Optical Synchrotron Radiation Diagnostic Beamline Manual

7.9.79.1 Rev. 4

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Canadian Light Source Inc.
101 Perimeter Road
University of Saskatchewan
Saskatoon, Saskatchewan Canada

	Signature	Date
	Original on File – Signed by:	
Author	J.M. Vogt	2010-02-16
Reviewer #1	J.C. Bergstrom	
Reviewer #2	W. Wurtz	
Approver	E. Matias	

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B	2003-03-18	Amended Draft	M. McKibben
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1.0 INTRODUCTION

1.1 PURPOSE AND SCOPE

This manual describes the design and operation of the Canadian Light Source Optical Synchrotron Radiation Diagnostic Beamline (OSR). It describes the procedure for setting up the optical chicane and it summarizes the parameters for setting up the instruments on the optical table for the various measurements that can be made on the beamline. These parameters are intended to provide a reasonable starting point for any of the measurements, not a complete list of all possible settings. Also, the interpretation of the data is beyond the scope of this manual.

It is assumed that the operator of the beamline is familiar with the layout of the facility and the beamline (see Ref. [1]), and knows how to use an oscilloscope and a multimeter. Familiarity with the CLS control system and with Microsoft Windows is also required.

The CCD camera and the Fast Steering Mirror are simple devices, which can be operated with the information given in this document. The ICCD camera can be operated with the information given in this document and in the ICCD operating manual [3].

The Streak Camera is a complex and expensive device. This document gives some instructions on setting up the Streak Camera, but these are meant as a reminder for the experienced operator. **In-depth hands-on training is required to operate the Streak Camera, as well as a good theoretical understanding of its principle of operation** (see Ref. [4]).

1.2 BACKGROUND

The Optical Synchrotron Radiation (OSR) beamline is located on port 02B1.2 (see Ref. [1]). This beamline is used to monitor Storage Ring characteristics using visible light. In normal operation the instrumentation is accessed from the control room. Access to the beamline hutch is required to configure and start up the Streak Camera and the Fast Steering Mirror. Users will have access to the image off the CCD camera.

1.3 DEFINITIONS AND ABBREVIATIONS

BPM: Beam Position Monitor

CCD: Charge-coupled Device

FSM: Fast Steering Mirror

KVM: Keyboard/Video/Mouse

OSR: Optical Synchrotron Radiation

PSD: Position Sensitive Detector

XSR: X-ray Synchrotron Radiation

X,Y,Z: A right-handed system of coordinates defined such that Y is up and the beam travels in the Z direction. Therefore X is left when looking downstream, i.e. in the OSR hutch the Storage Ring is in the -X direction and the IR hutch is in the +X direction.

2.0 DESCRIPTION

2.1 VACUUM / MACHINE PROTECTION

Vacuum control is identified on the P&ID. Vacuum / Machine protection includes:

- Interlocking of cold cathode gauges, thermocouple gauges, residual gas analyzers, and pumps to valve operation in the event of a vacuum loss. Because of the lack of an actual front-end on this beamline the machine protection function is implemented with the Storage Ring machine protection system.
- Allowing a valve to be opened only if the differential pressure across the valve is below a specified threshold.

2.2 SOURCE POINT

The source point is at an angle of 5º into dipole 02B1.

2.3 PHOTON SHUTTER

The shutter is protected by stopping the electron beam in the Storage Ring if the cooling water flow is less than 35% (FLT1402-B10-01).

Motion control of the shutter in and out of the beam is provided by a pneumatic cylinder, a pneumatic control valve and two position sensing switches. The shutter can only be opened when the vacuum valve is open.

2.4 OPTICAL CHICANE

2.4.1 Photon Absorber

A photon absorber is located 1.957 m from the source point. Its aperture is 12 mm in X and 16 mm in Y. This corresponds to an angular acceptance of θ_x = 6.13 mrad and θ_y = 8.18 mrad. The transmitted beam power, integrated vertically, is approximately 70 W/mrad (horizontally) at 500 mA. Therefore, the total power passing through the photon absorber is about 430 W at 500 mA.

2.4.2 Primary Mirror

The primary mirror is located 5 m from the source point. It only intercepts the visible light in the upper half of the synchrotron light cone.

The mirror consists of aluminum-coated glidcop with a 200 nm SiO_2 coating. The SiO_2 coating is specified to withstand 10^8R without noticeable darkening. The mirror is water-cooled with a liquid gallium layer as thermal coupling. The size of the mirror is 50 mm · 50 mm. The mirror can be moved in and out of the beam at a fixed angle of 45º. A thermal probe with two K-type thermocouples is attached to the lower edge of the primary mirror.

The mirror is protected by closing the front-end photon shutter:

- If the cooling water flow is less than 30% (FLT1402-B10-02),
- If either or both of the thermal probe temperatures exceed 50ºC (TM1402-B10-04, TM1402-B10-05).

2.4.3 Beam Stop

The beam stop is protected by closing the front-end photon shutter:

- If the cooling water flow is less than 30% (FLT1402-B10-03),
- If the return water temperature exceeds 28ºC (TM1402-B10-03).

2.4.4 Secondary Mirror

The secondary mirror is located 5.5 m from the source point. It is identical to the primary mirror, except for the water cooling and the temperature monitoring. It can be moved in the following manner:

- Vertical translation,
- Rotation about the horizontal axis,
- Rotation about the vertical axis.

In normal operation the secondary mirror is tilted 45º about its horizontal axis. However, it can be turned perpendicular to the optic centre line so that light from the optical table is reflected back to the table.

2.4.5 Slit Assembly

The slit assembly is located 5.615 m from the source point. It has 4 independent blades, but control of the blades is combined into “gap” and “centre” in both X and Y. The following settings are used in normal operation:

	Gap	Centre
X	22 mm	0 mm
Y	30 mm	15 mm

The Y gap allows all visible light to pass through the slits. The Y centre has an offset because the primary mirror only intercepts the upper half of the light cone (see 2.4.2).

The X gap was determined empirically in order to optimize the resolution of the system, considering the spot size vs. diffraction from the slit.

2.4.6 Lens

The lens is an achromat with a diameter of 150 mm and a nominal focal length of 3 m. It was found, however, that the true focal length is 2.965 m. Therefore the lens is located 5.93 m from the source point, 70 mm closer than the design position. This results in a magnification of 1 with the primary focus at a distance of 11.86 m from the source point. The lens is mounted on a 3 axis translation stage. The settings used in normal operation are:

X	0 mm
Y	0 mm
Z	-70 mm

2.4.7 Controls for the Optical Chicane

Rack R2405.1-04, located on top of the Storage Ring, contains the control hardware for the optical chicane. A K-type thermocouple (TM1402-B10-06) is mounted inside the optical chicane. This thermocouple is used to monitor and log the temperature inside the chicane.

2.5 RESOLUTION

The resolution of the OSR line is determined by the following effects:

- Diffraction from the primary mirror (2.4.2) in Y and from the slits (2.4.5) in X,
- Depth of field,
- Dispersion of the electron beam,
- Curvature of the electron beam (X only).

For the typical slit settings given in 2.4.5, the resolution in Y is 55 µm, which is mostly due to diffraction at the primary mirror (51 µm). In X the resolution is also 55 µm, with diffraction from the slits accounting for 48 µm. These are 1-σ values, which need to be subtracted in quadrature from the measured beam spot size in order to obtain the true beam spot size.

Note: The beam spot size (typically 400 µm in Y and 700 µm in X) is given as 4-σ values, and needs to be divided by 4 before the resolution is subtracted in quadrature.

2.6 OPTICAL ELEMENTS ON THE OPTICAL TABLE

The layout of the optical table is captured in drawing 02B1-2/ME/OPT/009400.

2.6.1 Shutter

In order to protect the cameras, the optical table is equipped with a shutter that closes automatically when any of the filter wheels are moved.

2.6.2 Beam Splitters

There are three beam splitters on the optical table. The first one has 50% transmission toward the ICCD camera and the CCD camera, and 50% reflection toward the Fast Steering Mirror or the Streak Camera. The second beam splitter is located in the ICCD/CCD line right behind the first splitter. It has 90% transmission toward the ICCD camera and 10% reflection toward the CCD camera. The third splitter is located in the FSM line and has 90% transmission toward the PSD and 10% reflection toward the CCD camera.

2.6.3 Fixed Mirror

There is one fixed mirror in the Streak Camera line. It is a Newport 20D20BD.1.

2.6.4 Neutral-Density Filters

There are four neutral-density filter wheels, one each for the CCD camera, the CCD camera in the FSM line, the ICCD camera, and the Streak Camera. The filters are Melles Griot absorptive neutral-density filters with a diameter of 25 mm and various optical densities.

2.6.5 Focusing Lenses

There are 7 focusing lenses on the optical table, all of them achromatic doublets with a diameter of 50.8 mm.

The FSM line uses point-parallel-point optics with two Newport PAC091 lenses (f = 500 mm).

The ICCD line uses point-to-point optics with either an Oriel 42640 lens (f = 160 mm for a magnification M = 4) or a Newport PAC088 lens (f = 250 mm for a magnification M = 1) moved into position with pneumatic lifters.

The Streak Camera line uses a fixed Newport PAC094 lens (f = 750 mm, point-to-parallel), and either a Newport PAC089 (f = 300 mm, parallel-to-point, magnification M = 0.4) or a Newport PAC086 (f = 150 mm, parallel-to-point, magnification M = 0.2). These two lenses are mounted on pneumatic lifters.

2.6.6 Dove Prism

The vertical sweep of the Streak Camera draws a top view of the beam. In order to allow a side view of the beam, a dove prism is moved into the optical path. The dove prism is a Melles Griot 01PDE005.

2.6.7 Bandpass Filters

There is a Melles Griot 03FIB006 bandpass filter in front of each camera. The filters have a FWHM of 80 nm and are centred at 500 nm. The filter diameter is 50 mm.

2.6.8 Fast Steering Mirror

The Fast Steering Mirror is a Newport FSM-320-01 with a diameter of 50.8mm.

2.7 DETECTORS ON THE OPTICAL TABLE

The optical table is a metric table, 1.2m · 2.4m, with M6 holes on a 25 mm grid. It is equipped with four detectors. The layout of the detectors is captured in drawing 02B1-2/ME/OPT/009400.

2.7.1 CCD Camera

The CCD camera is a COHU Model 6612-3000, configured for interlaced mode with a shutter speed of 1/60 s. The video signal is distributed to:

- A video monitor located in the OSR hutch,
- A video to Ethernet adapter, which is used to make the image available on a web page and on the facility monitors,
- A fibre link to the control room,
- A frame grabber in the OSR hutch.

The digitized images from the frame grabber are analyzed by a software package called “Spiricon”. Although the computer running Spiricon is located in the OSR hutch, it can be accessed from the Control Room via a KVM extender.

The wiring of the CCD camera is shown in O2B1-2/EE/WIR/0090780.

2.7.2 CCD Camera in the FSM Line

An identical CCD camera is mounted in the FSM line. It uses the same readout as described in 2.7.1 (the video signal cable is moved between the two cameras).

2.7.3 Position Sensitive Detector in the FSM line

The detector is a Hamamatsu Model S1300 Duo-Lateral, Super Linear Position Sensing Detector mounted on a C4757 signal processing board. It is used to provide position feedback to the Fast Steering Mirror controller.

2.7.4 Intensified CCD (ICCD)

The Intensified CCD (ICCD) camera provides bunch-by-bunch or single bunch position analysis of the beam. It is a 4 Picos Camera running in interlaced mode and it includes a software package to control it. This software runs on a computer in the OSR hutch, but remote control from the Control Room is available via a KVM extender. The camera is connected to a frame grabber, and the Spiricon software (see 2.7.1) is used to analyze the images.

The camera is normally triggered by the Storage Ring synchronous trigger, but the Storage Ring injection trigger is available for injection studies. The trigger is selected by moving the ICCD trigger cable to the appropriate spigot on P1602.1-02 (see O2B1-2/EE/WIR/0090780). The trigger circuit of the camera ignores trigger signals that are sent while the camera is not ready to accept them. However, experience shows that the camera should not be triggered at a rate > 200 Hz, in order to avoid temperature drifts in the trigger circuit. A pre-scaler (BL#/EE/DIAG/0106150) is used to divide down the trigger rate when running with the Storage Ring synchronous trigger.

The range of exposure times is 200 ps to 80 s, although in this application it is usually not practical to exceed exposure times of 100 μs, because the light intensity would be too high. Nevertheless, it is possible to acquire images of a single bunch or, at the other extreme, average over hundreds of turns. The camera has a built-in delay of 0 s to 80 s in steps of 100 ps. Again, only the bottom end of the range is practical in this application. The delay can be used to select a single bunch or the start of a sequence of bunches, or to select a turn during injection studies. *Note: A delay of approximately 163 μs needs to be set to select the first turn after injection. For injection studies, the Storage Ring RF needs to be turned off, since the ICCD would otherwise be blinded by the stored beam.*

2.7.5 Streak Camera

The purpose of the Streak Camera is to monitor the state of individual bunches:

- Measure the bunch length,
- Observe the bunch from the front, top, or the side,
- Monitor the bunch for unstable motion.

The Streak Camera is a Hamamatsu C5680-31 camera with a cathode height of 500 μm and with A1976-01 broadband input optics. It has an RS170 video output connected to a frame-grabber, and is controlled by the vendor-provided “HPD-TA” software package through a GPIB interface.

