Nocturn Camera: Optimized for Long-Range Observation in Low Light Conditions

The ability to observe, and record images and scenery undetected are paramount to the safety of both life and infrastructure. Modern warfare techniques, whether static monitoring or mobile surveillance, rely heavily on information gathered via covert long-range surveillance methods such as hidden cameras. The imaging technology is most effective if the camera can produce high quality images in both daylight and nighttime conditions.

There are three distinct progressions of a surveillance image: Detection, Recognition and Identification. At long range, detection may simply indicate movement or a change in the scene being observed, with no additional information as to friend or foe. Typically, recognition takes place at a mid-distance range, where details become clearer and some details are present to begin evaluating if there is a threat. Identification is a short-range function, as it needs a great level of detail and a high quality image to clearly determine if there is a threat and what it may be. Identification is most difficult under low-light conditions as the proximity to the potential threat needs to be very close in order to achieve the level of detail required to make life-or-death decisions.

The advent of digital imaging technologies has assisted in increasing resolution of targets at long-range to achieve better detection and recognition abilities. High resolution cameras can, at long distances, produce a good quality image, and software can easily zoom or enhance the high resolution image to provide some increased level of recognition without physically moving closer to the object in question. These surveillance cameras are relatively inexpensive, simple to operate, and provide good quality images in daylight. However their ability to produce actionable data in low lighting conditions is limited. To compensate for this, many cameras are augmented with near infrared (NIR) LEDs or laser illuminators in order to provide light not visible to the naked eye, yet can be seen by the camera sensor.

NIR illumination is a viable alternative for short-range observation, particularly in non-threatening environments. However, in long-range observational situations, the cost to install high-power laser illuminators capable of emitting enough light for identification over several hundred meters becomes cost-prohibitive. For most static surveillance applications, NIR illumination is acceptable, but for covert operations, the presence of supplemental illumination is easily detected, and therefore not widely used, regardless of the detection range.

For cameras that promise low light vision, high quality imagery is difficult to achieve. This is because most are unable to achieve a high enough signal-to-noise ratio (SNR) to be able to clearly identify targets or threats. While the SNR can be increased by increasing the integration time (slower frame rates), or averaging multiple frames, the camera provides poor imagery when tracking moving objects and thus recognition at long range is elusive at best.

In order to address the technical concerns that plague long-range observation in low lighting conditions, PHOTONIS has developed Nocturn, a low-light CMOS camera. Nocturn provides a high frame rate with a high resolution, making the camera well-suited for long-range observations - even of high speed moving objects - without the need for supplemental illumination or cooling. The digital architecture also prevents damage from sudden bright event damage and halos, allowing it to operate equally well in full daylight conditions as well as in low light situations.

Nocturn is based on a proprietary CMOS architecture, which features large 9.7µm x 9.7µm pixel array, operates with a rolling shutter and is capable of frame rates up to 100Hz to easily provide high-quality images of both static and moving targets. To improve the sensitivity of the image in low light, micro-lenses have been added, which enables quantum efficiency near 80% at peak efficiency. See Figure 1 below:
Nocturn features a low power consumption in a small footprint, but provides SXGA (1280x1024) resolution with real-time imaging capabilities in the NIR (800-1100nm for detection of illuminating lasers), and visible spectrum to light level 3 (quarter moon). The camera can be equipped with a wide range of standard CS mount lenses and is capable of up to 8x digital zoom.

To illustrate the long-range abilities of the Nocturn camera, comparative testing was done to simulate the probability of detection, recognition, and identification of an adult human. In addition to the Nocturn, a low light CCD (LLL CCD) and a low light CMOS (LLL CMOS) camera were used for comparison. The tests were simulated at two light levels: Full moon (100 mlux) and quarter moon (15 mlux).
The charts above show the overall performance of the LLL CCD camera is far below both of the CMOS sensors performance due to its lower resolution and hence lower number of pixels on target. It should also be noted that there is nearly a 50% reduction in identification (70% probability) range for both the LLL CCD and LLL CMOS between full and quarter moon illumination. In comparison, the NOCTURN shows less than a 15% reduction in that range. This difference in SNR is significant since it indicates that the NOCTURN is capable of producing good quality imagery to quarter moon illumination (1×10^{-2} Lux), whereas the LLL CCD and CMOS have only good performance down to approximately half moon illumination 2.5 to 1×10^{-1} Lux). At quarter moon lighting conditions, Nocturn can provide over 90% detection probability at quarter moon at 1000m, recognition capability greater than 75% at 300m, and identification greater than 80% at 200m – far superior to the comparison technologies.

Next, to further illustrate SNR performance, Lux transfer curves were generated for each of the cameras at identical frame rates. It should be noted that, although the Nocturn is capable of 100 frames per second (fps), it was compared at 30 fps as this was the limiting rate of the LLL CCD camera. As can be seen below, the Nocturn offers significant advantages in image quality at light levels below 0.2 Lux and offers almost three times the sensitivity of the ISO12232 minimum image quality limit.

Finally, actual images taken from the camera in both monochrome and color versions show the capability to identify distinguishing characteristics of the human in the image, such as shirt pattern and color and that he is wearing glasses. The images were taken at 15mlx with an f/1.4 (see Figure 6, next page).
From both the experimental and actual data, it can be seen that Nocturn provides a significant advantage in low-light conditions, specifically at long range. The high signal to noise ratio (SNR) provides excellent contrast even at quarter moon, allowing identification of targets at significantly longer distances than other digital surveillance options.

Nocturn also provides excellent images from daylight through low light. Digital technology virtually eliminates the potential for damage from sudden bright light events or long-term exposure to high light conditions. Yet the low light response for the Nocturn camera also eliminates the need for supplemental illumination, allowing 24/7 long range surveillance for covert observation in a single, cost-effective camera.

The small size, weight and power consumption (SWaP) of the Nocturn camera makes it ideal for installations in remote, unmanned locations or for hand-held devices such as monocular devices or rifle sights. Additionally, the high SXGA resolution, paired with the 100Hz rolling shutter, provides high-quality video even in mobile applications such as in UAVs or for night driving.

Nocturn is available in a variety of connectivity options including Gigabit Ethernet, USB, NTSC, and PAL (monochrome) and USB3 (color) for installation and communication virtually anywhere.

For more information about the Nocturn camera family, including videos, applications and specifications, please visit us on the web at:

www.nocturncamera.com

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