Applied Scientific Instrumentation
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Comparison of TILL Imago CCD Cameras to "Ideal" Intensified Camera

What do you get and what do you lose by using an intensified CCD camera for acquisition of low light images? There was a time when the only way to adequately image very dim objects was by using an image intensifier in conjunction with the video camera. This is no longer strictly the case, now that low-noise, cooled CCD cameras are available. The "ideal" intensified camera has no dark noise and will generate an easily visible signal from a single photo-electron. The only noise this camera will have is the inherent statistical noise present when you are dealing with only a few photons. Furthermore, the only limitation this "ideal" imaging device has, is that it can only turn about 35% of the photons that strike the photo-cathode into photo-electrons for detection (i.e., the quantum efficiency of the photo-cathode is 35% for typical good quality image intensifiers).

We will compare this "ideal" camera with the TILL Imago 12-bit cooled CCD cameras to give some idea how really good these new generation cameras are. For most CCD cameras, including the TILL Imago camera, the limiting factor for looking at low light images is the readout noise of the camera electronics. As with most things, there is a trade-off to be made to get the lowest readout noise possible. The more time you spend making the measurement (i.e., the slower you read out the image) the lower the readout noise can be made. However, for real-time imaging you need speed to get all of the information off of the CCD chip before the next exposure is made. The specification for the TILL Imago cameras are listed in the table below.

Specification	Till Imago VGA CCD Camera	Till Imago SVGA CCD Camera	TILL Imago SVGA pixels 2×2 binned
Pixels	640 × 480	1280 × 1024	640 × 512
Pixel Size	9.9μm × 9.9μm	6.7μm × 6.7μm	"13.4μm × 13.4μm"
Readout Speed	12.5 MHz	12.5 MHz	12.5 MHz
Full Well Capacity	35000 e^-	25000 e^-	25000 e^-
Q.E.	40% @ 505nm	40% @ 505 nm	40% @ 505 nm
A/D Conversion	7.5 e^-/count	5 e^-/count	5 e^-/count
Readout Noise (RMS)	13-14 e^-	7-8 e^-	7-8 e^-
Maximum Full Frame Rate	30 frame/s	8 frame/s	16 frame/s

We can compare the signal-to-noise ratio of an "Ideal" intensified camera with TILL cameras by looking at the statistical noise and readout noise on a pixel by pixel basis. Figure 1 shows how the TILL cameras with finite readout noise compare to an 'Ideal" camera with none. Note that at very low photon counts, the "Ideal" camera outperforms the CCD cameras. However, as the photon rates increase, eventually the CCD camera does better due to its superior quantum efficiency compared to the ICCD's photo-cathode.

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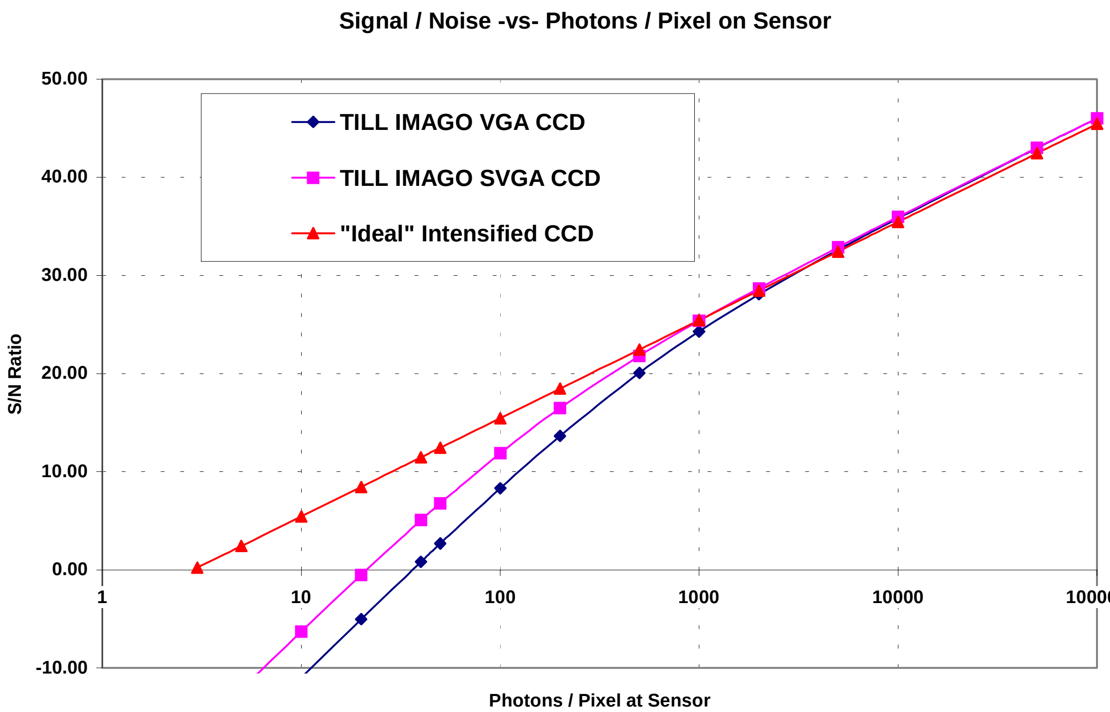

Figure 1: S/N ratio comparing the TILL cameras with and "Ideal" intensified camera.