The wiring diagram for the Streak Camera is shown in 02B2-02/EE/MON/WIR/0108280. The camera has the following plug-ins:

2.7.5.1 M5675 Synchroscan Sweep Unit

The Synchroscan Sweep Unit has a vertical sweep frequency of 166.7 MHz (1/3 f_{RF}). It is synchronized with the Storage Ring RF frequency f_{RF}, and therefore paints every third bunch in

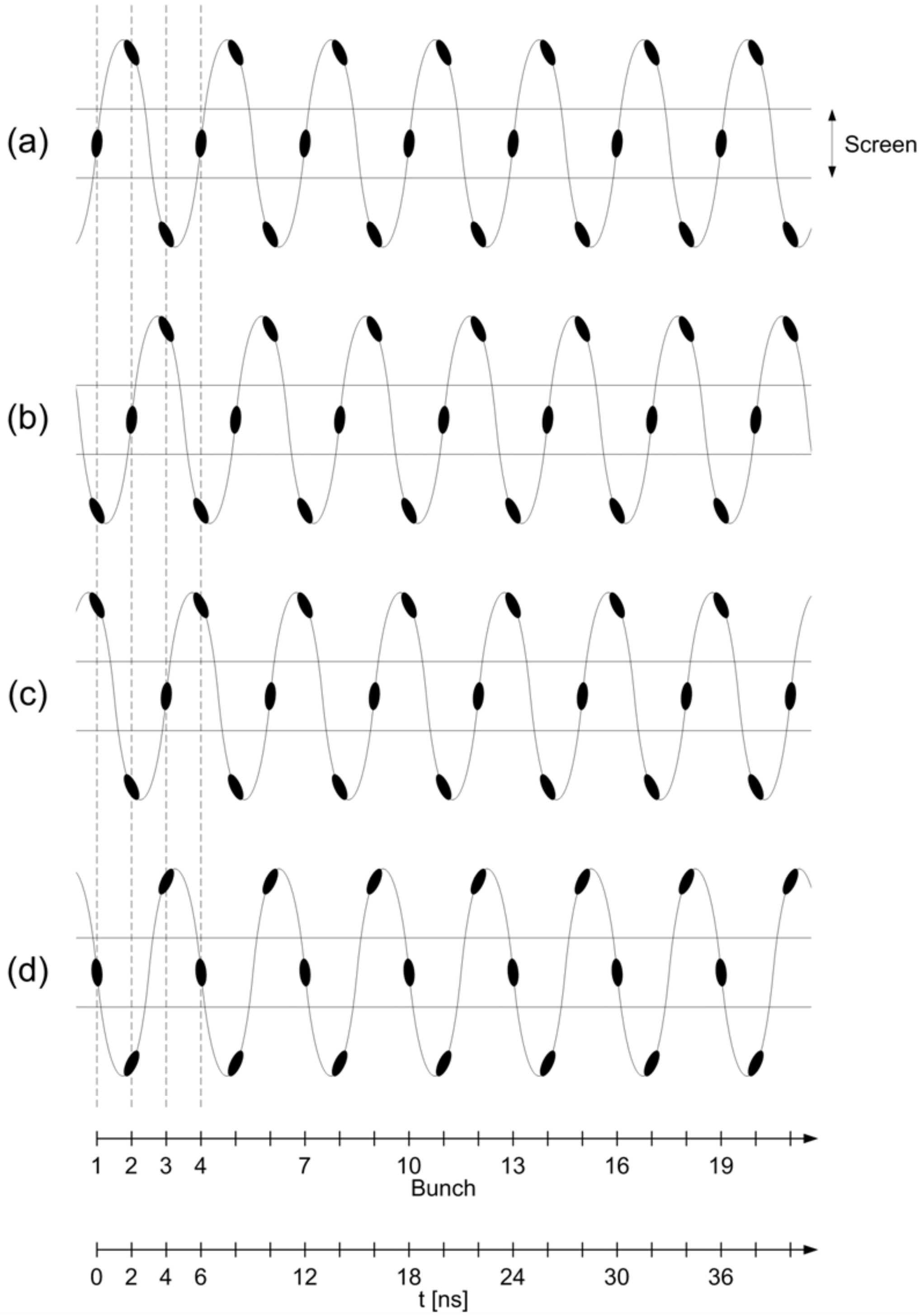


Fig. 1: The Synchroscan Sweep Unit sweeps vertically at a frequency of 166.7 MHz, while the Dual Timebase Extender Unit (see 2.7.4.3) applies a linear horizontal sweep. Only bunches 1,4,7,... are displayed on the screen in graph (a). If the 166.7 MHz signal is delayed by 2 ns, bunches 2,5,8,... are displayed (b). If the signal is delayed by 4 ns compared to (a), bunches 3,6,9,... are displayed (c). If the signal is delayed by 3 ns compared to (a), all bunches are displayed on the down-stroke (d) rather than the up-stroke. Note that no Synchronous Blanking Unit is needed, since there is no light hitting the camera during sweepback.

the Storage Ring (see Fig. 1) while the other bunches arrive when the vertical sweep is above or below the screen. Since the harmonic number of the Storage Ring (=285) is divisible by 3, the Synchroscan Unit paints the same subset of 95 bunches in every turn, i.e. either bunches 1,4,7,...,283 (Fig. 1(a)), or 2,5,8,...,284 (Fig. 1(b)), or 3,6,9...,285 (Fig. 1(c)). The 166.7 MHz signal to the Synchroscan Unit is delayed in a Hamamatsu C1097-04 Delay Unit. The beam bunches can be positioned on the screen by making small adjustments to the delay setting. The desired subset of bunches can then be chosen by increasing or reducing the delay setting in steps of 2 ns (Fig. 1(a), 1(b), 1(c)). Increasing or reducing the delay setting by 3 ns switches between painting the same subset of beam bunches on the up-stroke (Fig. 1(a)) or on the down-stroke (Fig. 1(d)).

The 166.7 MHz signal is generated from the 500 MHz master oscillator signal in a divide-by-3 module (CDAC/EE/TMNG/0090870). The 500 MHz sine wave is converted into a digital signal and divided by 3 in such a way that a square wave with a 50% duty cycle results. A low pass filter is then used to reject the higher harmonics, resulting in a 166.7 MHz sine wave. It now appears that the higher harmonics would be rejected by the input of the Streak Camera anyway, but at the time the circuit was designed (before delivery of the camera) this information was not available.

2.7.5.2 M5677 Slow Speed Sweep Unit

The Slow Speed Sweep Unit is used to paint entire bunch trains. The unit is triggered by a signal that is derived from the Storage Ring synchronous trigger. The maximum trigger rate that the Slow Speed Sweep Unit can accept depends on the sweep speed setting. Trigger signals that arrive during the deadtime are ignored. However, unless the vertical trigger rate is an integer multiple of the horizontal trigger rate, the image produced by the camera walks horizontally. A pre-scaler (BL#/EE/DIAG/0106150) is therefore used to set the trigger rate low enough so that all triggers are accepted by the Slow Speed Sweep Unit. Also, the time delay between a trigger and the start of the vertical sweep depends on the sweep speed. A combination of a fibre delay and a NIM delay module is used to adjust the timing of the trigger signal in order to position the image on the screen.

2.7.5.3 M5679 Dual Timebase Extender Unit

The Dual Timebase Extender Unit has a horizontal sweep frequency of 10 Hz or less, depending on the sweep speed. Trigger signals that arrive during the deadtime should be ignored. However, it was found that the behaviour of the trigger circuit is unpredictable when triggered during the deadtime. Furthermore, a synchronization problem was noticed between the camera and the frame grabber when the horizontal sweep and the frame grabber were triggered simultaneously as recommended by Hamamatsu.

Both problems were addressed by building a Streak Camera Synchronizer module (BL#/EE/DIAG/0106190). It monitors the video signal of the Streak Camera and recognizes odd and even fields. It then divides the 30 Hz odd/even field frequency by a selectable number to obtain a horizontal trigger frequency <10 Hz. The timing of the horizontal trigger signal is then determined by the first pre-scaled storage ring synchronous trigger (see 2.7.4.2) to follow the pre-scaled odd/even field signal. This setup satisfies all of the following conditions:

- No horizontal trigger signal arrives at the camera during its deadtime,
- The frame grabber is synchronized to the Streak Camera CCD and to the horizontal sweep,
- The vertical trigger rate is an integer multiple of the horizontal trigger rate (see 2.7.4.2).

2.8 LOCAL MONITORS AND DISPLAYS

The following monitors and displays are permanently installed in the OSR hutch:

- A rack-mounted video monitor connected to the CCD camera,
- A rack-mounted video monitor connected to the CCD camera in XSR,

- A rack-mounted computer monitor and keyboard tray, switched between the CCD/ICCD and Streak Camera data acquisition computers,
- A rack-mounted control computer for beamline control and other diagnostics,
- A rack-mounted video monitor, which is connected to the CCD in XSR.
- 2 Keithley 6485 Picoammeters, which are connected to the XSR X-ray BPM.

2.9 TEST EQUIPMENT

The following test equipment is dedicated to the OSR hutch:

- A 0.5 mW laser made by Research Electro Optics Inc., model # 31008,
- A Hamamatsu C8898 Picosecond Light Pulser with a peak power of 66 mW and a pulse duration of 70 ps,
- The “Canadian Light Source”, a battery powered, white LED mounted in a box with an ST connector,
- A Tektronix TDS3052B oscilloscope,
- BK Precision 1856D 3.5 GHz frequency counter,
- A Fluke 87 handheld multimeter,
- An Agilent 33120A arbitrary waveform generator,
- A Sony MHC-GX250 stereo system, which is used for acoustic vibration studies.

3.0 USER'S GUIDE

3.1 HOW TO SET UP THE OSR OPTICAL CHICANE

On the control screen, select **CLS Logo** → **Storage Ring** → **OSR Diagnostic Beamline** and click on **Optical Chicane** tab.

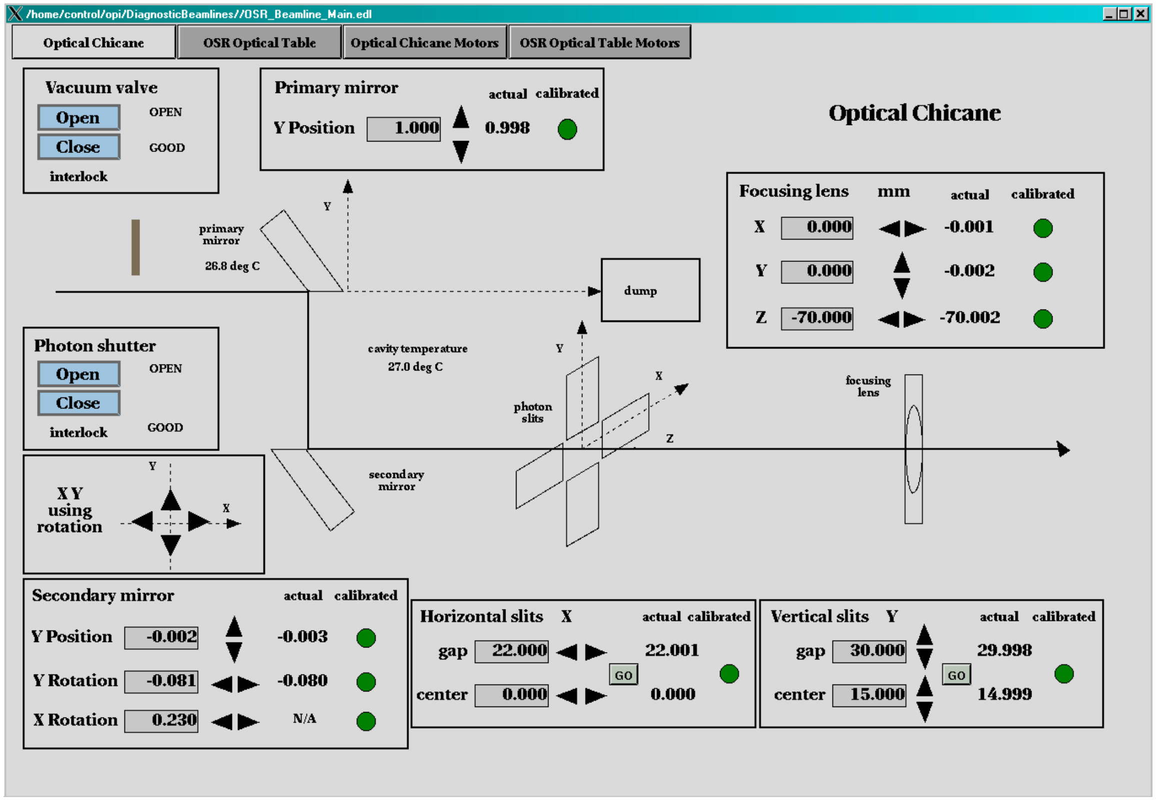


Fig. 2: The optical chicane control window showing the nominal settings for all optical elements.

Verify that all positions are calibrated. This is indicated by green dots in the "calibrated" columns of the settings. Altogether there have to be 9 green dots as indicated in Fig. 2.

If any of the positions is not calibrated, click on the **Optical Chicane Motors** tab (see Fig. 3). Click **RUN** for any motor that does not indicate **CALIBRATED**. Wait until all motors finish their position calibration. *(Note: The* **"secondary mirror rotation – horizontal"** *takes significantly longer than all other motors. This is normal.)*

Return to the optical chicane control window by clicking on the **Optical Chicane** tab. All the settings should be as shown in Fig. 2, otherwise correct the settings that are wrong. Open the vacuum valve first, and then the photon shutter. Use the CCD camera as a reference for aligning the beam. (Note: The settings in Fig. 2 provide a good starting point, but in all likelihood will not steer the beam into the active area of the CCD camera.)

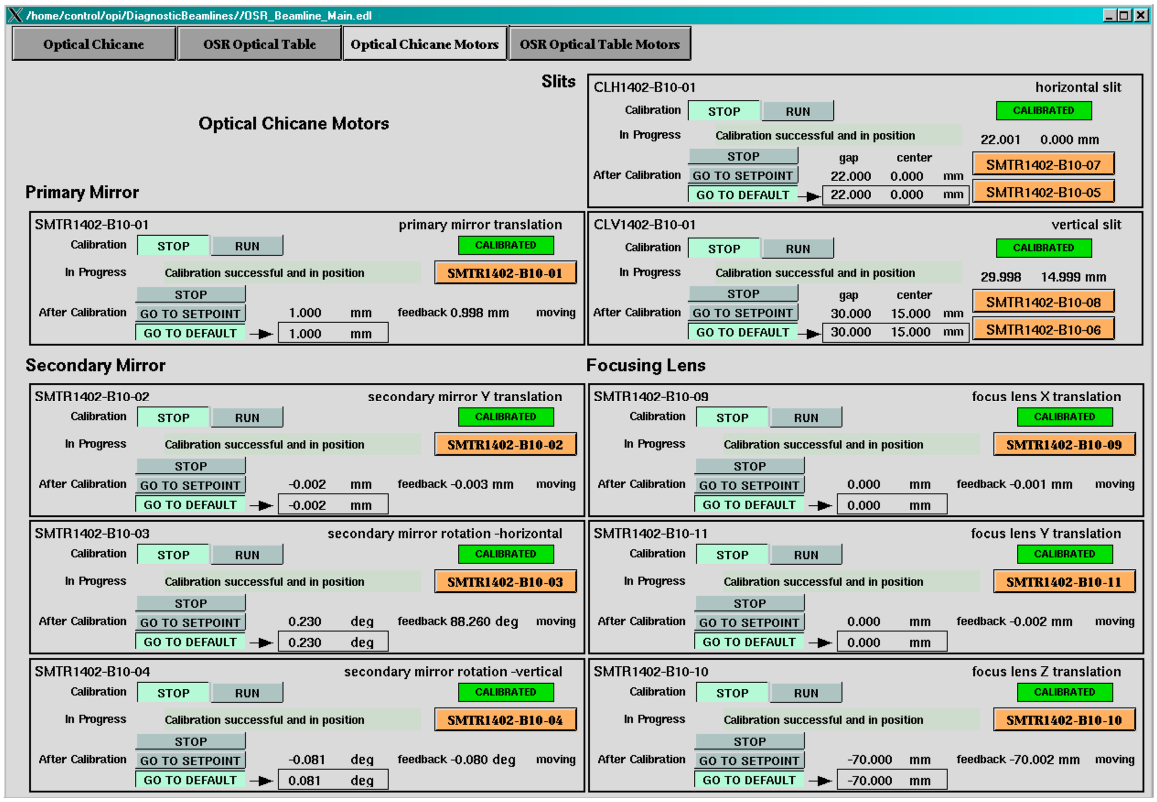


Fig. 3: Optical Chicane Motors control window. All motors are calibrated.

Click on the **OSR Optical Table** tab. The window shown in Fig. 4 will open. Verify that the dove prism stage indicates **CALIBRATED**. If not, click on the **OSR Optical Table Motors** tab (see Fig. 5) and click **RUN**.

