What is Binning ?

The mechanism used to transport charge from the photosite to the imager output lends itself very naturally to performing simple addition on-chip. Summing small neighborhoods of pixels together on-chip into larger "super-pixels" is known as binning and allows the user to trade off imager resolution for other operational parameters. Binning is usually done in square neighborhoods such as 2x2 which decreases resolution by 2x in both the x-and-y directions. In some cases, binning may also be done in rectangular neighborhoods such as 3x5 which sums 15 pixels together resulting in decreased resolution by 3 in the x-direction and by 5 in the y-direction.

A significant advantage to binning is that combining charge from adjacent pixels into a single storage well is a virtually noiseless process. While this summation could theoretically have been done digitally at the camera output, the improvement in signal to noise ratio is more dramatic if all operations are done within the sensor itself. For example, if a 4x4 neighborhood of pixels were summed together off-chip, the signal level would increase by 4x4=16, but the CCD's inherent noise floor would simultaneously go up by =4. Thus, the SNR increase obtained by off-chip summation would be 16/4 = 4x increase. In contrast, if a 4x4 neighborhood of pixels is summed on chip, the signal increases by 16x and the noise stays as it was - resulting in an increased SNR of 16x. For low-light imaging, binning can offer dramatic improvements in image quality over off-chip pixel summing.

Why would you want to do Binning?

From the foregoing discussion, it is clear that one reason for implementing binning is to capture higher quality images at low-light levels. Since the camera can electronically be switched from full resolution to binning modes, this means that a single camera can be used to provide high-resolution images when light levels are adequate, and lower resolution images when light is scarce. Figure 1 shows a microscope image taken at full resolution on the left and 2x2 binning on the right. The full resolution image is dark and low contrast whereas the 2x2 binned image is sharp and bright. Notice that while the resolution of the 2x2 binned image is ½ that of the full resolution image, the field-of-view is identical. Thus, binning allows the user to trade off resolution for sensitivity.

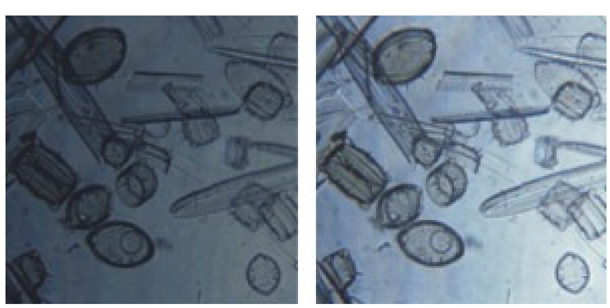

Figure 1. (left side full resolution, right side 2x2 binning).

Binning can also be useful for a variety of other reasons. For example, since on-chip binning reduces the number of pixels which must be processed by the sensor's output amplifier, the frame rate of the camera can be increased when operating in binning mode. This allows the camera to programmably trade off frame rate for resolution. For example, a 2048x2048 sensor may provide only 5 frames per second at full resolution. At this speed, it is difficult to make adjustments to focus and light level, or to scan large areas for an object of interest. However, in 4x4 binning, this same camera would run at 512x512 resolution and 20 frames per second allowing the user close to real-time feedback.

Binning is also used occasionally to provide physically large pixels when needed in some optical configurations. In some applications (particularly low light) a camera user may not need extremely high resolution, but wishes to have a pixel size of, for example, 56 microns on each side. Finding a commercially available chip with a 56-micron pixel would be very difficult and would probably require a custom sensor development at an expense of several hundred thousand dollars. A simple alternative would be to use a 2Kx2K chip with 14-micron pixels. By placing this chip in 4x4 binning mode, the camera user can obtain an equivalent pixel size of 14x4 = 56 microns at a resolution of 512x512 using an off-the shelf chip. Finally, binning is sometimes used to give a larger full well capacity for the sensor. In some sensors, it is possible to bin pixels with, say 100,000 electron full well together in a 2x2 binning mode yielding a new full well capacity of 4x100,000 or 400,000 electrons. This higher full well can be very useful in applications which are photon shot noise limited due to high background illumination.