

HOW NIGHT VISION WORKS

EVERYTHING YOU'VE ALWAYS WANTED TO KNOW

Letter From The Editor

New Night Vision technologies are rapidly being developed and an ever-expanding pool of users are looking to night vision to solve challenging security and surveillance problems. We are pleased to launch a new tutorial designed to explain, in simple terms, how various night vision technologies work including image intensifiers, thermal imaging, low-light CCD cameras and new infrared illuminations technologies. We hope you find this information useful and we encourage you to forward this tutorial to your colleagues. This information is also available at www.hownightvisionworks.com. In addition your comments on how Electrophysics can provide and expand this informative, non-commercial information are always welcome.

We trust you will find the information of great value.

[VIEW IMAGE GALLERY](#)

"Night Vision" as referenced here is that technology that provides us with the miracle of vision in total darkness and the improvement of vision in low-light environments. This technology is an amalgam of several different methods, each having its own advantages and disadvantages. The most common methods as described below are [Low-Light Imaging](#), [Thermal Imaging](#) and [Near-Infrared Illumination](#). The most common applications include [night driving or flying](#), [night security and surveillance](#), [wildlife observation](#), [sleep lab monitoring](#), and [search and rescue](#). A wide range of [night vision products](#) are available to suit the various requirements that may exist for these applications.

Low-Light Imaging

- [Image intensifiers](#)
- [On-chip gain multiplication cameras](#)

Thermal Imaging

- [Cooled-detector infrared cameras](#)
- [Uncooled-detector infrared cameras](#)

Near-Infrared Illumination

- [IR Illumination](#)

Glossary of Night Vision Terms

Other Links



The final stage of the image intensifier involves electrons hitting a phosphor screen. The energy of the electrons makes the phosphor glow. The visual light shows the desired view to the user or to an attached photographic camera or video device. A green phosphor is used in these applications because the human eye can differentiate more shades of green than any other color, allowing for greater differentiation of objects in the picture.

All image intensifiers operate in the above fashion. Technological differences over the past 40 years have resulted in substantial improvement to the performance of these devices. The different paradigms of technology have been commonly identified by distinct [generations of image intensifiers](#). Intensified camera systems usually incorporate an image intensifier to create a brighter image of the low-light scene which is then viewed by a traditional camera.

Image Intensifiers	
Advantages	Disadvantages
<ul style="list-style-type: none"> • Excellent low-light level sensitivity • Enhanced visible imaging yields the best possible recognition and identification performance. • High resolution • Low power and cost • Ability to identify people 	<ul style="list-style-type: none"> • Because they are based on amplification methods, some light is required. This method is not useful when there is essentially no light. • Inferior daytime performance when compared to daylight-only methods • Possibility of blooming and damage when observing bright sources under low light conditions.

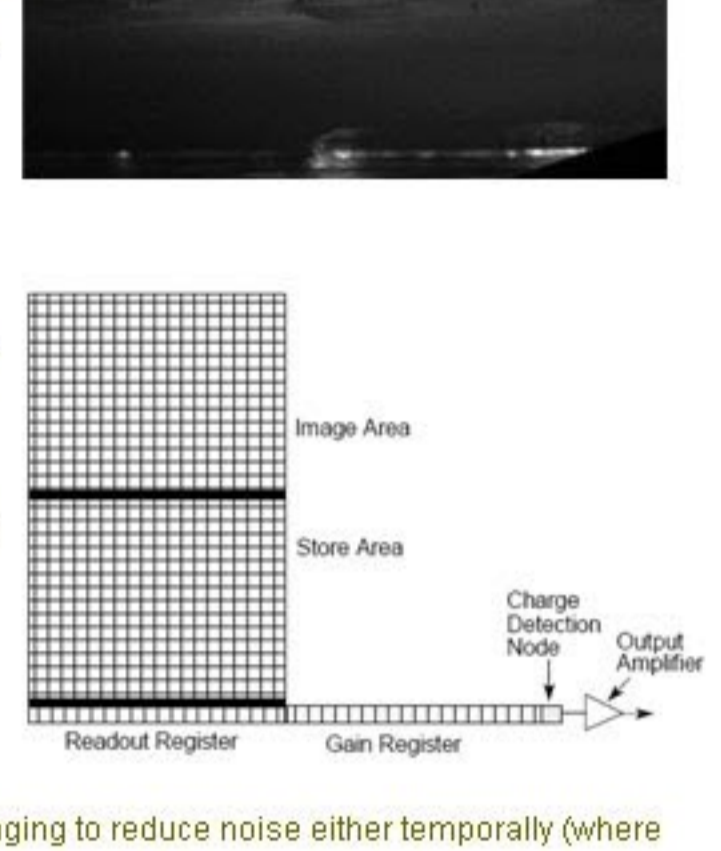
Image intensifier based products:

