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# Pixpolar's MIG Image Sensor Technology in Security & Surveillance

In Security & Surveillance (S&S) camera applications identification is generally performed from a stored video stream. In low light, however, the image quality of single video frames is often too poor for identification. In order to improve the image quality one should look in the stored video stream after periods when the subject remains more or less still throughout several frames. By merging frames together during such a period image quality and consequently identification can be improved considerably.

When frames are merged together Pixpolar's Modified Internal Gate (MIG) image sensor technology enables much better image quality than conventional image sensor technologies. This is due to the fact that in MIG sensors the signal can be readout accurately in a non-destructive manner whereas in CMOS Image Sensors (CIS) or Charge Couple Devices (CCD) accurate readout is always destructive, i.e., the signal is always destroyed. In **FIGURE 1** simulated images of merged frames are presented for MIG and high-end CIS.

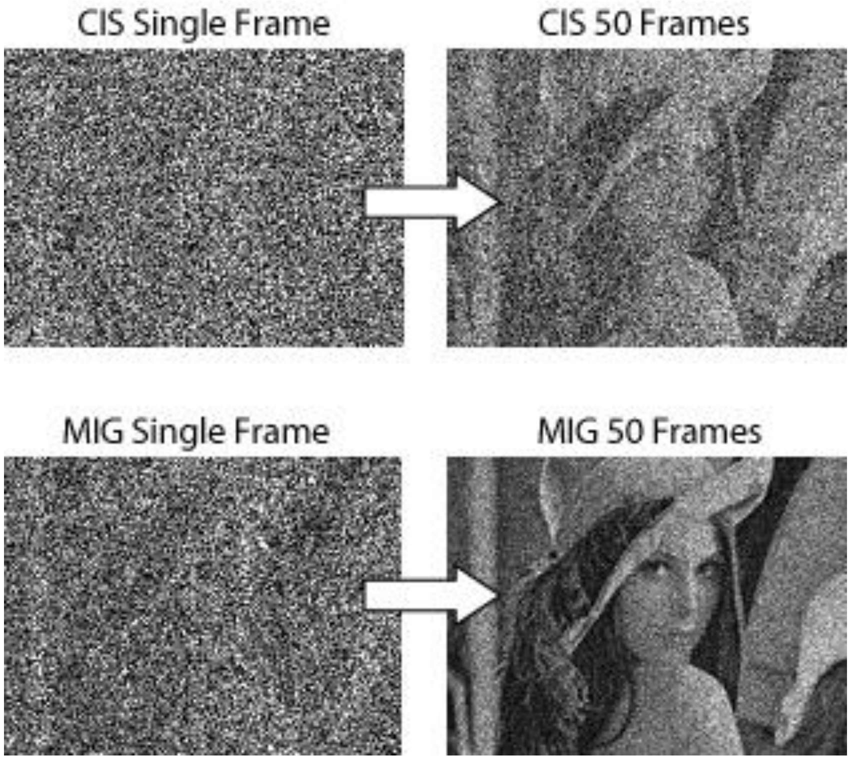


**FIGURE 1. Physics based simulation of 50 merged frames in MIG and high-end CIS sensors corresponding to a low light circumstance wherein the brightest pixels receive 50 photons per second. In both cases the conditions are the same – only the sensor is different (the sensor parameters are presented in TABLE 2). The simulation was performed with Pixpolar's open source image sensor simulator which can be found at http://imager-simulator.appspot.com**

The performance difference in low light between MIG sensors and CIS can be highlighted also by comparing the ratio of detection distances or the ratio of detectable areas. Such a comparison is presented in **TABLE 1** for two different MIG sensor operation modes, namely, for the destructive and non-destructive modes as well as for two different temperatures (-40°C & -70°C). The detectable area refers to the area corresponding to certain detection range.