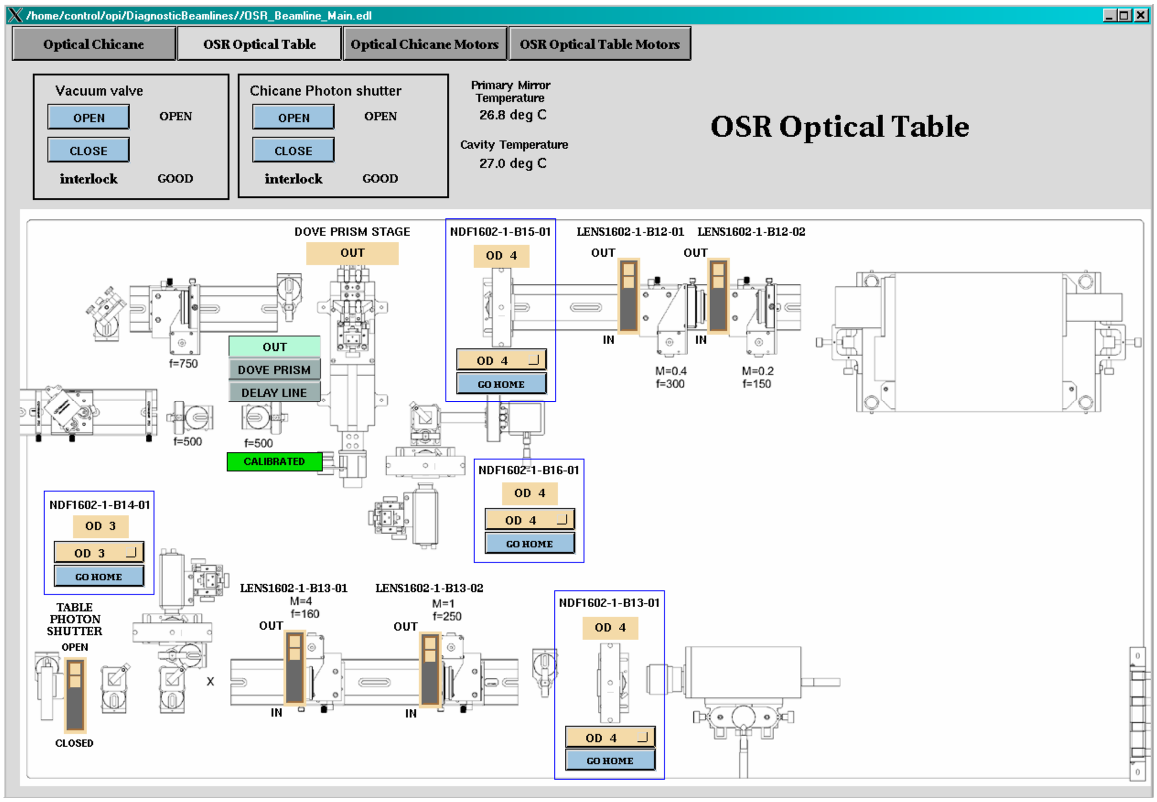


Fig. 4: The OSR Optical Table window. The table photon shutter is open and filter wheel B14-01 in front of the CCD camera is set to OD3, as it would normally be for a stored beam current of 200 mA. In the ICCD camera line at the bottom, both lenses are out and filter wheel B13-01 is set to OD4. In the Streak Camera line the dove prism is out, both lenses are out, and filter wheel B15-01 is set to OD4. Filter wheel B16-01 of the FSM line is set to OD4. The fast steering mirror is shown out of the beam, but it would be moved in manually when the FSM line is used.

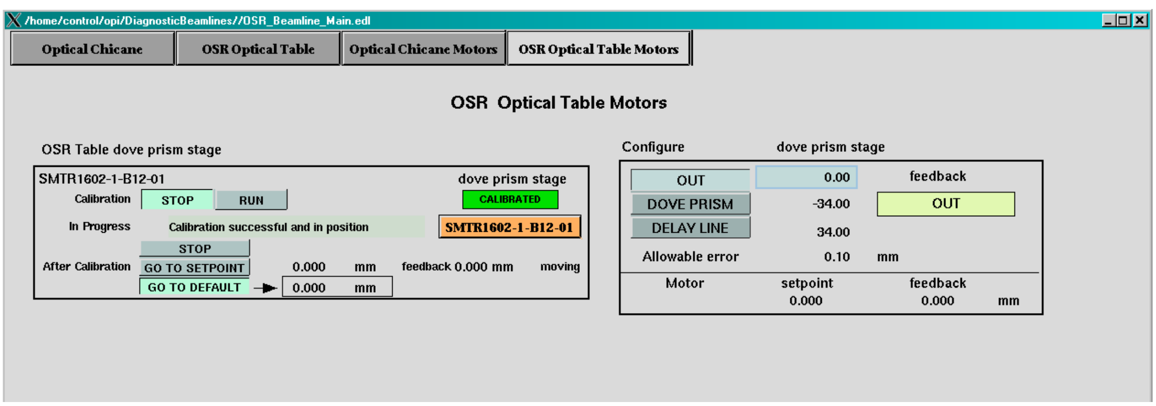


Fig. 5: The OSR Optical Table Motors control screen.

Select a reasonable OD setting for the CCD camera:

Beam in the Storage Ring	Optical Density
1 mA	0
10 mA	1
100 mA	2
200 mA	3

Open the table photon shutter. If the beam spot does not appear on the video monitor, close the table shutter again and look at the upstream side of the table shutter. There is a label on the table shutter, which indicates the nominal beam spot position. The actual spot should be visible somewhere on the table shutter. *(Note: If the light above the optical table is dimmed, the spot is clearly visible at a beam current of a few mA)*. Steer the beam towards the nominal position using the **“XY using rotation”** arrows in the optical chicane control window (Fig. 2). This moves the secondary mirror. The direction of motion is:

XY Using Rotation	TV Monitor	Table Shutter	Beam Coordinates
↑	↓	↑	+Y
↓	↑	↓	-Y
→	→	←	+X
←	←	→	-X

3.2 HOW TO SET UP SPIRICON FOR THE CCD CAMERA

To start up Spiricon, click on the icon

Spiricon has a large number of features and options. Some have not been explored yet, and some are not applicable to the CCD camera. The following configuration is suggested as a starting point. A detailed description of the Spiricon software can be found in Ref. [2].

Select **Options** → **Camera** and set the configuration shown in Fig. 6. “Frames” may be set as desired.

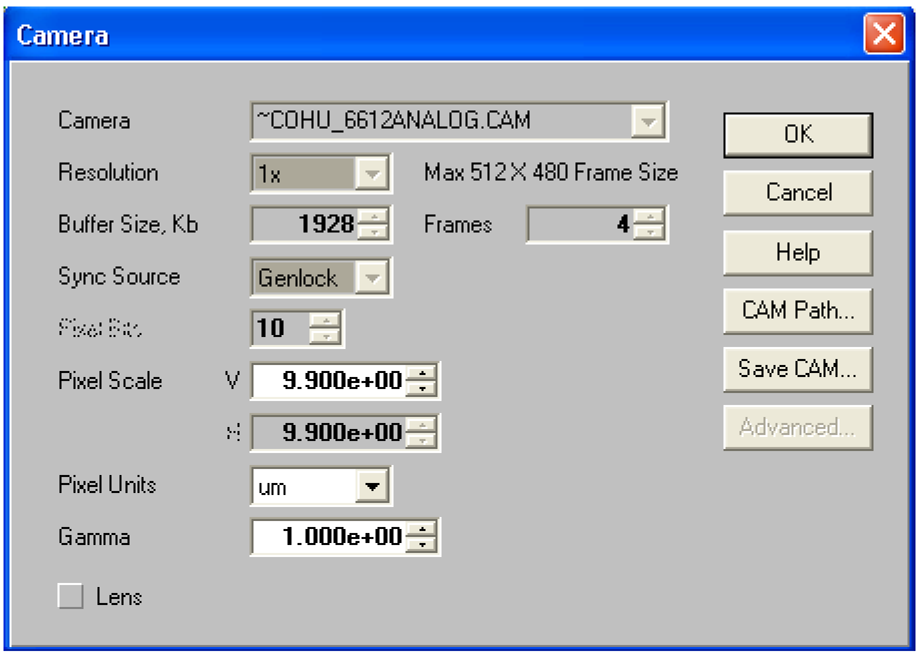


Fig. 6: Configuration of the “**Camera**” window for the CCD camera.

Select **Options** → **Capture** and set the configuration shown in Fig. 7:

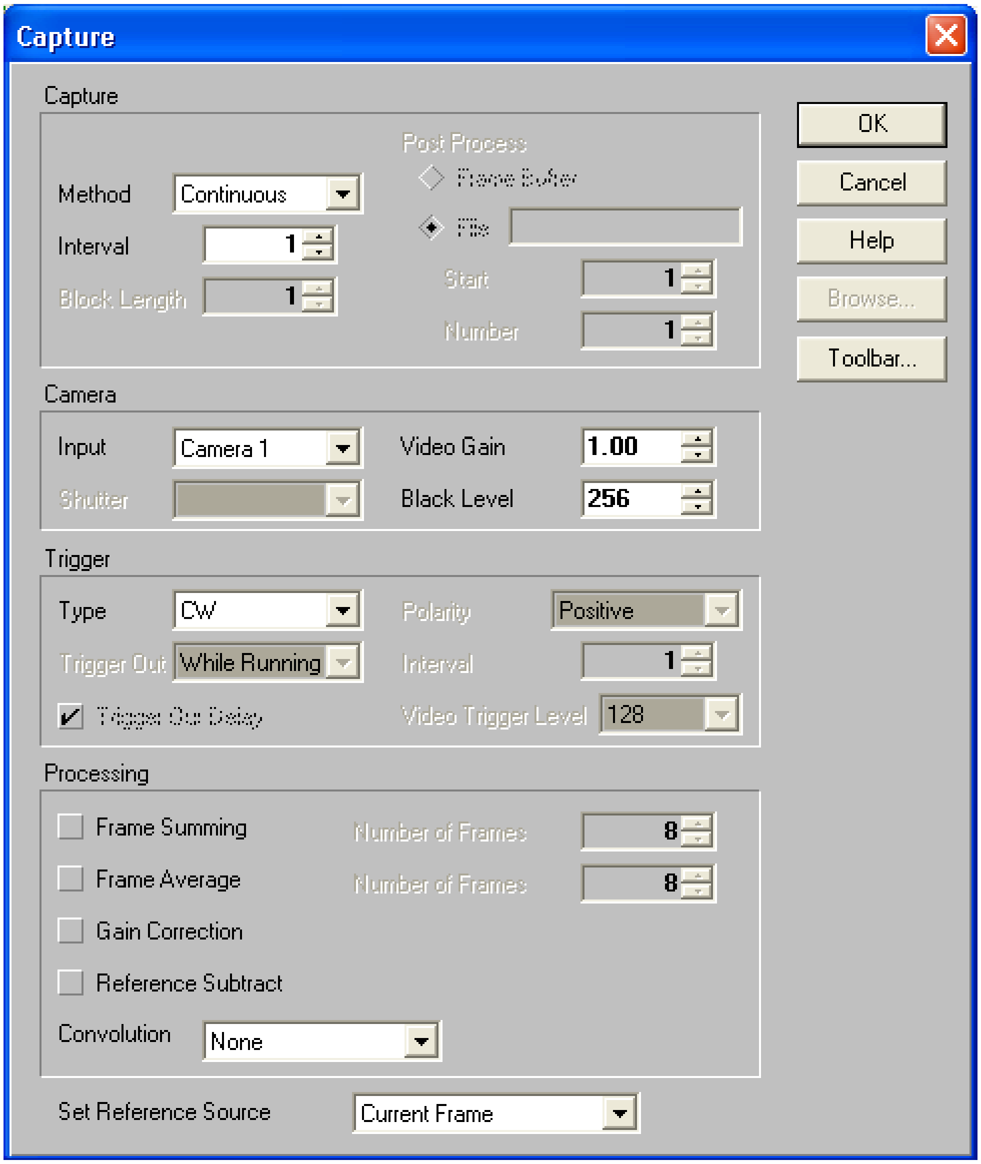


Fig. 7: Configuration of the "**Capture**" window for the CCD camera.

The CCD camera can be used to capture an image of the beam at its “moment of death”, as the Storage Ring trips. In this case the “**Capture**” window needs to be set up as shown in Fig. 8.

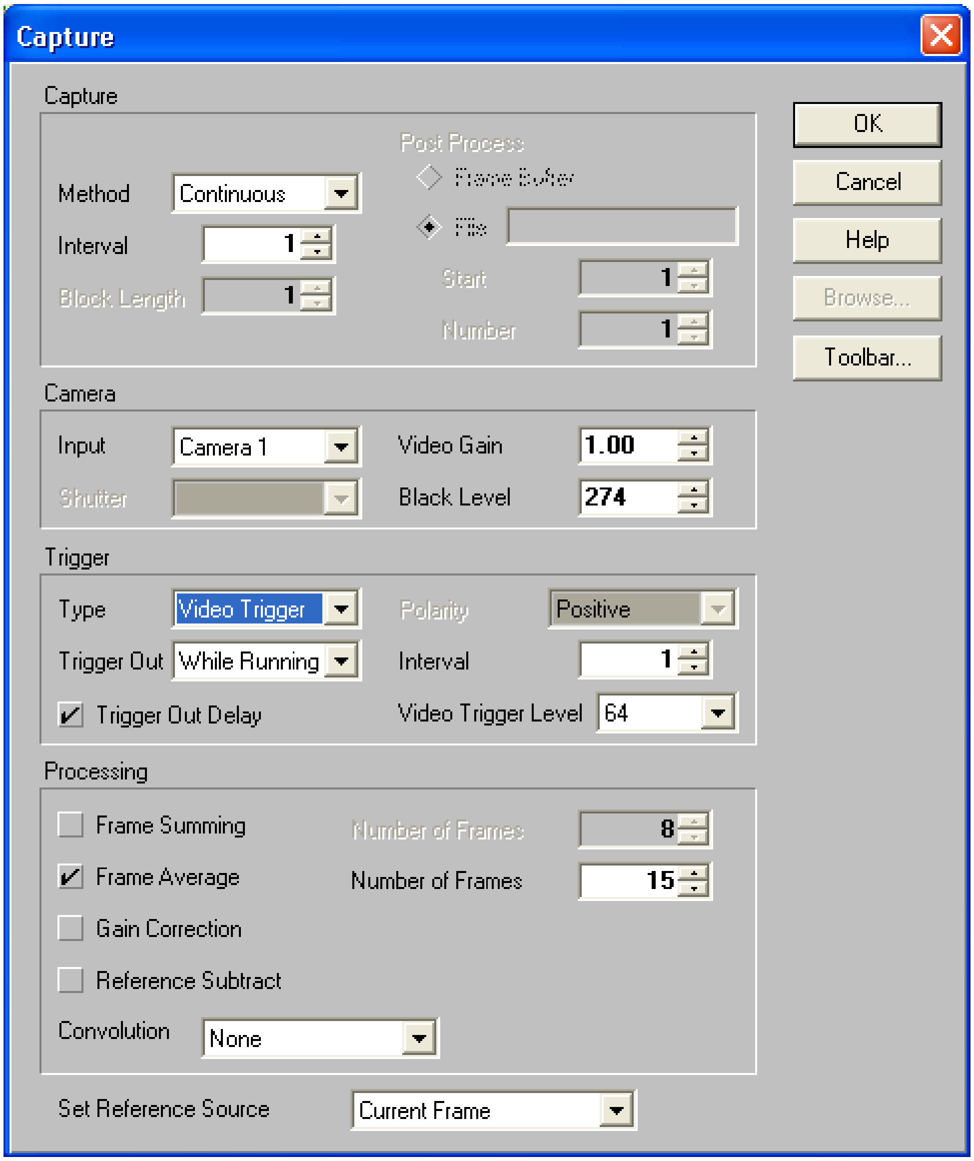


Fig. 8: Configuration of the “**Capture**” window for capturing the beam at its “moment of death” using the CCD camera.