Spatial resolution also comes into play for a valid comparison. We assume that our “Ideal” intensified camera has the same resolution as the TILL VGA camera (which is reasonable for a high quality intensified camera). If we now divide the number of photons per pixel by the pixel area, we can plot the signal-to-noise ratios versus the photons per unit area at the sensor. Figure 2 shows the results of this calculation. Here we also show what happens when one uses “binning” to improve the signal to noise ratio. The three curves for the TILL cameras all have different pixel sizes. With larger pixels, the camera will collect more photons/pixel which will improve the statistics. For the comparison in Figure 2, the 2×2 Binned SVGA Image has roughly the same number of total pixels as the VGA camera. The 2×2 binned SVGA super-pixels are slightly larger than the VGA pixels and the read noise is lower on the SVGA camera, so the S/N ratio for a given photon flux is significantly better for the 2×2 binned camera.

The bottom line is that extremely low light levels, less than 1 photon/μm^2 at the sensor may require an intensified camera, but much above that there will be little to be gained in picture quality.

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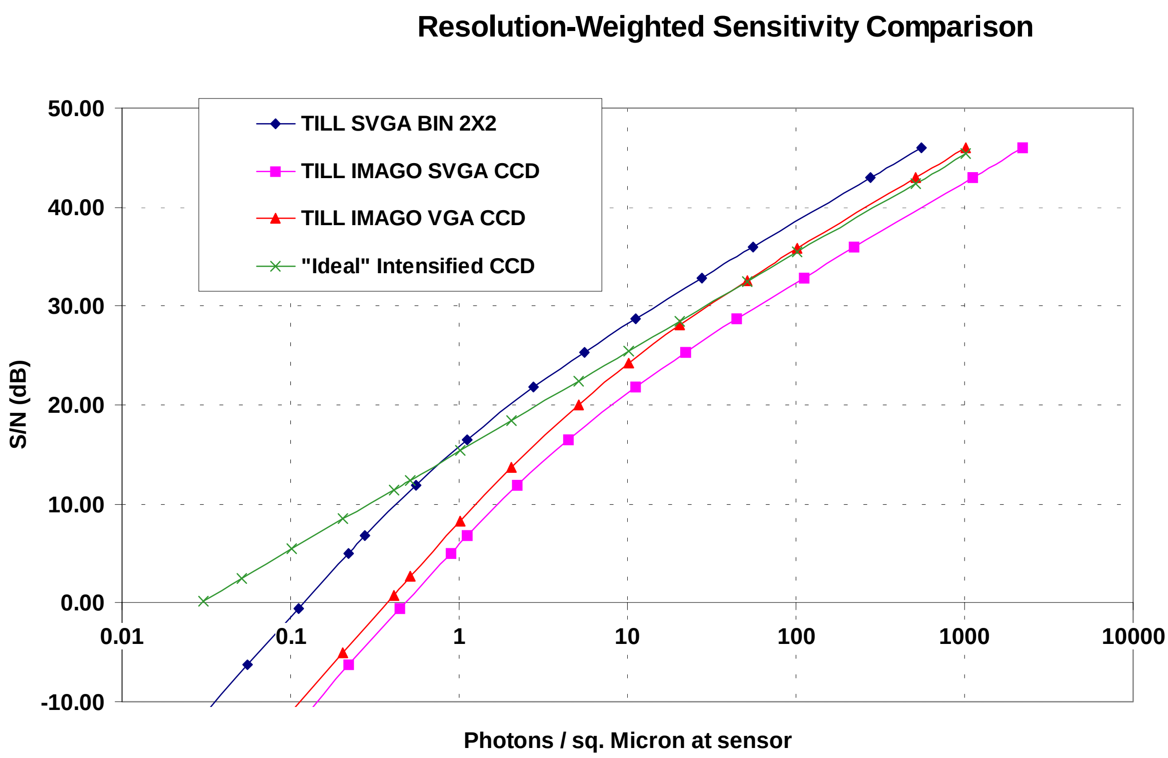

Figure 2: Pixel-size-weighted sensitivity comparison.