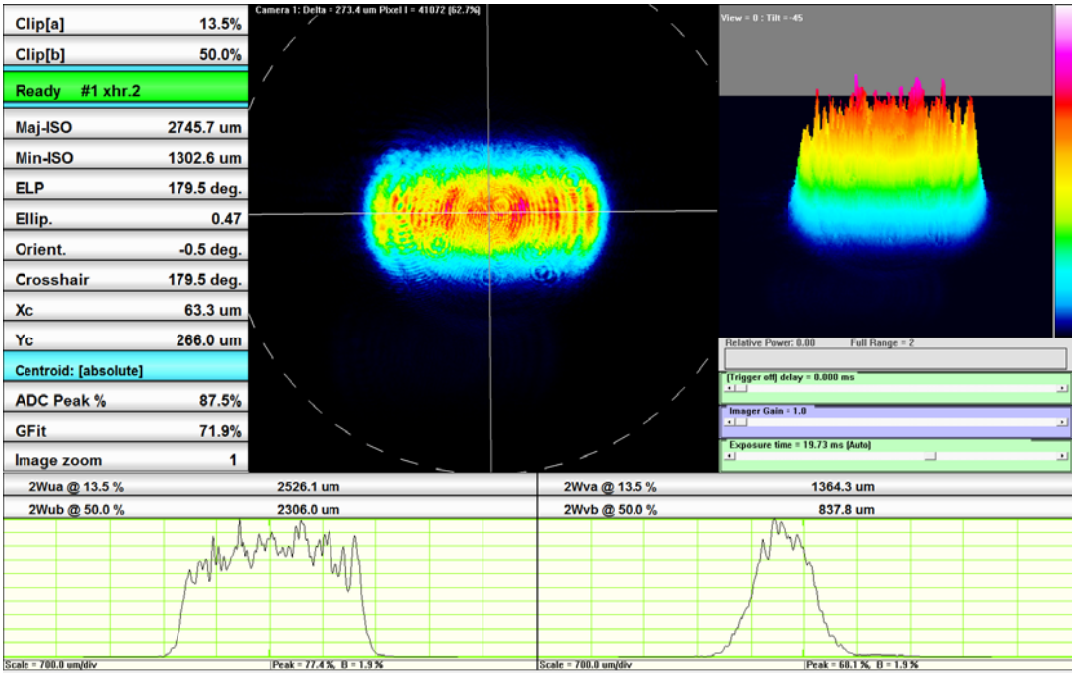
WinCamD Baseline Setting – DataRay Confidential

Applies to: All current WinCamD series products. Software version 7.1H10 & higher for the current iteration.



Summary: This Technical Note describes the four baseline setting modes of DataRay WinCamD series software.

Note: Competitor assertions that theirs is the only beam profiler algorithm that sets the baseline in the center of the noise and does not truncate electronic noise below zero are simply incorrect.

- **Auto-baseline**: This default real-time mode, present in various iterations since the 90's, handles most beams. On the laser pointer in the example above, the un-averaged diameter readings in a typical lab environment are stable to ≈ 0.05% rms, ≈ 0.25% pk-to-pk, a direct consequence of the auto-baseline algorithm stability.
- **Baseline Lock**: Use with beams which overfill the sensor. Locks auto-baseline at its current value.
- **Background Subtraction**: Use if there is substantial optical background to deal with.
- **HyperCal™**: Real-time subtraction of electronic shading. Important in *Use equivalent slit* mode & with comet tailing.

Real-time, frame-by-frame, baseline setting & the background subtraction option have been features of DataRay software since the nineties - what we simply call 'doing it properly'. Auto-baseline has recently been further refined. HyperCal is a new feature.

Technical Background: *For a perfect Gaussian, the $1/e^2$ beam diameter error is nearly twice the baseline setting error.*

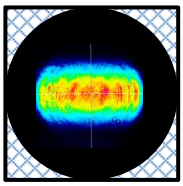
e.g. a 0.1% error in the baseline setting results in a 0.18% error in the measured beam diameter.

There are no perfect sensors, and no perfect electronics. Real world cameras must set a baseline for analysis that corresponds to zero irradiance. Negative irradiance does not exist, but electronic noise and offsets at the input to the ADC (**A**nalog to **D**igital **C**onverter) can drive signal above and below the zero irradiance equivalent input voltage. [ADC's are unipolar so zero irradiance is always a non-zero voltage at the ADC input, servoed to around 2% of the ADC range in DataRay systems with ADC's external to the sensor.] Because background & noise can vary over time, real-time baseline setting is important.

[Historically, noise, offsets and offset drifts were higher than with current generation sensors and electronics, and processing power was lower. One approach was to spend time at the start of a measurement session allowing everything to stabilize, taking and processing a reference frame in the dark, and performing a live image correction based on subtraction of this processed reference data. This was then applied to all subsequent beam images in the session until a recalibration was deemed appropriate. DataRay considers now this approach no longer necessary or appropriate.]

Implementation Descriptions:

Real-time auto-baseline - No user intervention required.