Select **Options** → **Computations** and set the configuration shown in Fig. 9:

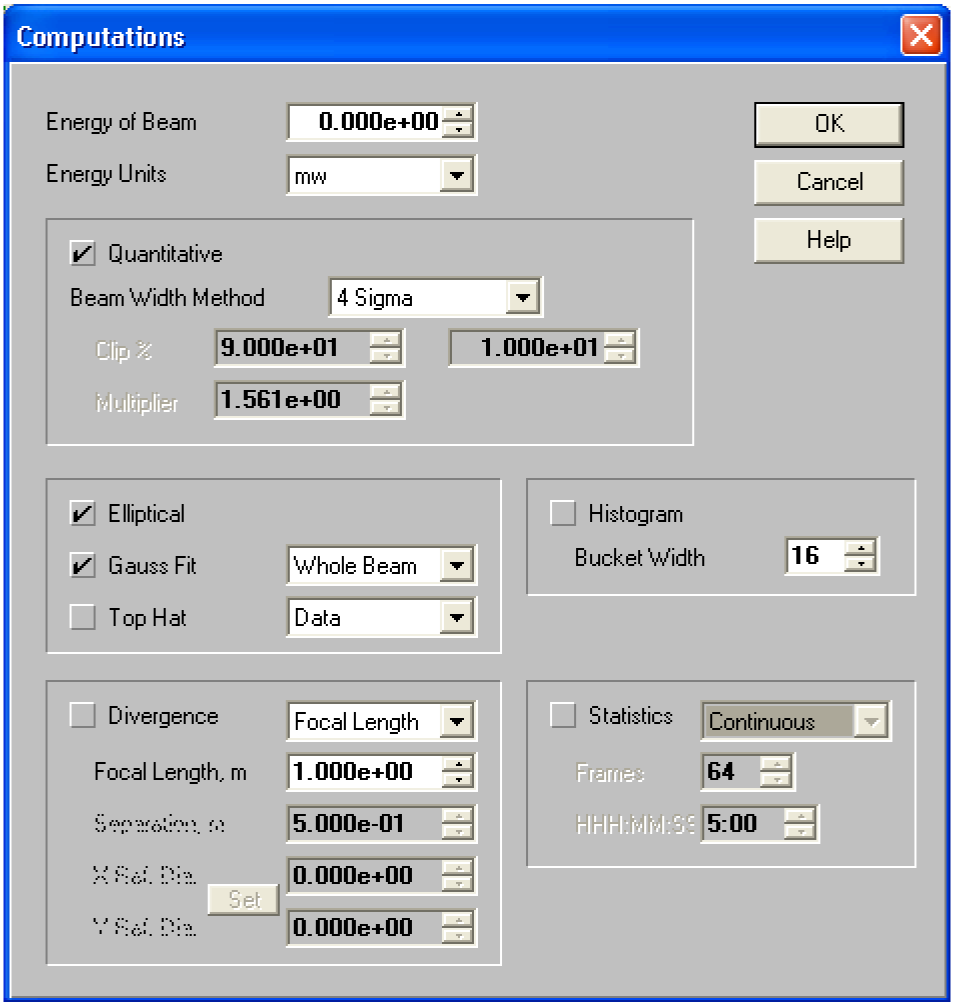


Fig. 9: Configuration of the "**Computations**" window for the CCD camera.

Select **Options** → **Beam Display** and set the configuration shown in Fig. 10. “Curser Orientation” may be set as desired.

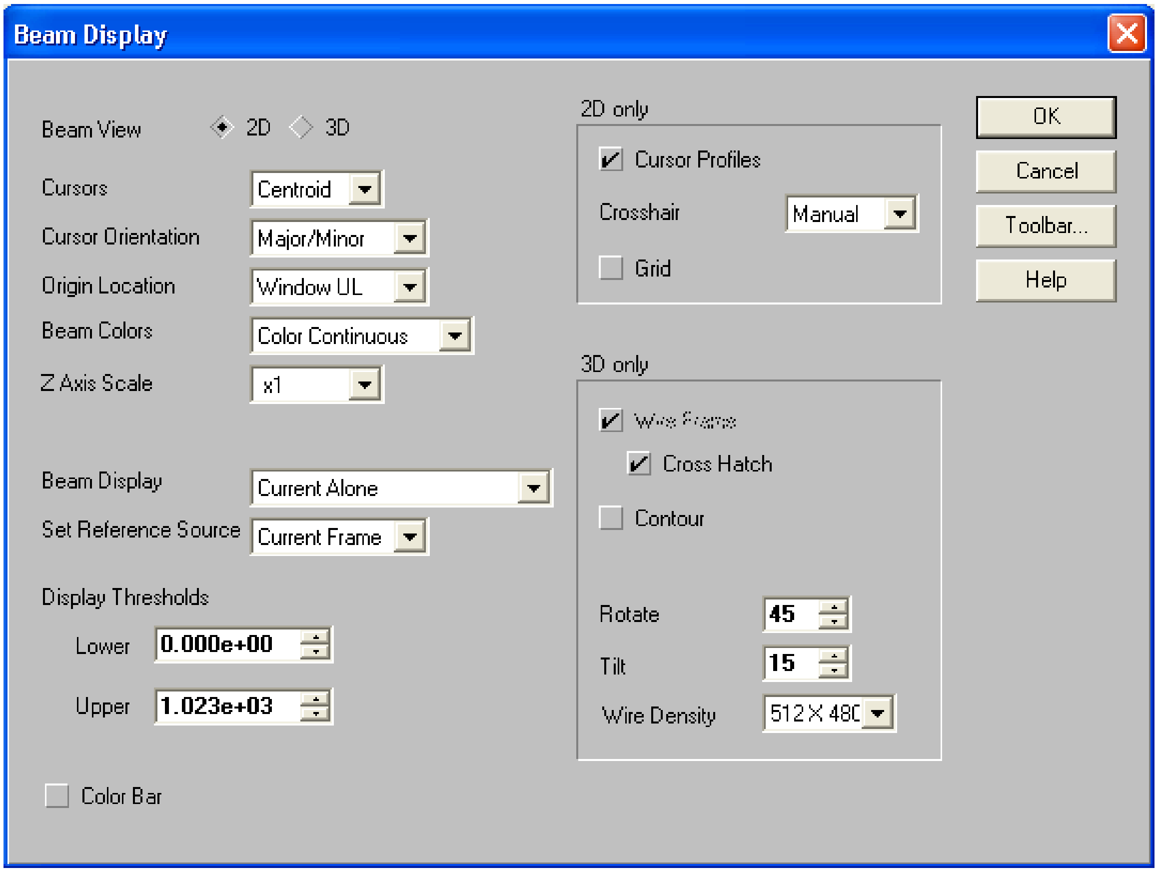
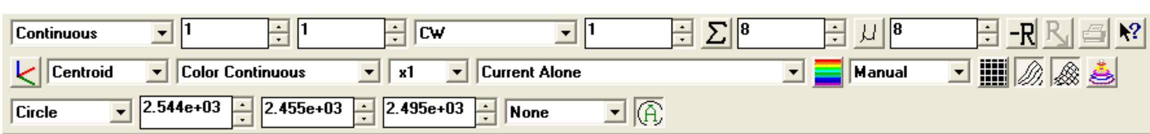


Fig. 10: Configuration of the “**Beam Display**” window for the CCD camera.

For a proper measurement of the beam size and position, it is important to subtract the background light. To start this background subtraction, close the table photon shutter (see Fig. 5) and click “**Ultracal**” in the Spiricon window. Open the table shutter again when the background measurement is finished (after a few seconds).

Spiricon has 3 toolbars:



The top toolbar is for triggering and sampling. It should be set as shown, with Σ and μ not pressed. The numbers to the right of Σ and μ are then meaningless.

The middle toolbar defines the crosshairs and should be set as shown.

The bottom toolbar describes the region of interest. The region of interest can be defined by entering coordinates or by dragging and resizing. The -button needs to be pressed to read meaningful values for the beam position or the beam size.

3.3 USING THE CCD CAMERA TO STEER THE BEAM

The following table lists the directions, in which the beam is steered, when the “XY Using Rotation” arrows are used. Normally, the “Lens” option in the Spiricon **Camera** window would not be checked. The beam direction at the table shutter is given as seen on the upstream side of the shutter, when the shutter is closed.

XY Using Rotation	TV Monitor	Spiricon	Spiricon “Lens” Option	Table Shutter	Beam Coordinates
↑	↓	↑	↓	↑	+Y
↓	↑	↓	↑	↓	-Y
→	→	→	→	←	+X
←	←	←	←	→	-X

Using Spiricon, set the centroid of the beam to X = 2500 μm and Y = 2500 μm. This is the reference beam position for all other devices on the Optical Table.

3.4 INTERPRETING THE CCD IMAGES

Fig. 11 shows how the beam at the source point is projected onto the TV monitor. See section 1.3 for the definition of the beam coordinates.

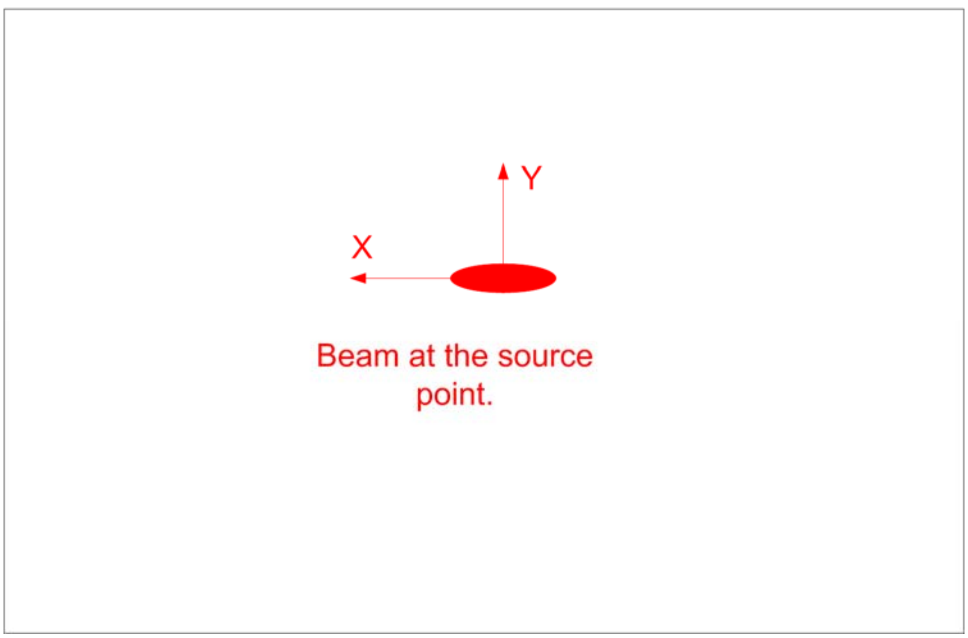


Fig. 11: The beam coordinates as they appear on the TV monitor for the CCD camera.

Fig. 12 shows how the beam at the source point is projected onto the Spiricon screen. Usually the “Lens” flag in the **Camera** window is not checked. The Spiricon coordinates are indicated for the purpose of interpreting the beam position numbers read from Spiricon.

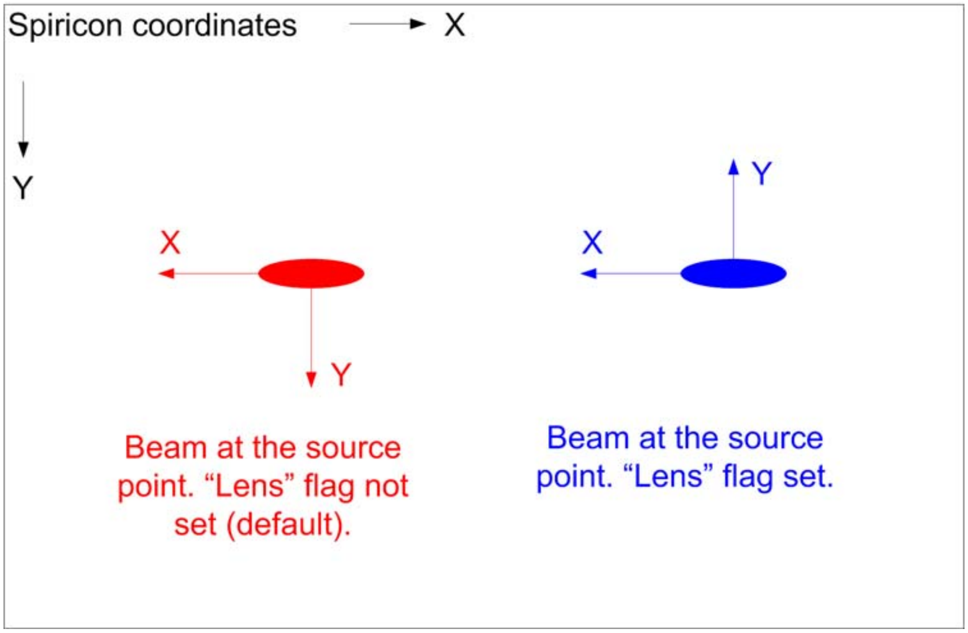


Fig. 12: The beam coordinates as they appear in the Spiricon window for the CCD camera.

3.5 HOW TO SET UP SPIRICON FOR THE ICCD CAMERA

To start up Spiricon, click on the icon 

Spiricon has a large number of features and options. Some have not been explored yet, and some are not applicable to the ICCD camera. The following configuration is suggested as a starting point. A detailed description of the Spiricon software can be found in Ref. [2].

Select **Options** → **Camera** and set the configuration shown in Fig. 13. “Frames” may be set as desired.

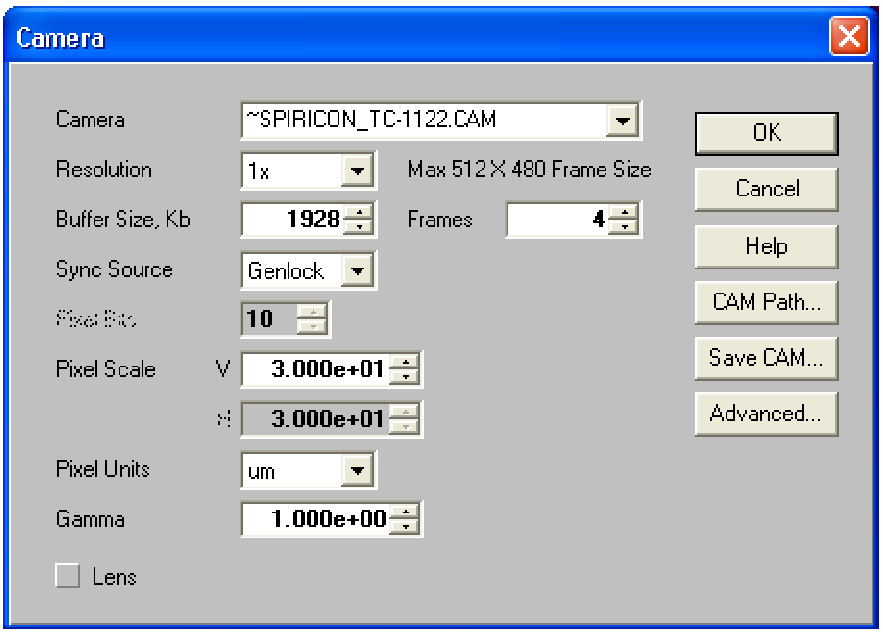


Fig. 13: Configuration of the “**Camera**” window for the ICCD camera.

