are in unsigned format and range from 0 to 16383 ADU's.

For convenience these 14 bits are padded to 16 bits by the adjunction of 2 high-weight bits.

Pixel format is shown in Figure 7: OCAM² pixel format.

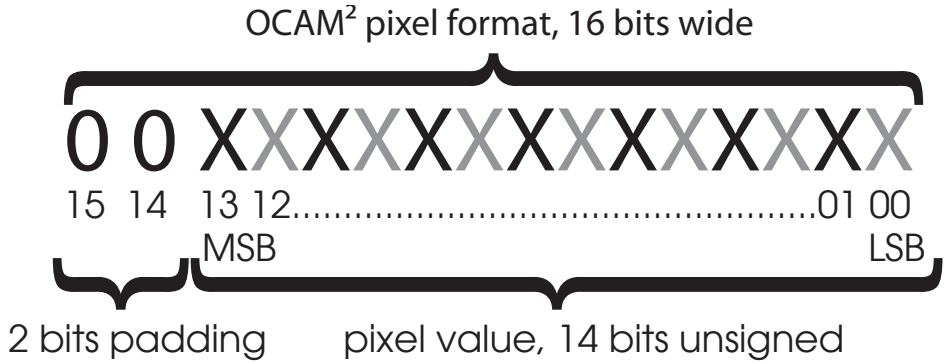


Figure 7: OCAM² pixel format

2.8.3 Camera Link data format

The Camera Link specification does not allow directly for detector geometry such as that of the CCD220, as it is not permitted to configure 8 outputs – 16 bits-per-pixel camera.

In order to comply with the Camera Link spec OCAM² has to multiplex its pixel data and act like an 8 outputs, 8 bits per pixel camera, but with twice the pixel clock speed.

The camera outputs Frame Valid (FVAL), Line Valid (LVAL) and Data Valid (DVAL) signals. The frame grabber should thus synchronize acquisition with these signals.

As the image format for OCAM² does not fit within the constraints of the Camera Link standard it is usually impractical to try to descramble the image data onboard of the grabber. See 2.5.6 below for a detailed description of the descrambling procedure.

The CCD220 geometry imposes a minimal number of overscan (e.g. non-image) pixels.

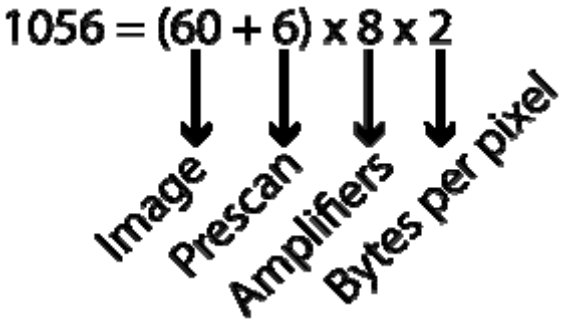
These overscan pixels are transmitted over CameraLink and can vary in number depending on the intent of the user.

For regular use though, these overscan pixels are kept to a minimum, ensuring maximal speed is achieved. For technical reasons, the overscan pixels of line *n* are seen as prescan on line *n+1*.

A regular image (normal mode) acquired by OCAM² has a geometry of 66x121 pixels per output.

This translates into a grabber geometry of 1056x121 8-bits pixels.

Pixels are transmitted in INTEL - Little Endian byte order. This means LSB first, then MSB.



The framegrabber should be configured for images that are 1056 pixels wide and 121 lines high.

Note : some grabbers may require even number of lines to function properly, or even image heights that are multiples of 8.

Although it is perfectly possible to modify the number of lines outputted by OCAM² to accommodate such requirements, it is not recommended as it will induce a reduction in frame rate proportional to the number of lines added.

2.8.4 Binning Mode 120x120 pixels

OCAM² now offers an optional 2x2 binning mode. In this mode the camera achieves roughly 190% of its nominal speed, ie. 2700FPS for OCAM² 1500, and 3700FPS for OCAM2K.