- [Night Vision Goggles](#)
- [Night Vision Pocketscopes](#)
- [Intensified Professional News Cameras](#)
- [Intensified Removable Lens Camcorders](#)
- [Intensified Prosumer Camcorders](#)
- [Intensified Nikon Cameras](#)
- [Intensified Canon Cameras](#)

[TOP](#)

On-chip Gain Multiplication Cameras

HOW THEY WORK: In order to overcome some of the disadvantages of image intensifiers, CCD image detector manufacturers have substantially improved the sensitivity of certain CCD detectors by incorporating an on-chip multiplication gain technology to multiply photon-generated charge above the detector's noise levels. The multiplication gain takes place after photons have been detected in the device's active area but before one of the detector's primary noise sources (e.g. readout noise). In a new multiplication register, electrons are accelerated from pixel-to-pixel by applying high CCD clock voltages. As a result, secondary electrons are generated via an impact-ionization process. Gain can be controlled by varying the clock voltages.



Because the signal boost occurs before the charge reaches the on-chip readout amplifier and gets added to the primary noise source, the signal-to-noise ratio for this device is significantly improved over standard CCD cameras and yields low-light imaging performance far superior than traditional CCD cameras. However, since the CCD temperature also affects the on-chip gain multiplication (lower temperatures yield higher gain) and because other noise sources exist that occur before the multiplication (i.e. dark noise), it is prudent in these systems to temperature stabilize these detectors at temperatures about of below room temperature.



Another method for improving a CCD camera's sensitivity is to perform averaging to reduce noise either temporally (where sequential video frames are averaged) or spatially (where neighboring pixels are "binned" or added together).

On-chip Gain Multiplication Cameras	
Advantages	Disadvantages
<ul style="list-style-type: none"> • High sensitivity in low light • Reduced likelihood of damage to the imaging detector due to viewing bright sources • High speed imaging capability • Good daytime imaging performance 	<ul style="list-style-type: none"> • High power dissipation due to the necessity to have a temperature stabilizer • Blooming when viewing bright sources in dark scenes

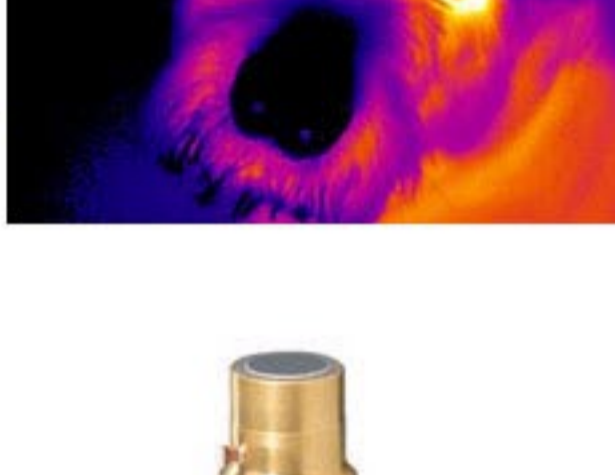
On-chip Gain Multiplication Camera-based products:

- [Daynight surveillance camera](#)
- [Frame-averaged and binned low-light CCD camera](#)

[TOP](#)

Thermal Imaging

Different from low-light imaging methods of night vision (which require some ambient light in order to produce an image), thermal imaging night vision methods do not require any ambient light at all. They operate on the principal that all objects emit infrared energy as a function of their temperature. In general, the hotter an object is, the more radiation it emits. A thermal imager is a product that collects the infrared radiation from objects in the scene and creates an electronic image. Since they do not rely on reflected ambient light, thermal imagers are entirely ambient light-level independent. In addition, they also are able to penetrate obscurants such as smoke, fog and haze. There are two types of thermal imaging detectors: cooled and uncooled. [Cooled detector infrared cameras](#) require cryogenic cooling to very cold temperatures (below 200K). [Uncooled detector infrared cameras](#) are normally either temperature stabilized (at room temperatures) or entirely unstabilized.