Select **Options** → **Capture** and set the configuration shown in Fig. 14:

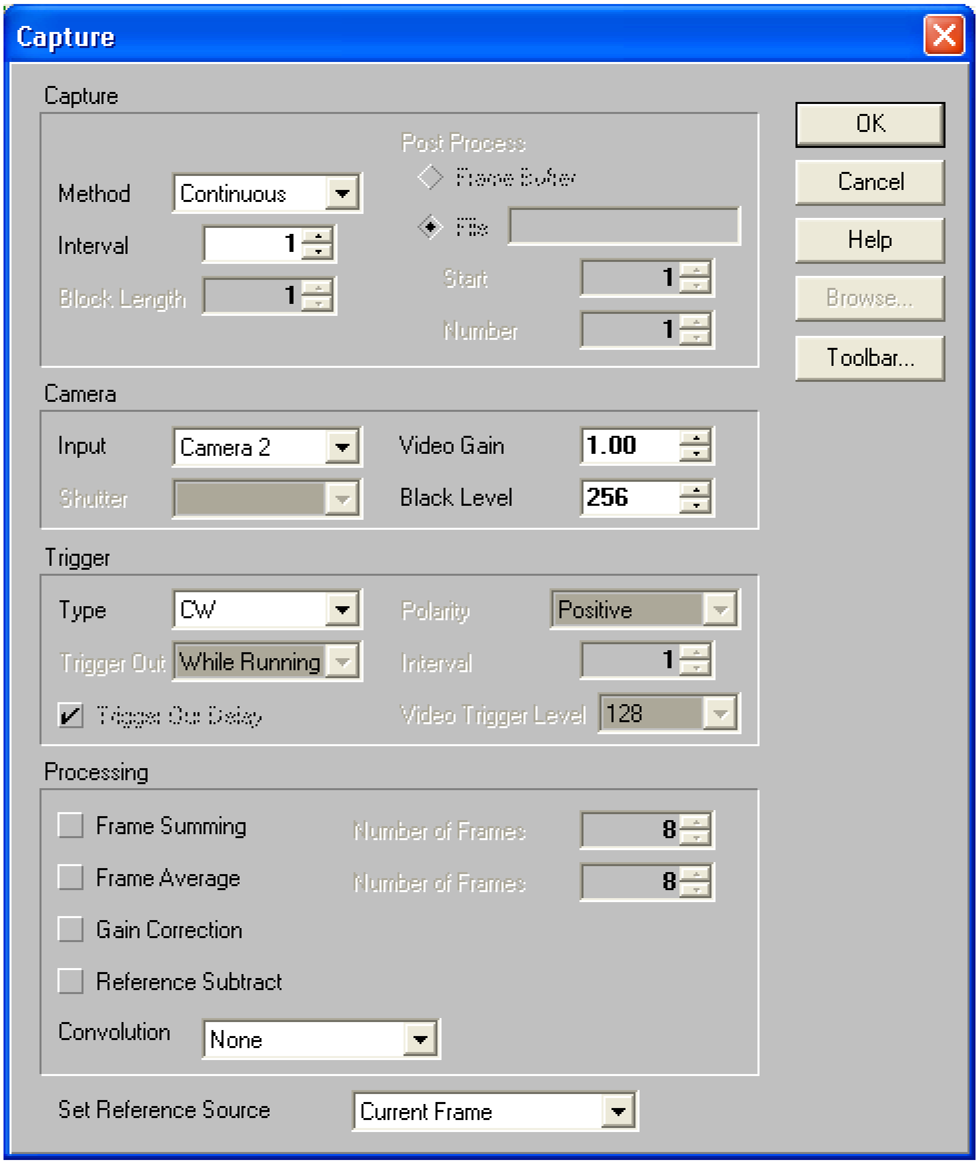


Fig. 14: Configuration of the "**Capture**" window for the ICCD camera.

Select **Options** → **Computations** and set the configuration shown in Fig. 15:

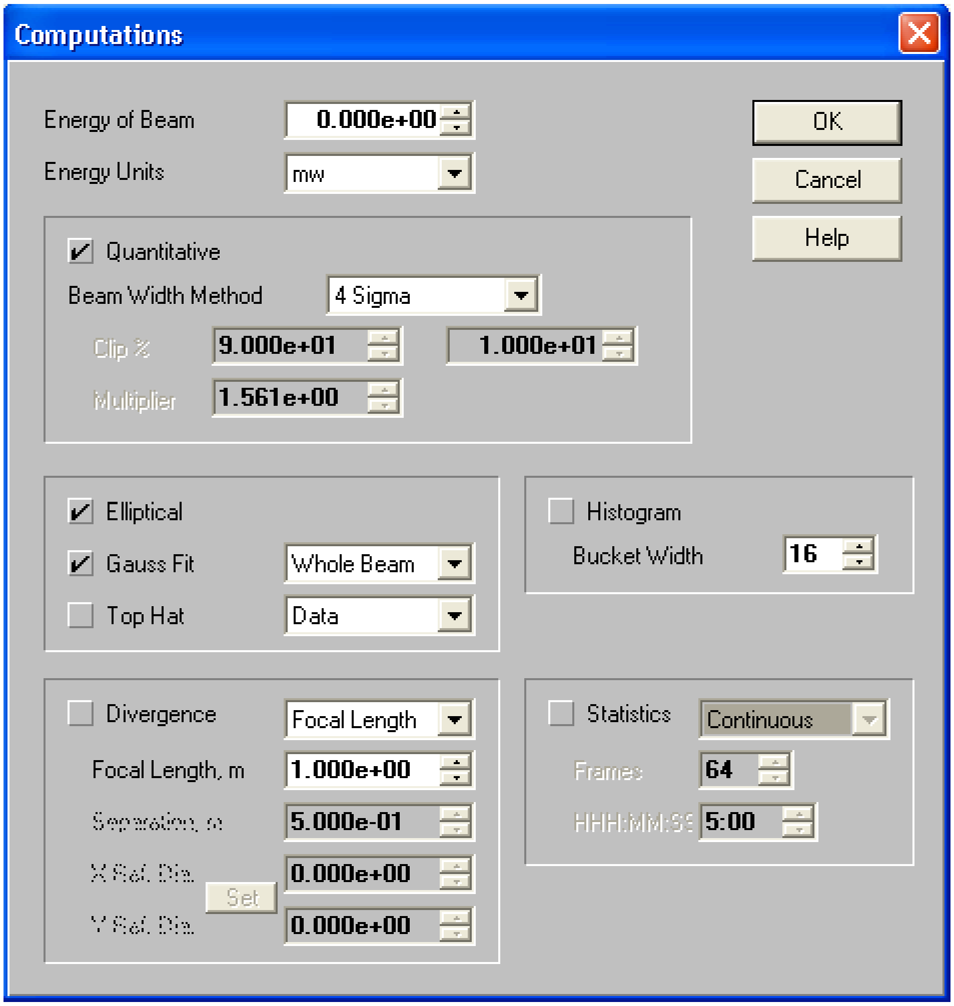


Fig. 15: Configuration of the "**Computations**" window for the ICCD camera.

Select **Options** → **Beam Display** and set the configuration shown in Fig. 16. "Curser Orientation" may be set as desired.

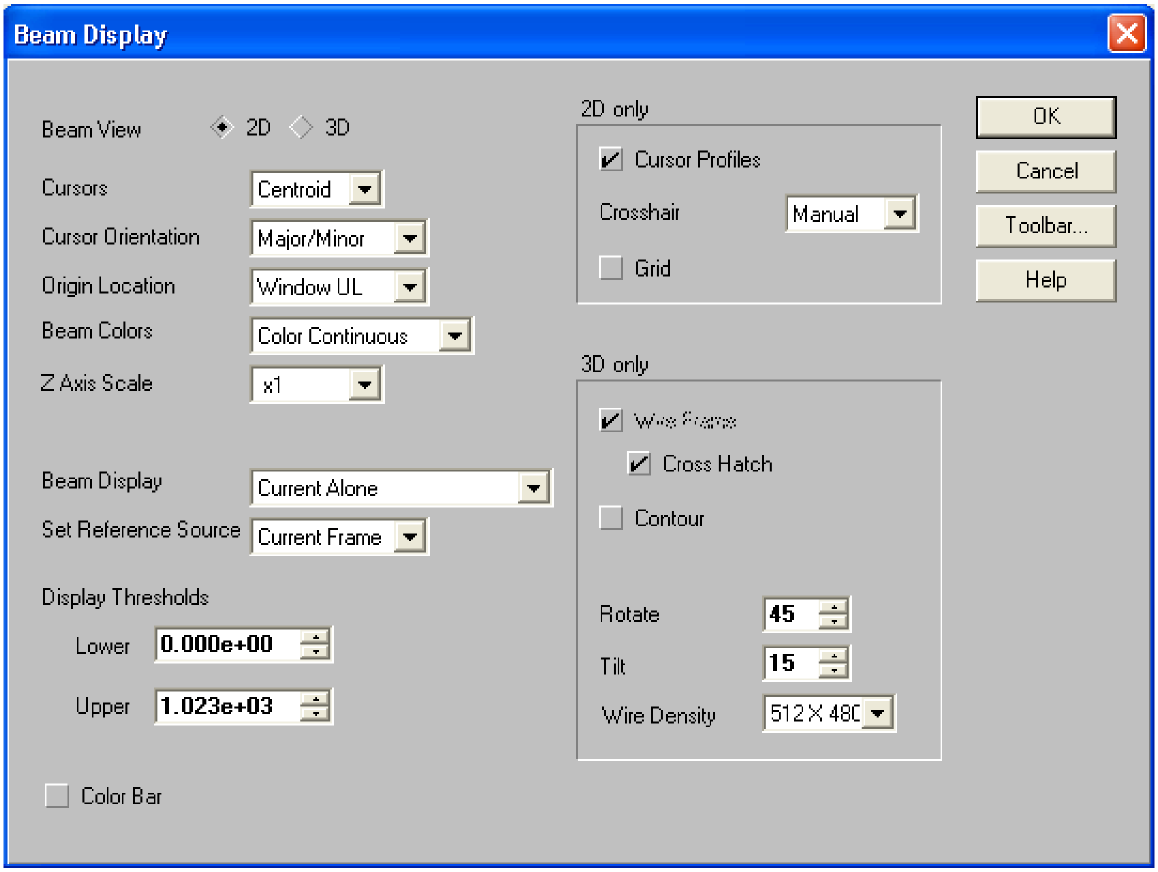
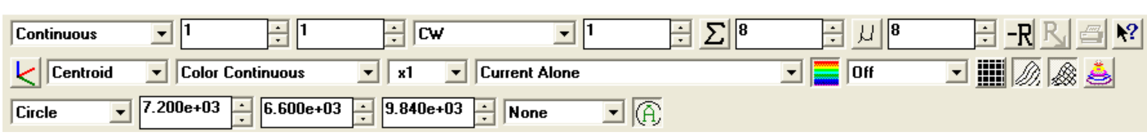


Fig. 16: Configuration of the "**Beam Display**" window for the ICCD camera.

For a proper measurement of the beam size and position, it is important to subtract the background light. To start this background subtraction, close the table photon shutter (see Fig. 5) and click "**Ultracal**" in the Spiricon window. Open the table shutter again when the background measurement is finished (after a few seconds).

Spiricon has 3 toolbars:



The top toolbar is for triggering and sampling. It should be set as shown, with Σ and μ not pressed. The numbers to the right of Σ and μ are then meaningless.

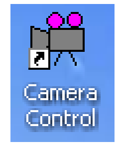
The middle toolbar defines the crosshairs and should be set as shown.

The bottom toolbar describes the region of interest. The region of interest can be defined by entering coordinates or by dragging and resizing. The -button needs to be pressed to read meaningful values for the beam position or the beam size.

3.6 CONTROLLING THE ICCD CAMERA

This section describes how to initialize the ICCD camera for its most common mode of operation in the OSR beamline. For a detailed description of all the features of the camera, refer to the Operating Manual [3].

To open the camera control window, click on the icon:



Click "Initialize", "Connect", then set the configuration shown in Fig. 17 and "Send it". Set "Delay" and "Time" according to the specific measurement you want to make.

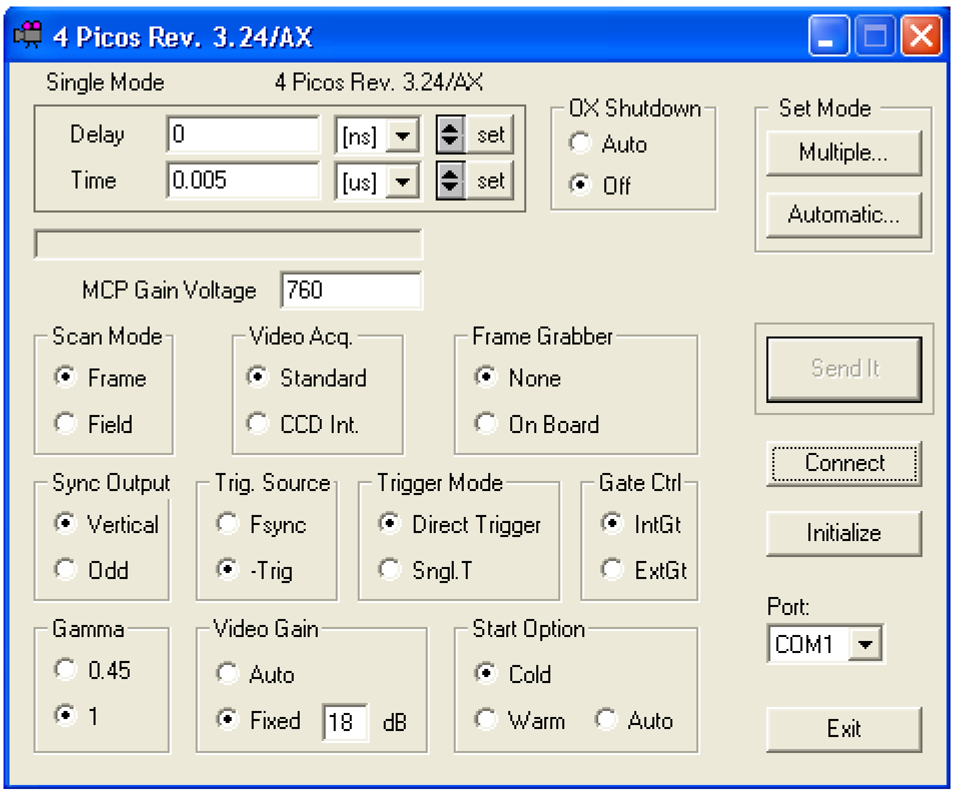


Fig. 17: Control window for the ICCD camera.

3.7 HOW TO RUN THE ICCD CAMERA

To avoid drifts of the ICCD shutter time, let the camera warm up for about 20 min before using it.

Turn off the lights above the optical table, pull the curtain, and dim the lights above the racks before removing the cap of the ICCD camera.