OCAM² binning mode offers 120x120 pixels. Image descrambling is essentially identical as for standard mode with the following differences:

Horizontal resolution stays at 240pixels, but the pixels are duplicated two by two.

Vertical resolution is halved, down to 120 pixels.

To unscramble the OCAM² image, the operation is identical as for standard mode, one just need to skip one pixel over two horizontally, and only parse 120 image lines.

The unscrambled geometry for binning mode is 1056x62 8-bits pixels. Horizontal resolution stays unchanged, vertical resolution is halved, plus a little overhead.

OCAM² maintains separate Flat & Bias correction maps for binning and standard modes. To modify a table for binning mode, simply load it with binning mode active.

When available, binning mode is entered and left through the use of the 'binning on' and 'binning off' commands.

(*see section 4 Camera commands)*

2.8.5 Simulation (test) mode

OCAM² can provide test data for setting up purposes and generic setup of the acquisition chain.

The data sent is generated within the camera with a geometry of 66x121pixels per amplifier, same as regular images.

Data is a simple counter (ramp) of pixel values, per amplifier.

See *Figure 8* for an illustration of how a 1056 pixels-wide, 128 lines high OCAM² grab should look like.

See *Figure 9* for an illustration of what the unscrambled, 8-outputs image should look like.

The camera is instructed turn its test pattern on/off by way of sending the 'test' command (*see section 4 Camera commands)*

- 'test on' starts the simulation mode, and
- 'test off' turns it off, resuming normal imaging operation.

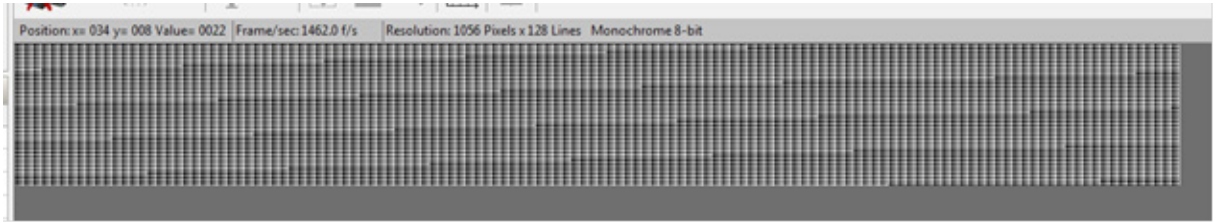


Figure 8 : OCAM² scrambled image as seen in framegrabber utility

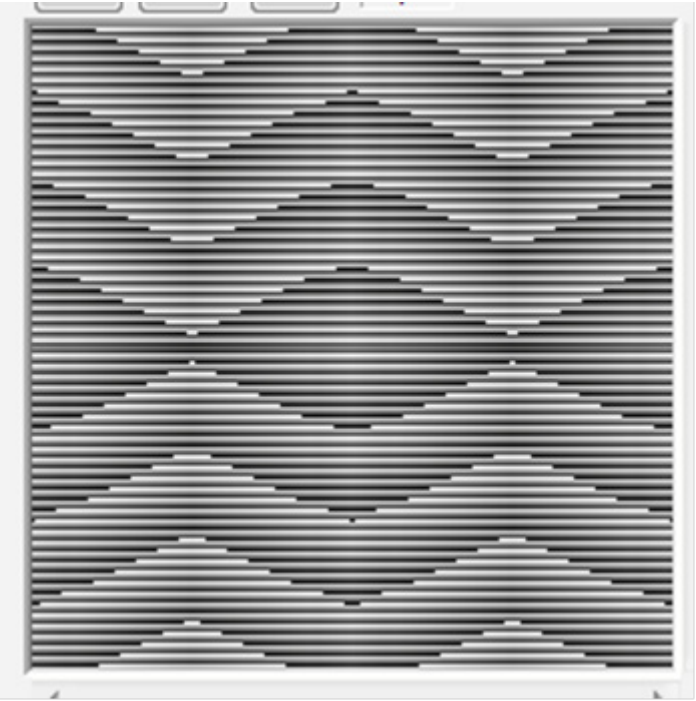


Figure 9: OCAM² unscrambled test mode image

2.8.6 Real image data

The OCAM² camera is normally operated at its nominal speed and resolution, described below as 'normal mode'.