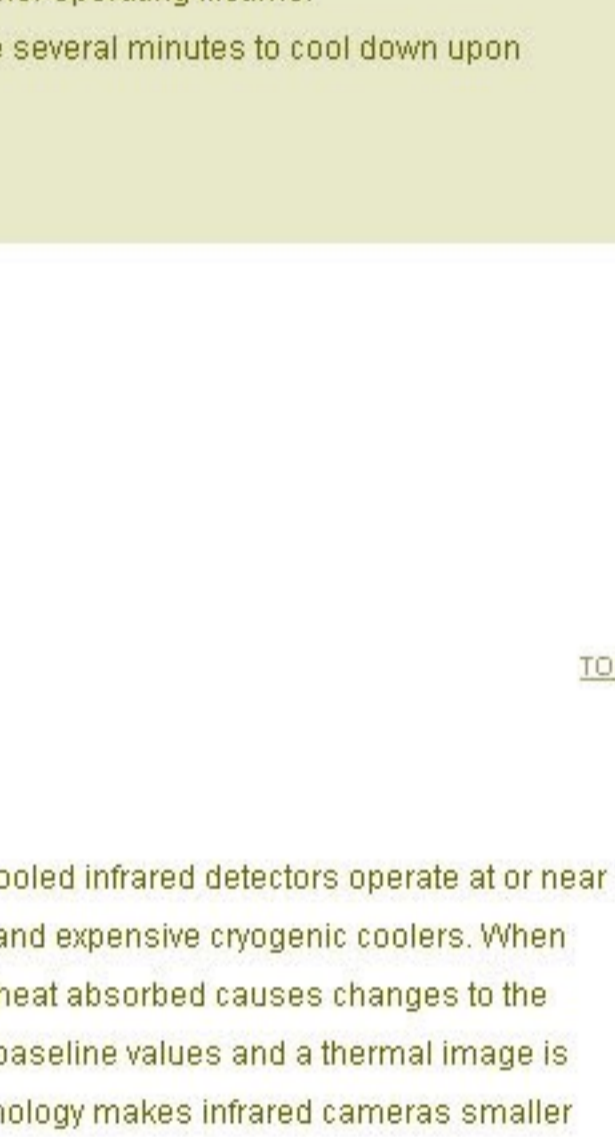


Thermal images are normally black and white in nature, where black objects are cold and white objects are hot. Some thermal cameras show images in color. This false color is an excellent way of better distinguishing between objects at different temperatures.



Cooled-detector Infrared Cameras

HOW THEY WORK: Cooled infrared detectors are typically housed in a vacuum-sealed case and cryogenically cooled. The detector designs are similar to other more common imaging detectors and use semiconductor materials. However, it is the effect of absorbed infrared energy that causes changes to detector carrier concentrations which in turn affect the detector's electrical properties. Cooling the detectors (typically to temperatures below 110K, a value much lower than the temperature of objects being detected) greatly increases their sensitivity. Without cooling, the detectors would be flooded by their own self-radiation.



Materials used for infrared detection include a wide range of narrow gap semiconductor devices, where mercury cadmium telluride (HgCdTe) and indium antimonide (InSb) are the most common.

Cooled-detector Thermal Imaging Cameras	
Advantages	Disadvantages
<ul style="list-style-type: none"> • The highest possible thermal sensitivity. • Able to detect people and vehicles at great distances. • Not affected by bright light sources. • Able to perform high-speed infrared imaging. • Able to perform multi-spectral infrared imaging. 	<ul style="list-style-type: none"> • Expensive to purchase and to operate. • Limited cooler operating lifetime. • May require several minutes to cool down upon initiation. • Bulky

Cooled-detector Infrared Cameras

- [Short-wave Infrared Camera](#)
- [Mid-wave Infrared Camera](#)
- [Long-wave Infrared Camera](#)
- [Multi-spectral Infrared Camera](#)

[TOP](#)

Uncooled-detector Cameras

HOW THEY WORK: Unlike the cryogenically-cooled detectors described above, uncooled infrared detectors operate at or near room temperature rather than being cooled to extremely low temperatures by bulky and expensive cryogenic coolers. When infrared radiation from night-time scenes are focused onto uncooled detectors, the heat absorbed causes changes to the electrical properties of the detector material. These changes are then compared to baseline values and a thermal image is created. Despite lower image quality than cooled detectors, uncooled detector technology makes infrared cameras smaller and less costly and opens many viable commercial applications.

Uncooled detectors are mostly based on materials that change their electrical properties due to pyroelectric (capacitive) effects or microbolometer (resistive) effects.