3.7.1 Studies of the Stored Beam

- Connect the “ICCD Trigger” cable to “Orbit” on panel P1601.1-02.
- Select the M=4 lens (see Fig. 5).
- Set the exposure time to 570 ns.
- Reduce the optical density of the neutral density filter (see Fig. 5) until an image of the beam appears.
- To find the first filled bucket, gradually reduce the exposure time to 1 ns while increasing the delay as required to keep the beam spot visible. Reduce the optical density of the filter if necessary.
- With the exposure time set to 1 ns, change the delay setting in 1 ns steps and watch the beam spot appear and disappear as you move from bunch to gap to bunch. If the beam spot does not disappear completely, change the delay setting by 0.5 ns and then repeat the 1 ns increments.
- Once a proper light/dark sequence is established, you can move from bunch to bunch by increasing/decreasing the delay by 2 ns. You can also change the number of bunches you are observing by increasing/decreasing the exposure time in 2 ns steps.

3.7.2 Studies of the Injected Beam

- Connect the “ICCD Trigger” cable to “Injection” on panel P1601.1-02.
- Select the M=1 lens (see Fig. 5).
- Inject beam with the Storage Ring RF turned off. Stored beam would blind the camera.
- Set the exposure time to 5.7 μs and the delay to 163 μs.
- In Spiricon, set the trigger type to “Video Trigger”.
- Reduce the optical density of the neutral density filter (see Fig. 5) until an image of the beam appears.
- Gradually reduce the exposure time to 570 ns. Adjust the delay if necessary. Also, reduce the optical density of the filter if necessary.
- With the exposure time set to 570 ns, change the delay setting in 570 ns steps and watch the beam spot jump as you move from turn to turn. If two locations are visible simultaneously, instead of the beam spot jumping from one location to another, two turns are observed in part. Adjust the delay.
- Reduce the delay in 570 ns steps until the beam spot disappears. Then increase the delay by 570 ns. This is turn 1.
- You can now move from turn to turn by increasing/decreasing the delay by 570 ns. You can also change the number of turns you are observing by increasing/decreasing the exposure time in 570 ns steps.

3.8 INTERPRETING THE ICCD IMAGES

Fig. 18 shows how the beam at the source point is projected onto the Spiricon screen. Usually the “Lens” flag in the **Camera** window is not checked. The Spiricon coordinates are indicated for the purpose of interpreting the beam position numbers read from Spiricon. See section 1.3 for the definition of the beam coordinates.

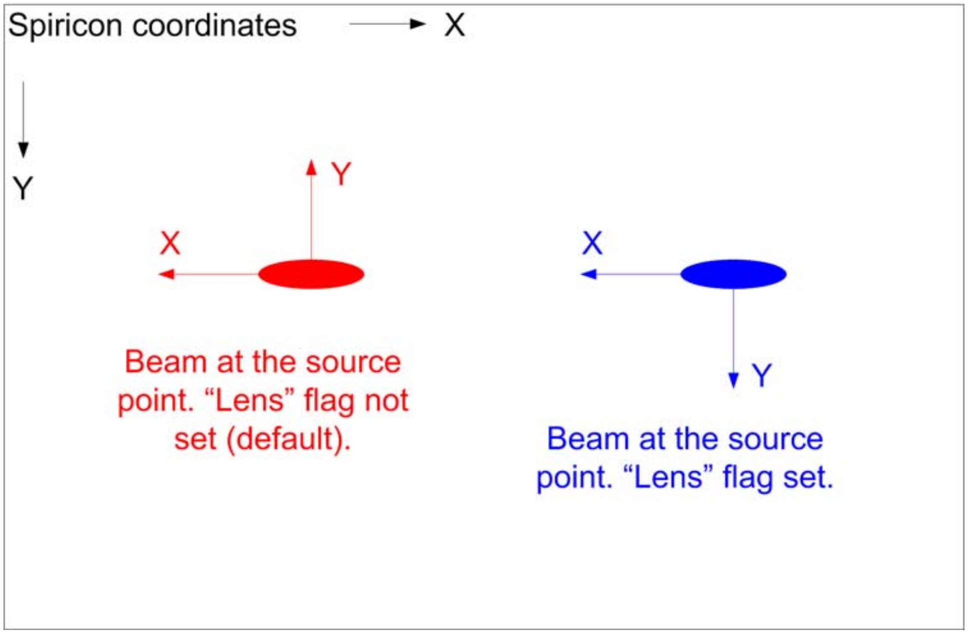


Fig. 18: The beam coordinates as they appear in the Spiricon window for the ICCD camera.

3.9 HOW TO OPERATE THE FAST STEERING MIRROR

- Slide the Fast Steering Mirror into the beam.
- Set the switches of the FSM Breakout Box to “PSD FEEDBACK”, “X CLOSED LOOP”, “Y CLOSED LOOP”.
- Power up the FSM Breakout Box and set the switches to “INTERNAL FEEDBACK”, “X CLOSED LOOP”, “Y CLOSED LOOP”.
- Turn off the light above the optical table and on the SR side of the hutch. The light on the IR side of the hutch may be left on if dimmed.
- Power up the FSM Breakout Box and the Fast Steering Mirror Controller FSM-CD 300B. It does not matter which one is powered up first.
- Power up the CCD camera of the FSM line and move the video cable from the other CCD camera. Power down the other CCD camera to avoid noise pickup that appears in the image. The CCD camera of the FSM line can now be used as described in 3.2.

Note: If the FSM breakout box is switched off or if the light to the PSD is below a certain threshold, the FSM mirror will run in internal feedback mode. If the light exceeds the threshold, the mirror will be switched to external feedback mode. Therefore the system will automatically reset itself after the beam in the storage ring trips or after the light to the PSD is blocked. The beam current, at which the threshold is crossed, depends on the slit settings in the optical chicane. If the nominal slit settings are used (see Fig. 2) the threshold is at a beam current of approximately 8 mA at 2.9 GeV.

3.10 HOW TO SET UP THE STREAK CAMERA

Although the Streak Camera can be controlled remotely from the control room, some initial checks are required in the OSR hutch before the camera can be used:

- Move the PSD out of the beam if necessary.
- Move the dove prism out if necessary (see Fig. 5).
- Set the vertical slit of the Streak Camera to 300 μm and open the horizontal aperture completely. This operation is done manually at the camera.
- Move out the neutral density filter and both lenses (see Fig. 5) and verify that the beam spot is roughly centred on the aperture of the Streak Camera.
- If you plan to use the dove prism, repeat this test with the dove prism in. Adjust the X-Y-stage of the dove prism manually if necessary.
- Put in the M=0.2 lens (see Fig. 5).
- With the dove prism out, verify that the beam is centred on the vertical slit. This is the case if roughly the same amount of light is reflected from the upper and the lower jaw.
- If you plan to use the dove prism, repeat this test with the dove prism in.
- **Put in the OD4 neutral density filter (see Fig. 5) before opening the shutter.**
- **Turn off the lights above the optical table, pull the curtain, and dim the lights above the racks before opening the shutter of the Streak Camera.**
- When the shutter is open, change to a lower optical density (see Fig. 5) as required to make an image appear.

3.11 HOW TO RUN THE STREAK CAMERA

To open the Streak Camera program, click on the icon:

The window shown in Fig. 19 will open.

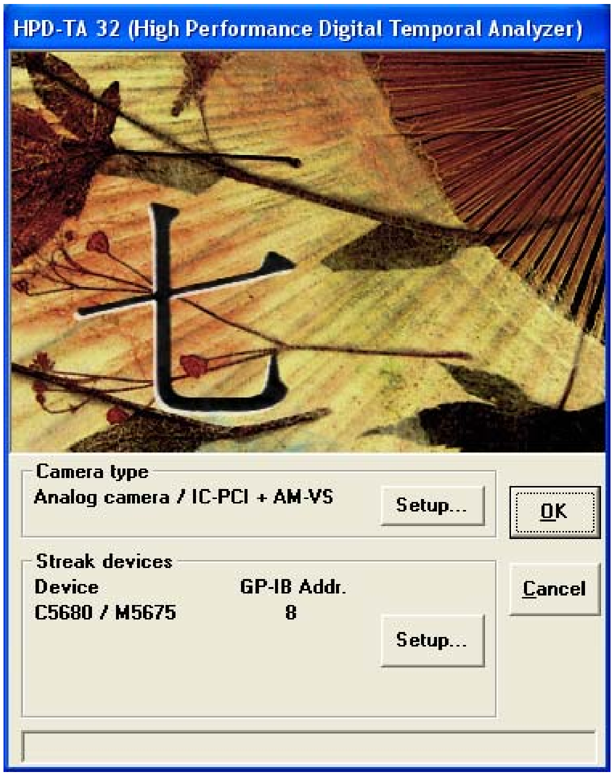


Fig. 19: Welcome window of the Streak Camera software.

It should not be necessary to click on the "**Camera type Setup**" button, as the configuration of the "**Camera and frame grabber setup**" window (Fig. 20) should be correct by default.

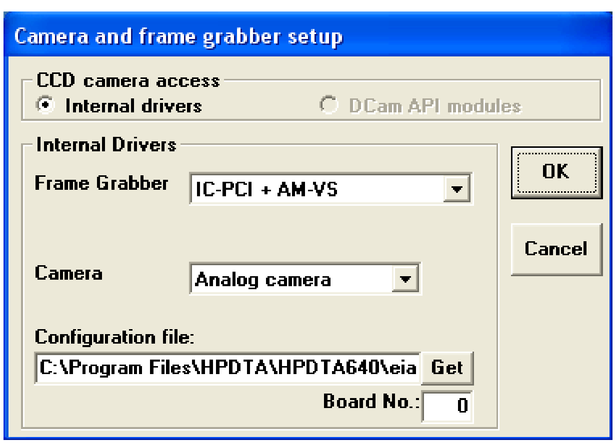


Fig. 20: "**Camera and frame grabber setup**" window. All settings should be correct by default.

3.11.1 Using the M5675 Synchroscan Sweep Unit

Make sure the M5675 Synchroscan Sweep Unit and the M5679 Dual Timebase Extender Unit are plugged into the camera.

In the "**HPD-TA 32**" window, click on the "**Streak devices Setup**" button and set the configuration shown in Fig. 21.

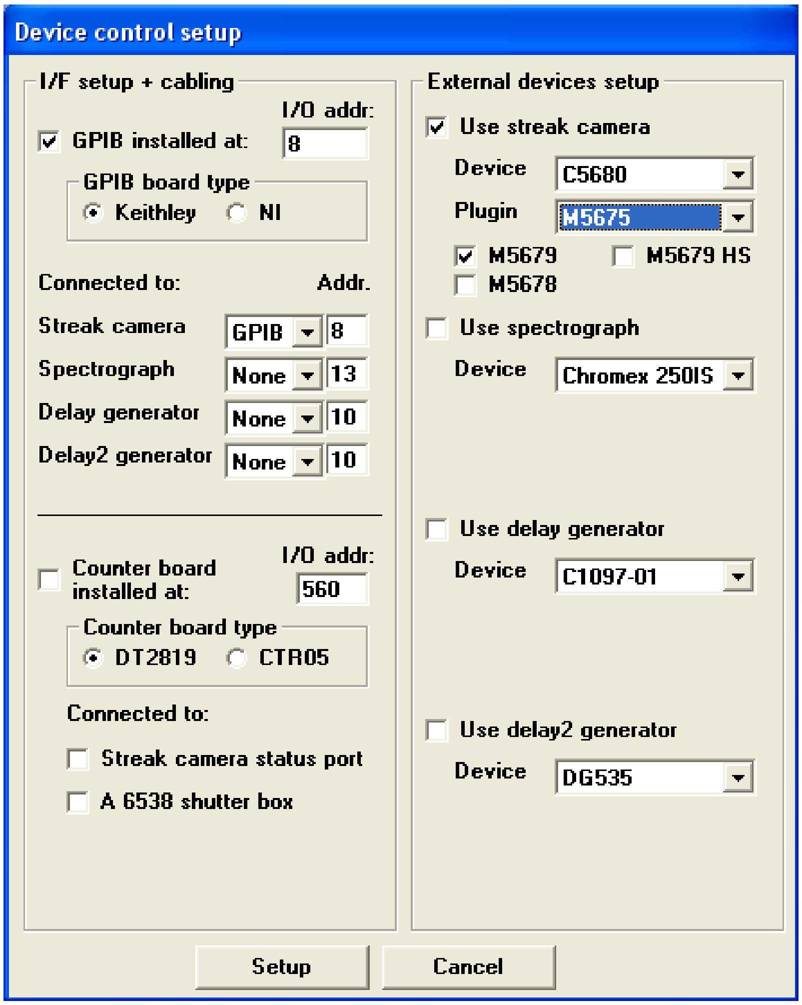


Fig. 21: The "**Device control setup**" window showing the correct settings for running the M5675 Synchroscan Sweep Unit. Except for the "**Plugin**" field (highlighted), the default configuration should be correct.

Click "**Setup**" in the "**Device control setup**" window and then click "**OK**" in the "**HPD-TA 32**" window. The 3 windows that are shown in Fig. 22 will open up.

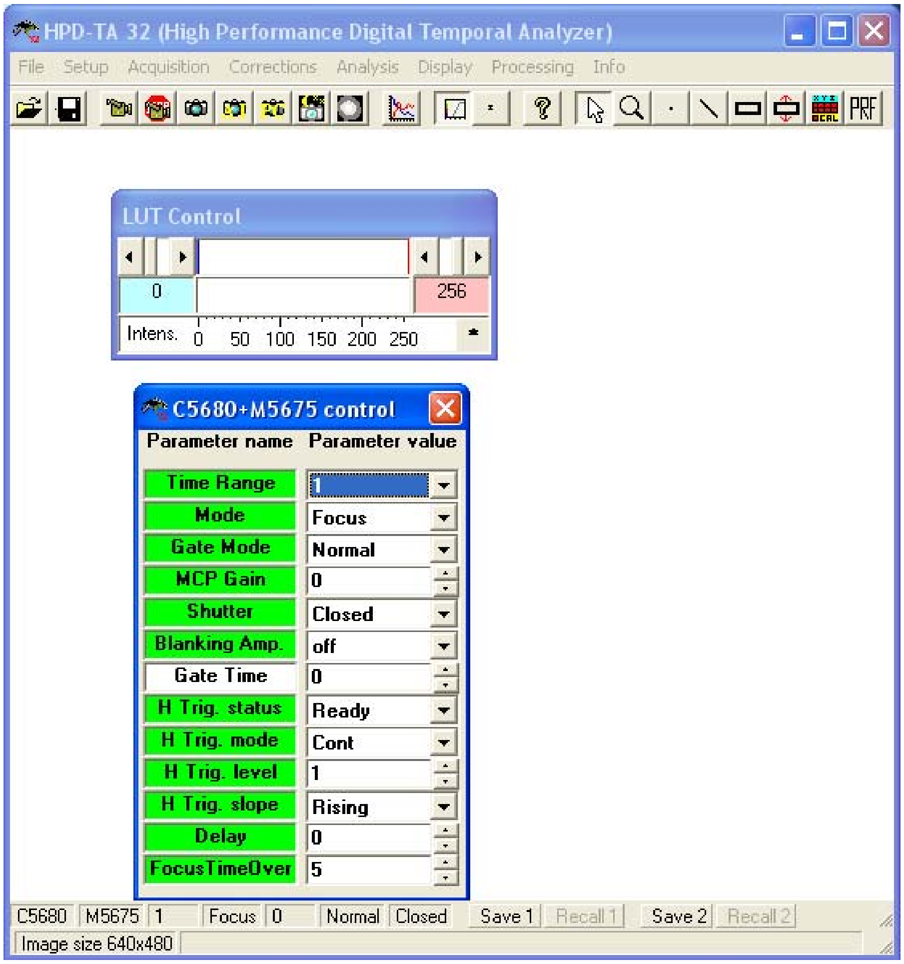


Fig. 22: After completing the device control setup, a new "**HPD-TA 32**" window opens up, which contains the "**LUT control**" window and the ""**C5680+M5675 control**" window.