In some cases though, special modes are useful, especially for characterization of the electronics and/or CCD. Two of these overscan modes are detailed below.

Other clocking schemes and geometries are possible but are outside the scope of this document. Contact the OCAM² team if your application requires such a scheme.

In normal (non test mode) operation OCAM² acquires images at its nominal speed, i.e.

1503Hz by default.

Normal mode is defined as free-run, no external synchronization; see *3.4 External synchronization*

(optional) on how to synchronize OCAM² image capture with external events.

In normal mode OCAM² amplifiers have a geometry of 66x121 pixels on all eight outputs. The first line is a prescan line and does not contain image data.

The first 6 pixels of each line are also prescan (actually, overscan from previous line) and contain no image data. See *Figure 10* for an illustration of a normal mode image amplifier output.

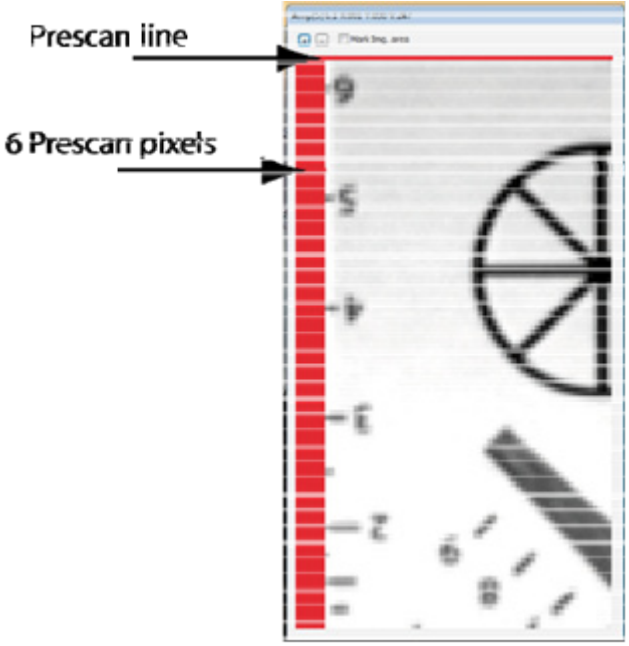


Figure 10 : Single Amplifier image showing prescan data

2.8.7 Unscrambling OCAM² data

The CCD220 at the heart of OCAM² is a split frame-transfer, 8 outputs CCD, as shown

Figure 6.

As the pixels are digitized using 14 bits precision padded to 16 the camera geometry does not fit within regular CameraLink specifications.

As such it is impractical to unscramble data directly on the frame grabber as one would usually do with simpler cameras.

This chapter will describe the proper way to recompose the complete OCAM² image, starting from the grabber.

2.8.7.1 Grabber configuration

As said in chapter 2.5.3 page 2, the grabber should be configured for an image that has 1056 pixels width and 121 pixels height, all 8 outputs should be used in an interleaved scheme.

> The actual 16-BPP (bits per pixel) pixels from the camera are temporally multiplexed to appear as twice the same number of pixels with only an 8-bits width.

Pixel clock should be set at 26MHz. It is not required to give a precise pixel clock as the synchronization is given

by the camera.

For overscan modes, it is required to double the width or height of the image, depending on the mode used.

CameraLink defines 8 ports labeled A,B,C,D,E,F,G,H that are 8-bits wide. In order to transfer the 8 ports 16 bits that OCAM² produces said ports A,B,C,D,E,F,G,H are used in succession, clocking the first 4 pixels from OCAM². Basically what goes out for 1 pixel is 8 MSB group then 8 LSB group, turning in 4 complete pixels per clock cycle.