Uncooled-detector Thermal Imaging Cameras	
Advantages	Disadvantages
<ul style="list-style-type: none"> • Relatively inexpensive compared to other thermal imaging technologies • High contrast in most night-time scenarios • Easily detects people and vehicles • Not affected by bright light sources • Higher reliability than cooled detector thermal imagers 	<ul style="list-style-type: none"> • Less sensitive than cooled-detector thermal imagers. • Cannot be used for multi-spectral or high-speed infrared applications.

Uncooled-detector Thermal Imaging products:

- [Uncooled thermal imaging camera \(fixed mount\)](#)
- [Uncooled thermal imaging camera \(portable\)](#)

[TOP](#)

Near-Infrared Illumination

A popular and sometimes inexpensive method for performing night vision is by near-infrared illumination. In this method, a device that is sensitive to invisible near-infrared radiation is used in conjunction with an infrared illuminator. The [Sony Night Shot camcorder](#) popularized this method. Because of the IR sensitivity of the camcorder's CCD detector and since Sony installed an infrared light source in the camcorder, infrared illumination was available to augment otherwise low-light video scenes and produce reasonable image quality in low-light situations.



The method of near-infrared illumination has been used in a variety of night vision applications including perimeter protection where, by integrating with video motion detection and intelligent scene analysis devices, a reliable low-light video security system can be developed.

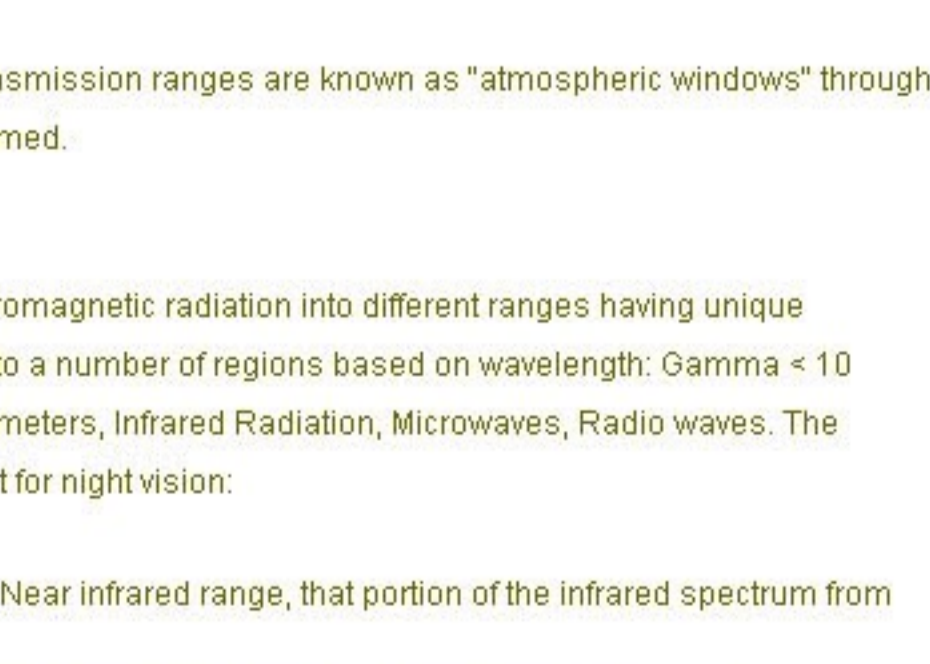
IR illumination

HOW THEY WORK: Several different near-infrared illumination devices are available today, including:

- **Filtered incandescent lamps:** A standard high-power lamp that is covered by an infrared filter designed to pass the lamp's near-infrared radiation and block the visible light component. These devices typically need good heat transfer properties since the intense visible light is internally absorbed and dissipated as heat.

- **LED-type illuminators:** These illuminators utilize an array of standard infrared emitting LEDs.

- **Laser type:** The most efficient infrared illuminator, these devices are based on an infrared laser diode that emits near-infrared energy.



Near-infrared illuminators are typically available in a range of wavelengths (e.g. 730nm, 830nm, 920nm). Providing supplemental infrared illumination of an appropriate wavelength not only eliminates the variability of available ambient light, but also allows the observer to illuminate only specific areas of interest while eliminating shadows and enhancing image contrast. The supplemental near-infrared lighting not only improves the quality of image intensifying devices (which have both a visible and a near-infrared response), but also permits the use of solid-state cameras, which also have the ability to convert near-infrared images to visible.