In the new "**HPD-TA 32**" window, select **Acquisition** → **Live** button and set the configuration shown in Fig. 23.

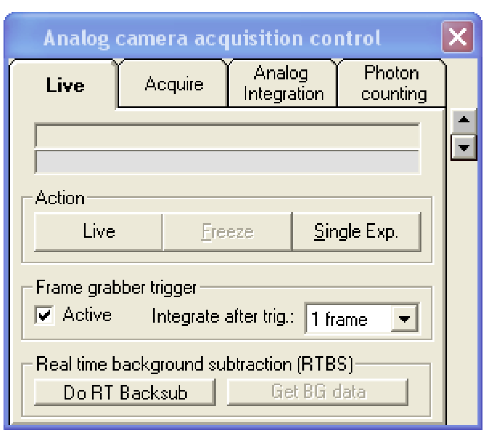


Fig. 23: The "**Analog Camera acquisition control**" window showing the most common configuration. The number of frames may need to be changed depending of the horizontal sweep (see 3.11.2).

The settings in the "**C5680+M5675 control**" window depend on the kind of measurement that is to be made. Fig. 24 gives a good start for measuring the bunch length.

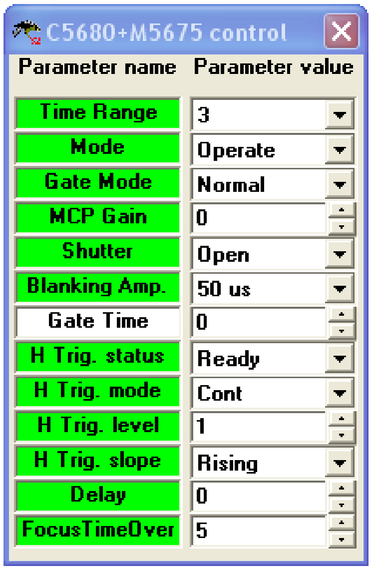


Fig. 24: The camera settings most commonly used to measure the bunch length in the Storage Ring.

The time ranges have been calibrated at CLS using a 117 ps optical delay line. These calibrations are inconsistent with the ones given by Hamamatsu.

Time Range	Calibration [ps/pixel]	Full Scale [ps] (Approx.)
1	-	150
2	0.59	300
3	1.21	600
4	2.16	1200

3.11.2 Horizontal Sweep when Using the M5675 Synchroscan Sweep Unit

The Streak Camera Synchronizer module synchronizes the horizontal trigger and the frame grabber trigger with the CCD frames of the Streak Camera. This scheme only works as long as the internal pre-scaling of the trigger input of the M5679 Dual Timebase Extender Unit is not activated. The Streak Camera Synchronizer module has a built-in pre-scaler, the ratio of which is selected by the "**Frame Rate Divider**" knob. If the knob is set to "**10**", the camera will work at all horizontal sweep speeds. However, for most of the sweep speed settings, the frame capture rate will be slower than necessary. The following table shows the minimum frame rate divider settings for the various horizontal sweep speeds when using the **M5675 Synchroscan Sweep Unit**:

Horizontal Sweep	# of Frames	Frame Rate Divider	Frame Rate
100 ms	8	10	2.72 Hz
50 ms	8	10	2.72 Hz
50 ms	4	5	5.00 Hz
20 ms	4	5	5.00 Hz
20 ms	2	3	7.49 Hz
10 ms	2	3	7.49 Hz
10 ms	1	3	7.49 Hz
≤ 5 ms	2	3	7.49 Hz
≤ 5 ms	1	2	9.99 Hz

The number of frames in the table is the minimum that must be selected in order for the image to cover the entire screen. Greater numbers may be selected as shown in some of the entries, but the maximum allowable frame rate will be affected. To change the number of frames, click “**Live**” in the “**Analog camera acquisition control**” window (See 3.11.1), click “**Freeze**” if the acquisition is running, and select the number of frames in the “**Integrate after trig.:**” field.

Note: If the frame rate divider is set too low, the internal pre-scaling of the camera trigger is automatically activated. The camera may work for most of the time, since failures tend to be sporadic. However, the image may flicker or may suddenly disappear for no obvious reason.

In Fig. 25 every third bunch is visible. The Storage Ring was running about 210 bunches, but obviously the fill was not quite even.

Fig. 26 shows the beam in the Storage Ring on a turn-by-turn basis. Bunches within one turn are overlapping so that individual bunches are not resolved.

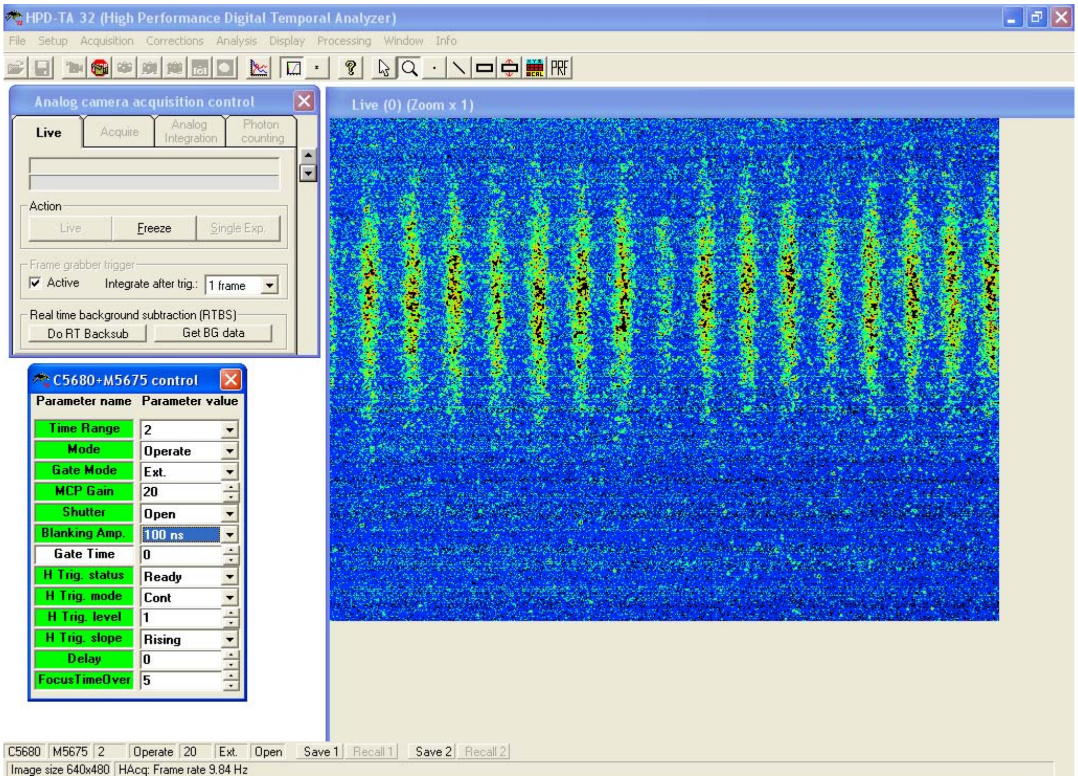


Fig. 25: The Streak Camera running in synchroscan mode. Each vertical line is one bunch in the Storage Ring, but only every third bunch is shown.

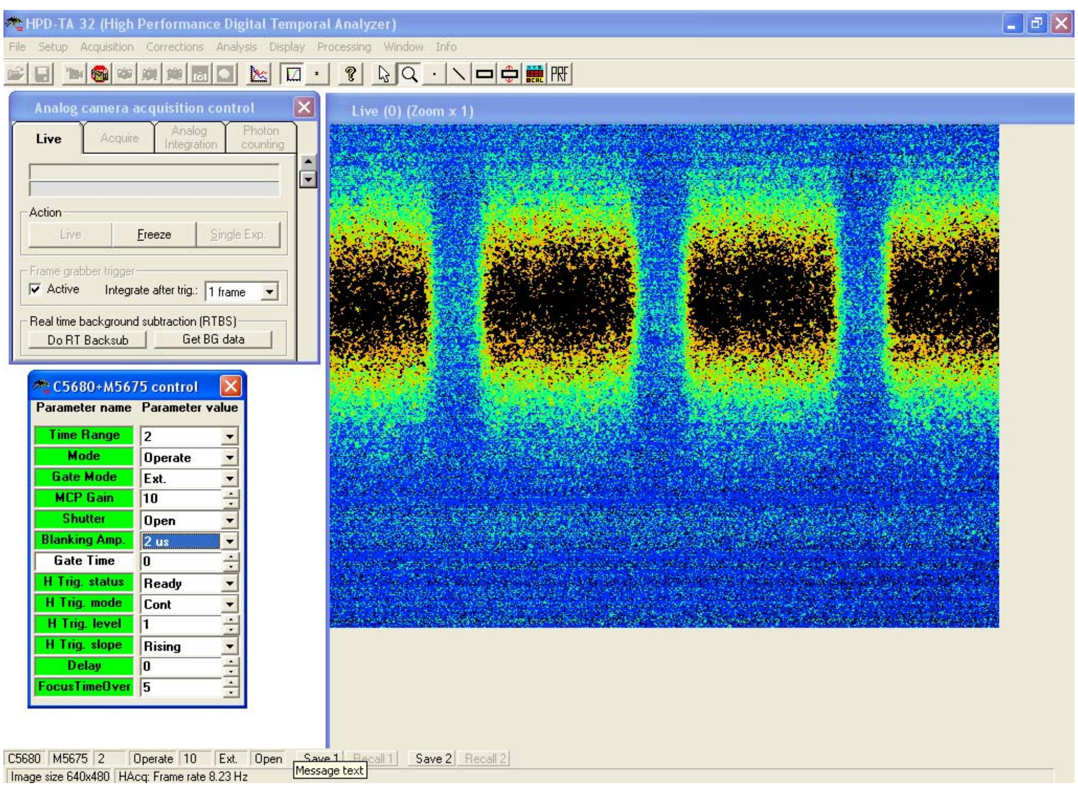


Fig. 26: The Streak Camera running in synchroscan mode. Each spot corresponds to 1 turn in the Storage Ring. Bunches within a turn are overlapping so that individual bunches are not resolved.

3.11.3 Using the M5677 Slow Speed Sweep Unit

Make sure the M5677 Slow Speed Sweep Unit and the M5679 Dual Timebase Extender Unit are plugged into the camera.

In the “**HPD-TA 32**” window, click on the “**Streak devices Setup**” button and set the configuration shown in Fig. 27.

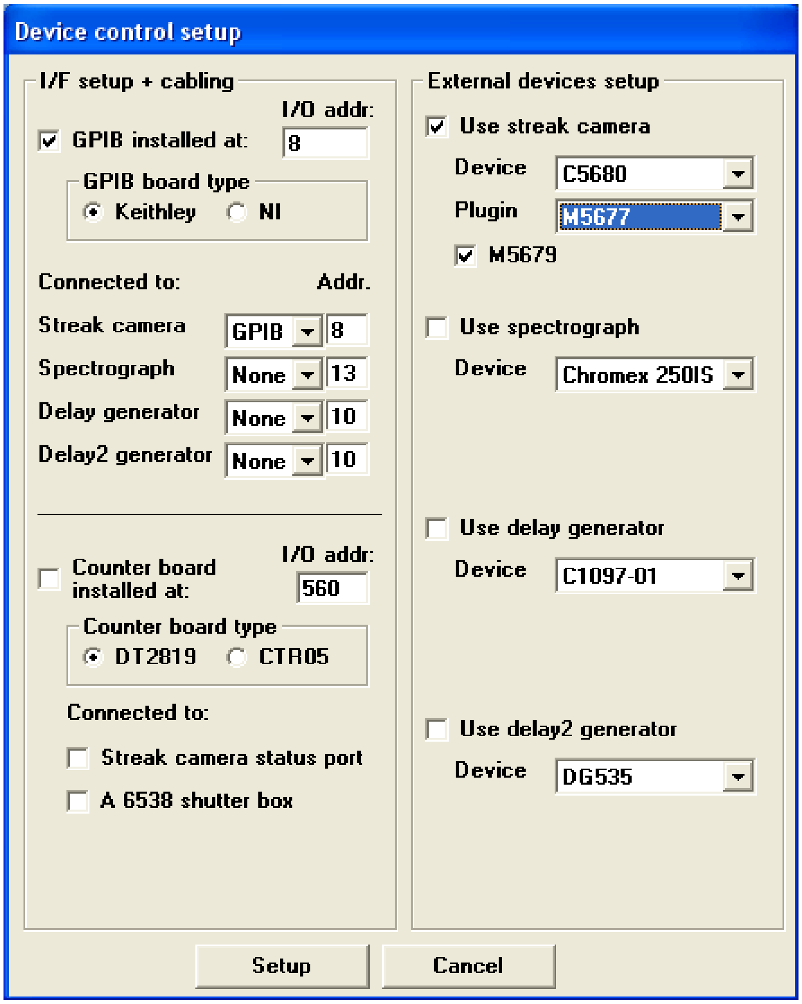


Fig. 27: The “**Device control setup**” window showing the correct settings for running the M5677 Slow Speed Sweep Unit. Except for the “**Plugin**” field (highlighted), the default configuration should be correct.

Click “**Setup**” in the “**Device control setup**” window and then click “**OK**” in the “**HPD-TA 32**” window. Follow the instructions in 3.11.1 on starting the acquisition.

The setting in Fig. 28 is a good start for displaying bunch trains.

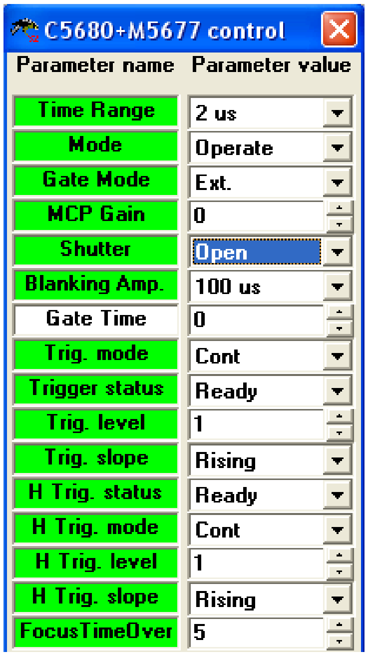


Fig. 28: A camera setting commonly used to display bunch trains in the Storage Ring.