**TABLE 1. The detection range ($r_{MIG}$, $r_{CIS}$) and detectable area ($A_{MIG}$, $A_{CIS}$) ratios between MIG sensor and high-end CIS are given for destructive and non-destructive MIG operation modes.**

| | -40°C | | -70°C | |
|---|---|---|---|---|
| | $r_{MIG}/r_{CIS}$ | $A_{MIG}/A_{CIS}$ | $r_{MIG}/r_{CIS}$ | $A_{MIG}/A_{CIS}$ |
| **destructive mode** | | | | |
| single frame | 1.42 | 2.02 | 1.56 | 2.43 |
| multiple frames | 1.33 | 1.77 | 1.54 | 2.38 |
| **non-destructive mode** | | | | |
| single frame | 1.33 | 1.77 | 1.41 | 1.99 |
| multiple frames | 1.58 | 2.50 | 2.8 | 7.9 |

The term multiple frames refers to a condition wherein a significant amount of video frames are merged together in order to compose a long integration time image.

## Technical Background for Sensor Performance Analyses (MIG & CIS)

The sensor parameters used in the simulation of **FIGURE 1** and in the calculations of **TABLE 1** are presented in **TABLE 2**.

**TABLE 2. Assumed sensor parameters for MIG sensor and high-end CIS having similar pixel size.**

| | MIG | CIS |
|---|---|---|
| Frame rate | 25 Hz | 25 Hz |
| Read noise | 1 e | 1 e |
| Dark noise per pixel per frame at -40°C | 1 e | 0 e |
| Dark noise per pixel per frame at -70°C | 0.1 e | 0 e |
| Quantum efficiency at 850 nm | 0.70 | 0.28 |

The reason for choosing the Quantum Efficiency (QE) at 850 nm for silicon based sensors operated in outdoor low light S&S applications is the following. First of all, Black & White (B&W) sensors enable the capture of both visible and Near Infra-Red (NIR) photons maximizing the amount of signal in low light circumstances. Secondly, in the darkest moonless and overcast nights the Near Infra-Red (NIR) photons dominate over visible photons (390 nm – 750 nm). On the other hand, the QE of silicon based sensors drops considerably towards 1000 nm. Consequently, QE at 850 nm is utilized as a ball park weighted average.

The reason behind MIG sensor's better QE in NIR is the following. In order to provide good QE in NIR a silicon based sensor should be relatively thick. In MIG sensors a fully depleted Back-Side Illuminated (BSI) design enables the MIG sensor thickness to be optimized (e.g. 50 um) for NIR light unlike in CIS where the Crosstalk (CT) becomes more and more an issue when the thickness is increased. The QE value for CIS at 850 nm was picked up from an existing high-end sensor. As a matter of fact, the thickness and thus the QE of the fully depleted MIG sensor design could be still increased without increasing the CT too much.

In the simulation and calculations sensor cooling is assumed which accounts for the low dark noise in CIS. The higher dark noise in MIG is due to thick fully depleted design optimized for NIR detection. The benefit of improved QE in NIR surpasses, however, the disadvantage of increased dark noise. In addition the accurate non-destructive Correlated Double Sampling (CDS) read-out means that when multiple frames are merged the read noise of the total overall noise is reduced to an insignificant level whereas in CIS the overall read of the merged frames adds up in a root mean square fashion.

## Other Possible Sensor Technologies

As already mentioned earlier the readout in CCDs is destructive meaning that the read noise in merged frames adds up just as in CIS. Unlike in CIS, however, it is possible to have similar cross-talk as well as QE for both visible and NIR light as in MIG sensors by utilizing Back-Side Illuminated (BSI) fully depleted CCD design. The problems with such CCDs are, on the other hand, blooming and smear impairing the applicability for S&S applications. In thick BSI CCDs designs the first one could be perhaps avoided in the future but the latter one is more or less unavoidable. The problem with smear and/or blooming is e.g. that cameras can be interfered with lasers or bright Light Emitting Diodes (LEDs).

Another possibility would be to use amplified sensor designs. In amplified sensors the accumulation of read noise can be avoided but the problem is amplification noise impairing the image quality and thus hampering identification. In addition the amplified sensors are typically very expensive and besides they suffer from aging phenomena limiting considerably the lifespan of the camera.

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