The first 4 pixels are the ones coming from the top of the camera sensor.

The next 4 pixels (on the second clock tick) are from the bottom of the CCD.

This 1056x121 (for normal operation) configuration ensures that the grabber will fill its memory without reordering data transmitted from the camera.

Once data has been written with 8 bit data the only task remaining is to read the buffer with 16 bits access.

2.8.7.2 Pixel order

OCAM² sends the pixels in the amplifier order 01234567.

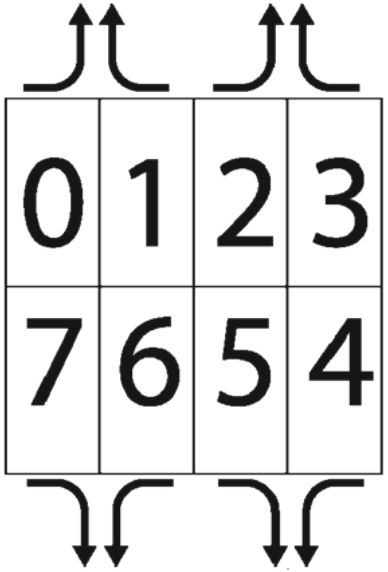


Figure 13 : OCAM² amplifier numbering

From the schematic in *Figure 13* one can figure out the way pixels are transmitted.

The 8 amplifiers are interleaved, meaning a pixel from amplifier *A* gets transmitted every *A* modulo 8 pixels

	17...	9	1	2	10					11	3	4	12		
		16	8	7	15					14	6	5	13		

The table above shows the order by which the pixels are sent by the camera.

Due to the geometry of the L3vision outputs of the CCD the order of the pixels is reversed from one output to the next.

Also, being a split frame-transfer CCD, the pixels from the 4 bottom amplifiers are read bottom to top.

- Amplifier 0 is read Right to Left, Top to bottom,
- Amplifier 1 is read Left to Right, Top to Bottom,
- Amplifier 2 is read Right to Left, Top to Bottom,
- Amplifier 3 is read Left to Right, Top to Bottom,
- Amplifier 4 is read Left to Right, Bottom to Top,
- Amplifier 5 is read Right to Left, Bottom to Top,
- Amplifier 6 is read Left to Right, Bottom to Top,
- Amplifier 7 is read Right to Left, Bottom to Top.

Configuration files are available for common grabbers.

Note: example C++ / C# code for unscrambling OCAM² images is provided for Teledyne®-Dalsa grabbers using SAPERA™ library, as well as Matrox® grabbers using MIL™ library.

OCAM² has an imbedded 32-bit unsigned frame counter that is reset at every powerup. The frame counter is transmitted at offset 8 (in bytes) of every image. This counter will cycle after 33 days of continuous operation at 1503FPS.

3 OCAM² FIRMWARE COMMANDS

OCAM² offers an onboard command-line interpreter that allows the tuning of many camera parameters as well as telemetry.

OCAM² Commands and results are passed through the Serial line embedded in the CameraLink connection.

Serial settings are 115200 Bauds, 8-bit data, 1 bit stop, No parity.

Commands are evaluated after reception of the CR/LF character pair (Carriage Return, Line Feed).

The Tab character (value 9) can be sent to recall last command.

3.1 General Camera instructions

- "**led on | off**" Turns the camera power LED on or off.
- "**interface 0|1**" sets the verbosity level of the camera. 0 is for machine interaction (ie. OCAM² example s/w), 1 is for human interaction / debugging (ie. telnet).
- "**ccdmodel read**" returns the model and serial number of the CCD in the camera in the form ("[%d][%d][%d]\n",model,serial1,serial2).

- "temp" : the 'temp' command requests the readings of the current temperatures as monitored by the camera.