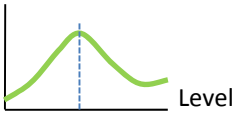


a) Philosophically, the aim is to establish and subtract the ADC level corresponding to zero irradiance. This requires us to find the peak in the levels near zero irradiance outside the beam area.

b) If the Capture Block is **H** x **V** pixels, the software inscribes a circle of diameter **H** or **V**, whichever is smaller. Pixels *outside* this circle but within the Capture Block constitute the data to be processed for baseline setting. E.g. For a square capture region, this selects the corners of the image – the hatched areas above.

c) The software creates an internal histogram of ADC level versus number of pixels at this level. It also performs a 32 frame rolling average of the histogram. Because a 16-bit ADC word has 65,536 levels, the histogram is smoothed by a 32 level wide, equal weight, smoothing function (0.05% of the total ADC range). Without this smoothing, such a histogram is too peaky to be useful.

d) The software analyzes the histogram to determine the first peak above zero in the histogram, $I_{baseline}$, typically around the 1300 level (the ≈2% level of the ADC range).



e) Create the array to be processed as an image: $I_{Image}(x,y) = I_{Raw}(x,y) - I_{baseline}$

This approach:

- Is the default mode of operation and works really well for the vast majority of beams, those roughly centered in the Capture Block but which do not overflow the Capture Block.
- Real-time. No 'accuracy' versus 'ease of use' tradeoff required.
- Requires no warm-up time and no user intervention.
- Works with Auto-exposure & Auto-gain, as well as at fixed Exposure &/or Imager Gain.

- Is simply confirmed by observing the profile baseline in log 40dB mode. Residual noise is typically below 0.1%.
- May be further improved by simply using the **Average** function.

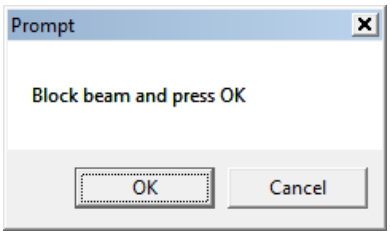
Baseline Lock - for large beams which overfill the camera. Set once. [User Manual Sec. 3.4, p. 56]

a) Philosophically, the aim is to establish and subtract the ADC level corresponding to zero irradiance for beams which overfill the camera, negating histogram peak finding in the default auto-baseline function.

b) The padlock style Lock and Unlock buttons allow you to Lock the baseline at the current level set by the auto-baseline function, above. This allows the measurement of beams which overfill the sensor and are therefore too large to allow the determination of a good zero level while the beam is on the camera.

c) With the beam on the camera, uncheck auto exposure. Then block the beam and click on the Lock padlock-style button. Then unblock the beam. The zero level from which clip levels are determined will be now be based upon the level determined while the beam was blocked. Obviously (?), if beam wings are absent, second moment (4σ) widths calculated for such a beam are invalid. To disable this feature, click on the Unlock padlock button.

Background Subtraction - for beams on top of an optical background which needs to be rejected. Set once. 
[User Manual Sec. 3.4, p. 57]



a) Philosophically, the aim is to subtract an unwanted optical background.

b) Right-click on the Exposure time box & disable auto-exposure. Click **OK**. If appropriate set **Average=20**, especially if the background to be subtracted is noisy.

c) Click the button to initiate background subtraction. The box shown right will appear. Block the beam, allow any selected averaging to complete, and then click **OK**. The captured background (optical and electrical) is subtracted from subsequent images. If **Average** is still engaged, subtraction will be gradual.

d) Auto-baseline operates on the difference image.

e) Press the bracket button to turn it off. 

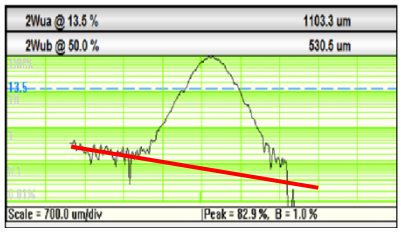
HyperCal™ - for occasions where 'shading' in the electrical offset need to be rejected. Set once. 
[User Manual Sec. 3.4, p. 57]

a) Philosophically, the aim is to subtract any unwanted *electronic* offset which is non-uniform across the sensor. Tends to matter most when Use Equivalent Slit is engaged, when baseline tilt – always present but normally negligible for practical purposes – can become significant in the integrated line profile. Can be engaged at any time for any reason, at exposures >0.4 ms.

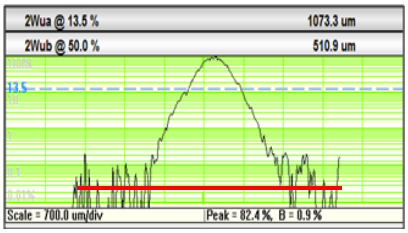
b) HyperCal alternately takes exposures at the lowest possible exposure and at the auto or set exposure and differences the frames. Auto-baseline operates on the difference image. HyperCal therefore completely removes electronic offsets at the ADC that do not result from the presence of an image.

c) Press the button again to turn it off.

Log profile displays, no averaging.



Without **HyperCal™**
0.3% noise + baseline tilt



With **HyperCal™**
Noise <0.1% & flat baseline