IR Illumination	
Advantages	Disadvantages
<ul style="list-style-type: none"> • Lowest cost compared to other night vision technologies. • Eliminate shadows and reveal identifying lettering, numbers and objects. Can also be used to perform facial identification. • Able to perform high-speed video capture (such as reading license plates of moving vehicles). • IR illuminators can see through night-time fog, mist, rain and snowfall as well as windows. • Eliminates the variability of ambient light. 	<ul style="list-style-type: none"> • Users of infrared illuminators can be detected by others that have near-infrared viewing devices.

IR illumination products:

- [Wide area infrared laser illuminator](#)
- [Portable Laser illuminator](#)

[TOP](#)

Glossary of Night Vision Terms

Atmospheric transmission

Absorption of the infrared energy by the atmosphere. High transmission ranges are known as "atmospheric windows" through which infrared imaging over very long distances can be performed.

Electromagnetic spectrum

The electromagnetic spectrum divides up the regions of electromagnetic radiation into different ranges having unique characteristics. This radiation is divided up rather arbitrarily into a number of regions based on wavelength: Gamma < 10 nanometers, Ultraviolet radiation, Visible light 0.4 to 0.7 micrometers, Infrared Radiation, Microwaves, Radio waves. The following is a sub-categorization for the infrared range relevant for night vision:

- **Shortwave infrared range (SWIR):** Also known as the Near infrared range, that portion of the infrared spectrum from 750nm to 2500nm.
- **Midwave infrared range (MWIR):** That portion of the infrared spectrum from about 3 microns to 5 microns.
- **Longwave infrared range (LWIR):** That portion of the infrared spectrum from about 8 microns to 12 microns.

Generations of image intensifiers

The different paradigms of image intensifier technology have been identified by "generations" of technology (also known as "Gen"). Generation 0 technology first developed in the 1950s depended on near infrared illumination to produce reasonable night vision images. After the light was converted to electrons, these electrons were accelerated so they hit a phosphor screen with greater energy, creating a visible image. Unfortunately, the accelerated electrons were somewhat distorted and vision with this method was impaired. Generation 1 image intensifiers were then developed that used a photocathode material that was better than Gen 0 in converting light to electrons. These units were able to operate at lower light levels than the Gen 0 and, became known as "starlight scopes" since near infrared illumination was not required. When three tubes were cascaded together, the sensitivity was sufficient for most night vision applications, but distortion existed. The Generation 2 image intensifier marked the development of a microchannel plate which multiplies the number of electrons by the thousands. A single unit of a Generation 2 image intensifier produced the same sensitivity as a 3-tube cascaded Generation 1 device but in a much smaller package and without distortion. Generation 3 is the most sophisticated night vision technology available today. The image intensifier's photocathode is coated with sensitive gallium arsenide, which allows for a more efficient conversion of light to electrical energy at extremely low levels of light. Generation 3 provides the clearest, sharpest night vision image available.

Image intensifier tube

An electro-optical device which converts photons to electrons, amplifies them, then converts them back to photons so the user can see at light levels that are normally too low.

Infrared

The range of electromagnetic radiation having a wavelength longer than that of visible light and shorter than that of microwave radiation. The name "infrared" translates to "below red", where red is the color of visible light of longest wavelength. Infrared radiation spans the wavelengths between approximately 750 nm (0.75 microns) and 1 mm (1000 microns). For a bit of history about infrared, [go here](#).

Microbolometer

An infrared detector that absorbs the IR radiation and warms slightly, the electrical resistance across the bolometer changes as a function of temperature, which can be measured and made into a thermal image. See also [How Microbolometer Detectors Work](#).

Pyroelectric

An infrared detector that absorbs the IR radiation and warms slightly, the electrical capacitance across the detector changes as a function of temperature, which can be measured and made into a thermal image. See also [How Ferroelectric Detectors Work](#).

[TOP](#)

To see our line of Night Vision products please [click here](#).

[VIEW IMAGE GALLERY](#)

Other Links

- [Contact Us](#)
- [See Us At Our Next Trade Show](#)
- [Become a Dealer](#)
- [Electrophysics Night Vision Imaging Product Line](#)

373 Route 46, Fairfield, NJ 07004 • 973-882-0211 • www.nightvisioncameras.com

© 2006-2010 Electrophysics Corp. All rights reserved. An ISO 9001 Certified Company. All content and the compilation of such content included on this site, including text, graphics, and images is the property of Electrophysics Corp. and protected by US and international copyright laws. Except as provided for by law, you may not use any of this copyrighted material without our expressed written permission.

[TOP](#)