Readings are returned as follows (classic C language printf formatting)

"Temperatures : CCD[%f] CPU[%d] POWER[%d] BIAS[%d] WATER[%f]\n

Cooling is ON. Power [%d]mW.\n"

The CCD and Water temperature values are given to 0.1°C precision, the other values are at 1°C precision.

NB: All temperatures are in Celsius degrees.

Example:

Temp←*User command*

Temperatures : CCD[-45.0] CPU[21] POWER[22] BIAS[21] WATER[20.5]LEFT[35] RIGHT[38]SET[-45] ← *Camera answer*

Cooling is ON. Power[16325]mW.

In this example the detector is at -45°C, the cooling block is at 20°C. The onboard cooling system is running and draws 16.3 Watts of power.

Note : OCAM² has an internal security system that monitors the temperature. Should the internal temperature rise to alarm levels the camera will shut down to prevent damage.

If this situation happens, unplug the power, allow for camera cooling and when proper

temperature is restored restart the camera and issue the command hereafter otherwise the internal cooling will refuse to operate.

- "**cooling reset**" restarts the cooling system after an alarm. Has no effect if the camera is not in alarm.

- "**cooling** *T#*": the 'cooling' command sets the required detector temperature in °C. This command starts the thermal regulation and actively cools the detector if necessary. Integer values only (i.e. you can't regulate at -45.3).

  NB: Accepted values are in the range +40°C to -60°C.

  Setting the regulation above current ambient temperature effectively turns it off. That is to say the system will not heat the CCD.

  The Cooling system is throttled to follow a **6°C per minute** (approx.) slope to minimize thermal stress on the CCD.

  Example:

  cooling -45← *User command*

  Cooling to -45°C. ← *Camera answer*

- "**cooling on**" Turns the cooling system on. Has no effect if the system is already active.

- "**cooling off**" Turns the cooling system off. Has no effect if the system is already off. **Warning : may cause thermal shock !**

Note : Thermal shock is dangerous. The camera follows a slope of 6°C per minute when cooling or warming up. It is very important to allow the cam-

era to properly warm up to ambient temperature before turning it off !

-
- **"Time"** The 'time' command returns the total run-time of the camera in days, hours, minutes and seconds, using the following format: "Camera has been running %dD:%dH:%dm:%ds.\n" (C-style formatting).

  Example:

  Time ← *user command*

  Camera has been running 2D:12H:31m:35s. ←*camera answer*

- "**history [#]**" The 'history' command without parameter lists the last 10 instructions received by the camera. Alternatively the user can specify the number of instructions to display, up to 20. Oldest instructions are displayed first.

3.2 IMAGE CONTROL INSTRUCTIONS

OCAM² offers a variety of functions controlling its image output. These include adjusting the L3Vision™ gain, Flat / Bias image correction and integration time.

3.2.1 Binning Mode (optional)

OCAM² binning mode is controlled by the binning keyword.

- **"binning on"** starts binning mode operation. The camera immediately loads its configuration and starts producing images in binning, 120x120 pixels mode.
- **"binning off"** stops binning mode and resumes full resolution (240x240) operation.

Flat/Bias tables are set for the current mode only. In other words, to load a bias table for binning mode one must be in binning mode.

NOTE: changing to/from binning mode resets the camera to its maximum speed. Also note that while OCAM² can switch from one operating mode to the next on the fly this will probably will not be true for acquisition software.

3.2.2 EMCCD gain

OCAM² EMCCD (L3Vision) gain can be easily adjusted by usage of the gain command.

The camera has an internal calibration table matched for its specific CCD.

Commands are:

- **gain *nnn*** sets the gain to the corresponding value. Accepted values are in the range 1-MAX_GAIN. There is a hard limit at 1000.
- **gain max** sets the maximum accepted gain value. Maximum needs to be equal or less than 1000.