3.11.4 Horizontal Sweep when Using the M5677 Slow Speed Sweep Unit

The Streak Camera Synchronizer module synchronizes the horizontal trigger and the frame grabber trigger with the CCD frames of the Streak Camera. This scheme only works as long as the internal pre-scaling of the trigger input of the M5679 Dual Timebase Extender Unit is not activated. The Streak Camera Synchronizer module has a built-in pre-scaler, the ratio of which is selected by the "**Frame Rate Divider**" knob. If the knob is set to "**10**", the camera will work at all horizontal sweep speeds. However, for most of the sweep speed settings, the frame capture rate will be slower than necessary. The following table shows the minimum frame rate divider settings for the various horizontal sweep speeds when using the **M5677 Slow Speed Sweep Unit**:

Horizontal Sweep	# of Frames	Frame Rate Divider	Frame Rate
50 ms	8	10	2.72 Hz
50 ms	4	8	3.33 Hz
25 ms	8	10	2.72 Hz
25 ms	4	5	5.00 Hz
10 ms	4	5	5.00 Hz
10 ms	2	3	7.49 Hz
5 ms	2	3	7.49 Hz
5 ms	1	3	7.49 Hz
≤ 2.5 ms	1	2	9.99 Hz

The number of frames in the table is the minimum that must be selected in order for the image to cover the entire screen. Greater numbers may be selected as shown in some of the entries, but the maximum allowable frame rate will be affected. To change the number of frames, click “**Live**” in the “**Analog camera acquisition control**” window (See 3.11.1), click “**Freeze**” if the acquisition is running, and select the number of frames in the “**Integrate after trig.:**” field.

Note: If the frame rate divider is set too low, the internal pre-scaling of the camera trigger is automatically activated. The camera may work for most of the time, since failures tend to be sporadic. However, the image may flicker or may suddenly disappear for no obvious reason.

3.11.5 Vertical Sweep when Using the M5677 Slow Speed Sweep Unit

The maximum vertical trigger rate, that the camera can accept, depends on the vertical sweep speed. If the vertical trigger rate exceeds this maximum, the camera automatically pre-scales the trigger input. In this case, however, synchronization between the vertical and the horizontal trigger is lost, causing the image to walk or jump horizontally. To avoid this problem, an external pre-scaler is used to divide the Storage Ring synchronous trigger (1.754 MHz) down to an acceptable rate. The minimum settings of this pre-scaler are shown for the various vertical sweep speeds. However, these settings are somewhat temperature dependent and may therefore be marginal. The pre-scaler may be set to a higher number than the recommended setting. However, the higher the setting, the fewer vertical sweeps (and possibly none) are drawn in the image.

Vertical Sweep	Minimum Setting	Recommended Setting	Recommended Sweep Frequency
100 ns	10	11	438596.5 Hz
200 ns	10	11	438596.5 Hz
500 ns	101	111	219298.2 Hz
1 µs	111	1111	109649.1 Hz
2 µs	11011	11111	54824.6 Hz
5 µs	101010	111111	27412.3 Hz
10 µs	1000100	1111111	13706.1 Hz
20 µs	1111001	11111111	6853.1 Hz
50 µs	100011001	111111111	3426.5 Hz
100 µs	1000100010	1111111111	1713.3 Hz
200 µs	10000110000	11111111111	856.6 Hz
500 µs	101001110000	111111111111	428.3 Hz
1 ms	1010100001000	1111111111111	214.2 Hz

Fig. 29 shows a number of bunch trains in the Storage Ring. Individual bunches are not resolved. The three bunch trains that are drawn by every vertical sweep are consecutive turns in the machine. The time between vertical sweeps depends on the setting of the pre-scaler.

In Fig. 30 the individual bunches are visible.

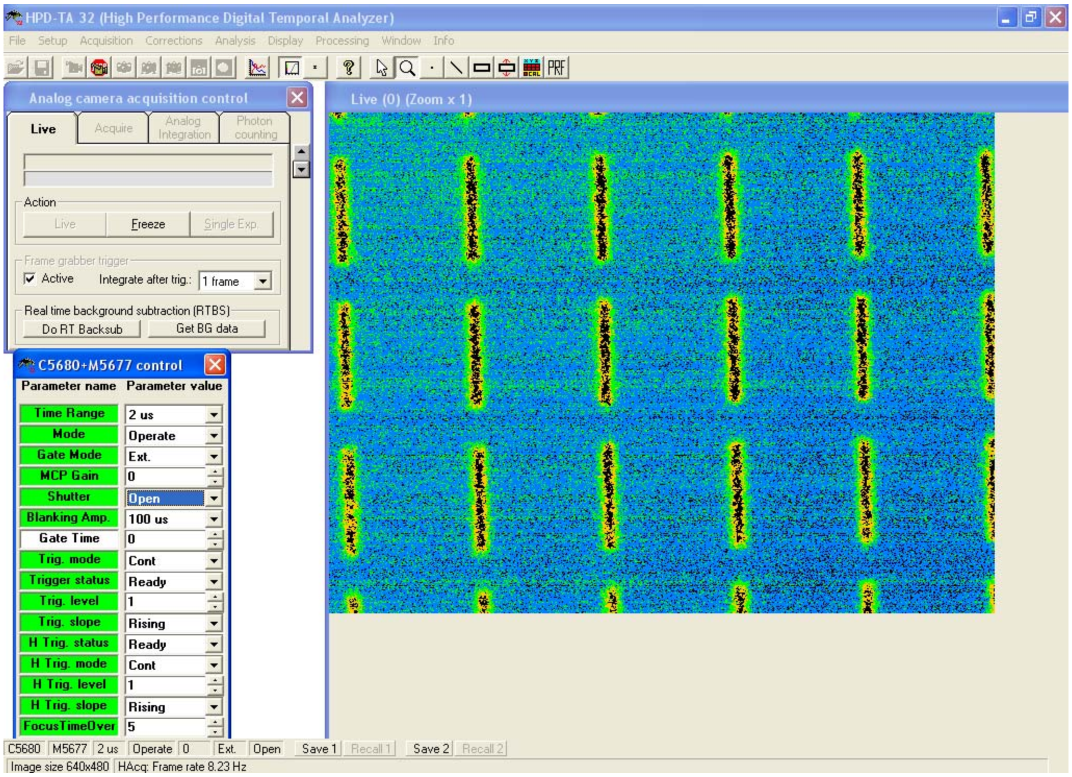


Fig. 29: The Streak Camera running in slow sweep mode. Individual bunches are not resolved. The three bunch trains in every vertical sweep are consecutive turns in the Storage Ring.

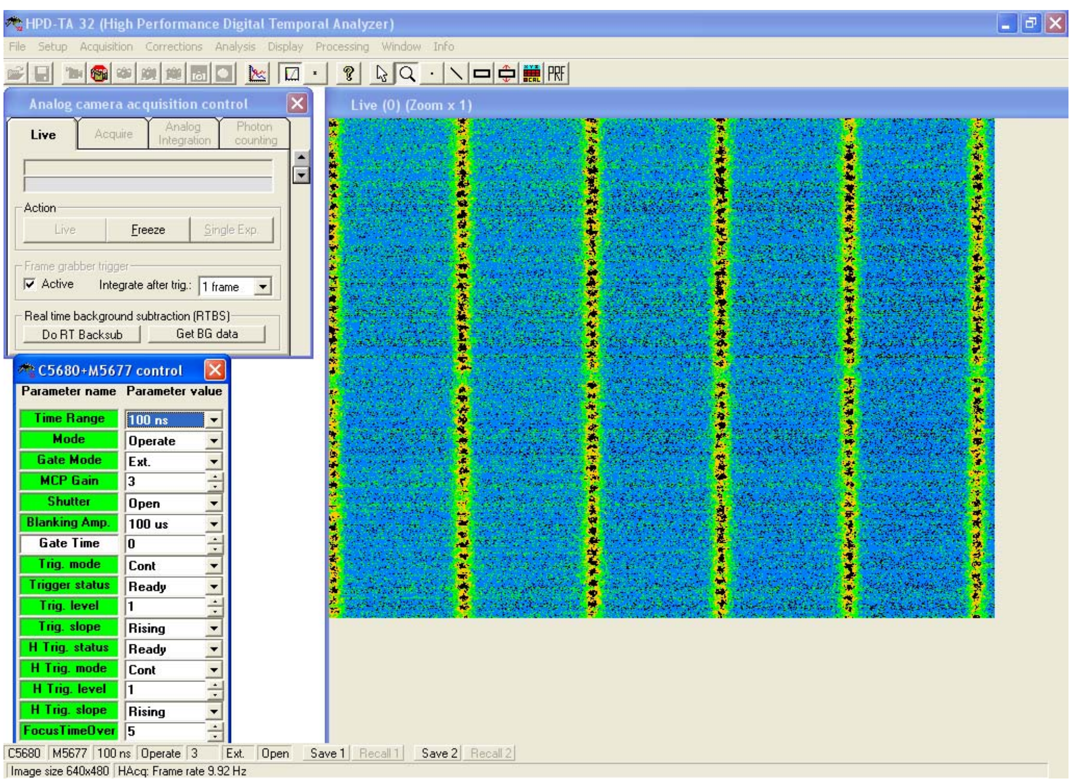


Fig. 30: The Streak Camera running in slow sweep mode. Individual bunches are resolved.

3.11.6 Analog Integration

To initialize analog integration, select "**Analog Integration**" in the "**Analog camera acquisition control**" window and set the configuration shown in Fig. 31. Adjust the "**# of exposures:**" field as required for the given amount of light. Click "**Integrate**" to start.

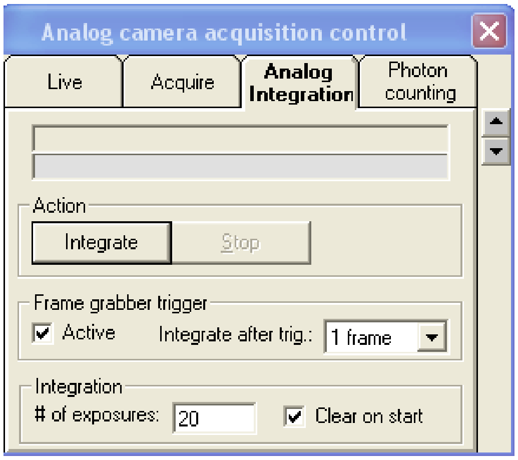


Fig. 31: The "**Analog Integration**" settings in the "**Analog camera acquisition control**" window.

3.11.7 Region of Interest

To define a region of interest, click the button and select a box. Then click the button to enable histogramming of the light intensity in this region of interest as shown in Fig. 32.

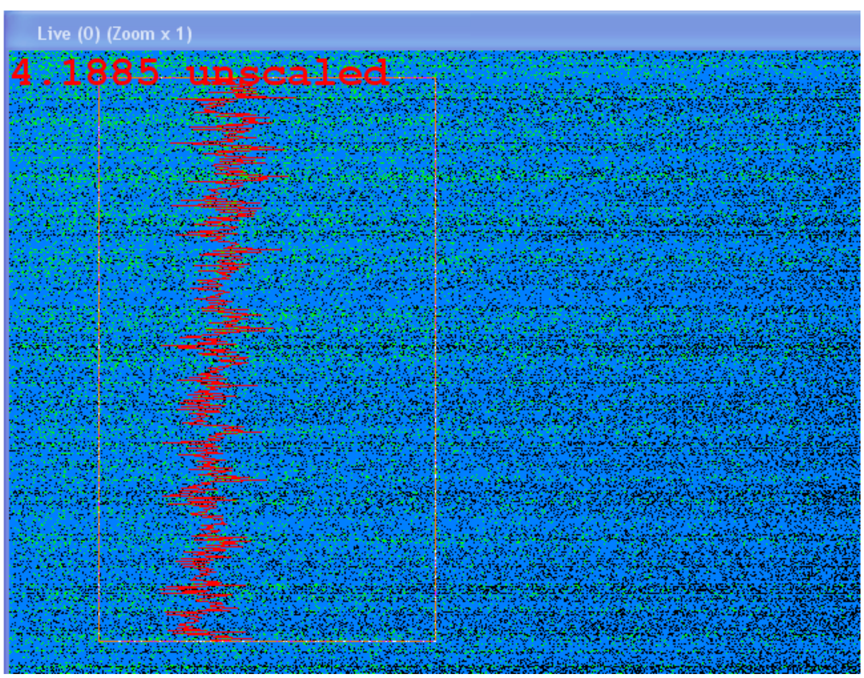


Fig. 32: Histogram of the light intensity in the region of interest as defined by the red box.

In order to view or change the display parameters, select **Analysis** → **Profile**. The "**Profile Analysis**", "**Profile Control**", and "**Profile Display**" windows will open (see Fig. 33).

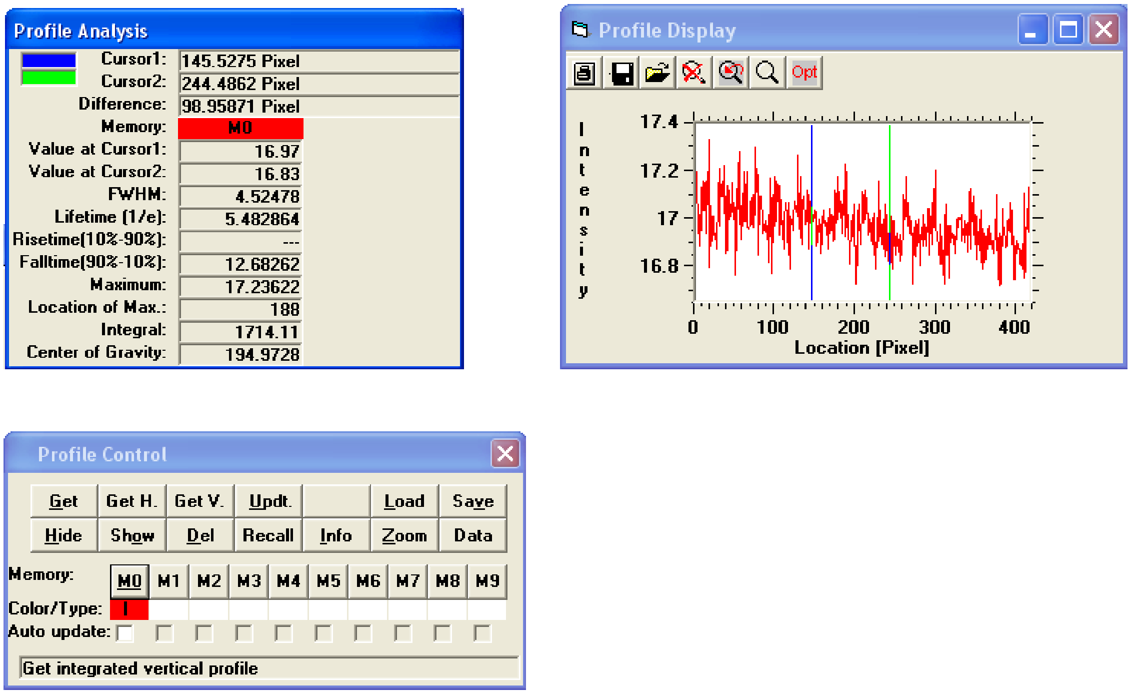


Fig. 33: The "**Profile Analysis**", "**Profile Control**", and "**Profile Display**" windows.

4.0 REFERENCES

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[2] SPIRICON Laser Beam Diagnostics Operator’s Manual, Spiricon Inc., Logan, Utah, USA.

[3] Operating Manual for the intensified CCD video camera systems, Stanford Computer Optics Inc. 2002.

[4] High Performance Digital Temporal Analyzer, Version 6.4, HPD-TA User Manual, Hamamatsu Photonics Deutschland GmbH, 2002