3.2.3 Integration time

- "**fps *nn***" Instructs the camera to grab *nn* images per second. Accepted range is 25..1503.

The special value 0, as in "fps 0" instructs the camera to run at its maximum speed (ie. 1503 FPS, 663µs integration time for OCAM²-1500).

3.2.4 Image Bias Correction

The first and foremost image correction applied in nearly any scientific use of a camera is Bias correction. OCAM² is capable of doing this correction onboard and on-the-fly, alleviating the computing load further down the image processing chain. The bias image used for subtraction is factory calibrated and kept in non-volatile memory.

Bias correction commands are as follows:

- "**bias on**" turns the bias correction ON. From this moment on OCAM² will deliver bias-corrected images.
- "**bias off**" turns the bias correction OFF. OCAM² delivers images uncorrected from bias.

3.2.5 Image Flat Level correction

Like for Bias correction, OCAM² can correct the flatness of its output for calibrated response. Instructions are as follows:

- "**flat on**" turns the Flat correction ON. From this moment on OCAM² will provide Flat field-corrected images.
- "**flat off**" turns the Flat correction OFF. OCAM² delivers images uncorrected for Flat field.

3.2.6 Overillumination protection

L3Vision devices are sensitive to aging if operated with high gain and high light levels. This aging can cause the performance of the CCD to degrade quickly depending on the gain/illumination ratio.

To prevent this OCAM² has an exclusive onboard monitoring system that constantly checks the camera output and automatically shuts down the L3Vision gain if the illumination rises to dangerous levels. This protection will prevent for destroying the CCD in most cases

Typically, the protection will react in 1/500th of a second whereas the CCD manufacturer recommends about a second reaction time. When the camera is used in special configurations (low number of pixels highly illuminated for example) it might happen that the protection won't trigger. It is the responsibility of the user to apply an appropriate gain on the camera depending on the signal level. Typically the pixel level should be maintained below 8000 ADU for a safe operation. Any gain applied with bright pixels in the image or excessive gain regarding the pixel level may destroy the CCD. This is a case of misuse of the system not covered by the warranty.

When triggered, the protection will return instantly the camera to unity gain, and prevent any gain change until the condition has been acknowledged.

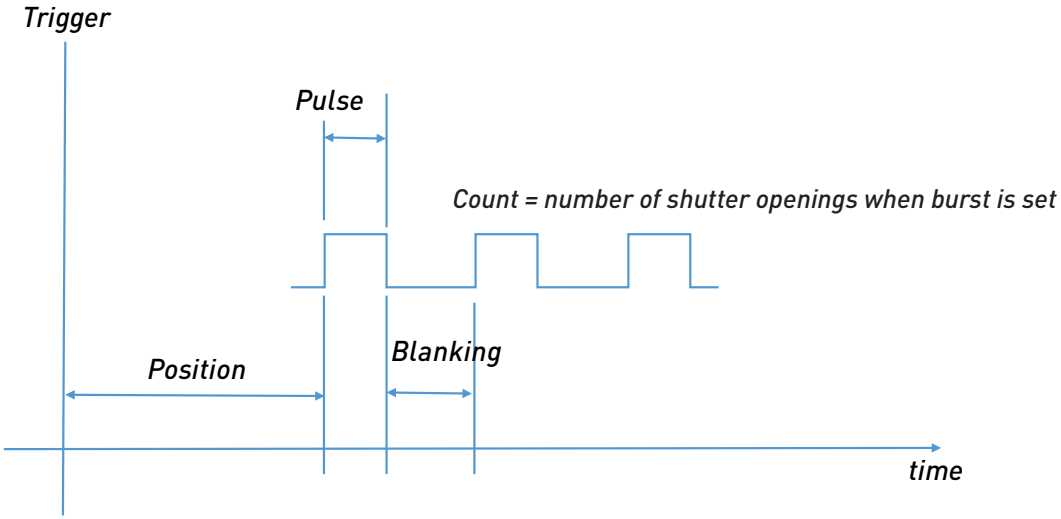
- Protection reset

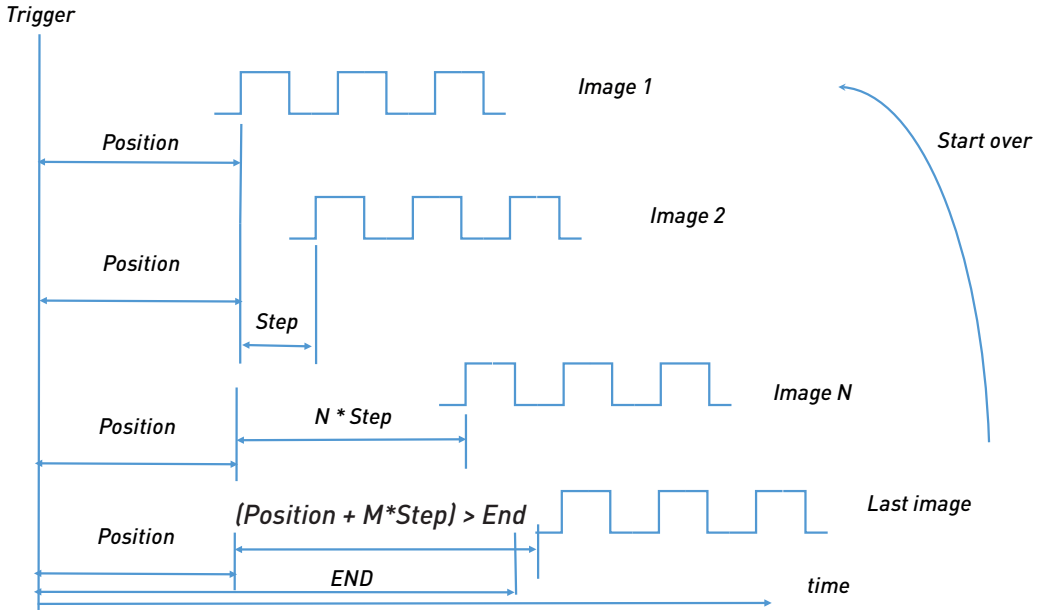
  Acknowledges a previous error condition and allows the raise of Gain values above safe levels afterwards.

3.2.7 OCAM2-S Specific Instructions

OCAM2-S offers an integral electronic shutter that offers excellent occultation with extreme temporal precision.

The operation of the electronic shutter can be summarized in the next two chronograms.





Note : at camera startup, the Electronic Shutter restores its previous (shutdown) state.

The electronic shutter operation is controlled by the following instructions

- "**shutter on**" Turns on the electronic shutter. Note that if the shutter parameters are incorrect and/or timing or synchronization are off it is perfectly possible that the images turns black.
- "**shutter off**" Turns off the electronic shutter, resuming normal OCAM2 operation, i.e. exposure time is maximal for any given frame rate.
- "**shutter internal**" This instruction tells the camera to generate the shutter pulses internally, without external input.
- "**shutter external**" This instruction slaves the electronic shutter to external input.
- "**shutter single**" The electronic shutter will now fire a single time per exposure (frame).
- "**shutter burst**" The electronic shutter will now fire multiple times per exposure.
- "**shutter sweep *[0|1|2]***" The electronic shutter will now sweep an interval at each exposure. The parameter sets the sweep mode. Mode 0 is Sweep OFF. Mode 1 is Sweep ON (continuous). Mode 2 is Sweep ON, with external trigger. When in Sweep Mode 2 the external line triggers the start of the sweep. Please note that in this special case the external input line does NOT control pulse width and blanking. These are controlled by the internal values (see instructions 'shutter pulse', 'shutter blanking' and 'shutter step').
- "**shutter pulse #ns**" Sets the duration of the electronic shutter opening, in nanoseconds. Note that the increment is 9.21ns for OCAM2-1500 or 6.7ns for OCAM2-2000.
- "**shutter blanking #ns**" Sets the duration of the blanking between two pulses, in nanoseconds. Like the Pulse duration, the Blanking duration has increments of 9.21ns for OCAM2-1500 or 6.7ns for OCAM2-2000. If the eletronic shutter is in Single Pulse mode this setting has no effect.
- "**shutter position #ns**" Sets the delay, in nanoseconds, between the frame trigger and the first pulse of the electronic shutter. Like the Pulse duration, the Position setting has increments of 9.21ns for OCAM2-1500 or 6.7ns for OCAM2-2000.

- "**shutter step #ns**" Sets the delay, in nanoseconds, that will be added to each frame's electronic shutter starting position when on sweep mode. For example, if Position is set to 1000ns after trigger and Step is 100ns, on the first frame the pulse will start at 1000ns, on the next one 1100ns, then 1200ns and so on.
- "**shutter end #ns**" Sets the time limit, in nanoseconds, that will reset the sweep mode. When the incremental delay that amounts to (Position + N*Step) nanoseconds, where N is the number of images reaches the End value, the frame counter is reset and the sweeping starts over.
- "**shutter count #n**" Sets the number of sequential pulses to fire in burst mode.

4 TROUBLESHOOTING

4.1 IMAGE ISSUES

4.1.1 Camera does not make images.

When OCAM² appears to not produce images check these points in order:

- Camera is properly cooled, plugged and power is on.
- CameraLink cables are connected in good order.
- User Acquisition software is running properly. Check for zombie processes that may hold on to the drivers.
- Camera responds to software commands (ie. Thermal readings, monitoring functions).

4.1.2 Images appear to be incorrect.

If some garbage is sent over the serial command line chances are that the CameraLink cables are inverted. Switch the two cables.

Otherwise, check illumination: sensor saturation can give strange images.

4.1.3 There is a pattern and no image.

Test mode is on. Send the 'test off' command.

4.2 COOLING ISSUES

4.2.1 Cooling does not start

Thermal protection has been set. Check the temperatures and coolant flow. If everything ok, send the 'cooling reset' command.

4.2.2 Cooling does not reach set temperature.

The internal cooling of the camera is dimensioned to provide proper cooling to -45°C with water temperature below 25°C. If the set temperature goes below -45°C or the water temperature rises above 25°C it is possible that the cooling system will fail to maintain the CCD temperature.

Solutions are:

- Set the cooling to a reachable operating temperature.
- Reduce the water temperature and/or increase its flow.

4.2.3 Cooling works then shuts down, image is gone

Thermal load is too high.

Water temperature rises above maximum temperature; the internal coolers are shut down to prevent damage to the CCD. Also the electronics shut down to reduce power usage to a minimum.

- Power down the camera, wait for it to cool down.
- Check the water flow, increase it if possible.
- Switch to an active water cooling (eg. Water chiller).
- Reduce the thermal load by augmenting the CCD temperature.

Note : should the camera be operated *without* water connectors plugged in (please don't do that), temperature raise will cause an increase in static pressure that can make it very difficult to plug the water connectors in. **Do not force the connectors in place**; instead power down and wait for the camera to cool before plugging the water back in.

4.3 Gain / illumination issues

At unity gain the camera cannot be damaged by saturation at normal levels (please don't look directly at sunlight or laser sources). When gain is applied however, excess light can lead to aging of the detector. Depending on the intensity of gain and light the CCD could even be destroyed in seconds.

In order to prevent this unfortunate event OCAM² cameras are equipped with an exclusive onboard illumination protection system.

When an overillumination condition is detected, the camera will protect the CCD by reverting to an L3Vision gain of 1.

When such an event occurs, the camera will refuse to apply gain until the error is acknowledged by issuing a 'protection reset' command.

At startup, the camera is in protection mode. To apply gain the user **must** issue the 'protection reset' command.