Terms for Night Vision Imaging Systems

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Night Vision Tutorial

https://usnightvision.com/night-vision-tutorial/

Downloaded 2020-04-08, slightly edited to correct minor errors

Understanding Night Vision Technology

Image intensifier tube technology has evolved over the past 50 years through a series of "generations." In order to differentiate night vision products and determine which is best for your application, you should understand the generations.

Each generation (Gen) has been defined by specific technology advancements. To date, there have been four generations of image intensifier devices produced: Gen 0 through Gen 3.

Gen 0—The earliest (1950s) night vision products were based on image conversion rather than intensification. They required a source of invisible infrared (IR) light mounted on or near the device to illuminate the target area.

Gen 1—The "starlight scopes" of the 1960s (Vietnam era) had three image intensifier tubes connected in series. These systems were heavy and bulky. The Gen 1 image was clear at the center but distorted around the edges.

Gen 2—The microchannel plate (MCP) electron multiplier prompted Gen 2 development in the 1970s. The "gain" provided by the MCP eliminated the need for back-to-back tubes—thereby improving size and image quality. It also enabled development of hand-held and helmet-mounted goggles.

Gen 3—Two major advancements characterized development of Gen 3 in the late 1970s and early 1980s: the gallium arsenide (GaAs) photocathode and the ion-barrier film on the MCP. The GaAs photocathode enabled detection of objects at greater distances under much darker conditions. The ion-barrier film increased the operational life of the tube from 2,000 hours (Gen 2) to 10,000 hours (Gen 3).

When discussing night vision technology, you also may hear the term "Omnibus" or "OMNI." The U.S. Army procures night vision devices through multi-year/multi-product contracts referred to as "Omnibus"—abbreviated as "OMNI." For each successive OMNI contract, ITT has provided Gen 3 devices with increasingly higher performance. Therefore, Gen 3 devices may be further defined as OMNI I, II, etc.

Night Vision Terminology

Automatic Brightness Control (ABC): An electronic feature that automatically reduces voltages to the microchannel plate to keep the image intensifier's brightness within optimal limits and protect the tube. The effect of this can be seen when rapidly changing from low-light to high-light conditions; the image gets brighter and then, after a momentary delay, suddenly dims to a constant level.

Black Spots: These are cosmetic blemishes in the image intensifier or can be dirt or debris between the lenses. Black spots that are in the image intensifier do not affect the performance or reliability of a night vision device and are inherent in the manufacturing processes.

Blooming: Momentary loss of the night vision image due to intensifier tube overloading by a bright light source. When such a bright light source comes into the night vision device's view, the entire night vision scene becomes much brighter, "whiting out" objects within the field of view. Blooming is common in Generation 0 and 1 devices.

Bright-Source Protection (BSP): An electronic function that reduces the voltage to the photocathode when the night vision device is exposed to bright light sources such as room lights or car lights. BSP protects the image tube from damage and enhances its life; however, it also has the effect of lowering resolution when functioning.

Diopter: The unit of measure used to define eye correction or the refractive power of a lens. Usually, adjustments to an optical eyepiece accommodate for differences in individual eyesight. Most ITT systems provide a +2 to -6 diopter range.

Distortion: There are two types of distortion found in night vision systems. One type is caused by the design of the optics, or image intensifier tube, and is classical optical distortion. The other type is associated with manufacturing flaws in the fiber optics used in the image intensifier tube.

Classical Optical Distortion: Classical optical distortion occurs when the design of the optics or image intensifier tube causes straight lines at the edge of the field of view to curve inward or outward. This curving of straight lines at the edge will cause a square grid pattern to start to look like a pincushion or barrel. This distortion is the same for all systems with the same model number. Good optical design normally makes this distortion so low that the typical user will not see the curving of the lines.

Equivalent Background Illumination (EBI): This is the amount of light you see through a night vision device when an image tube is turned on but no light is on the photocathode. EBI is affected by temperature; the warmer the night vision device, the brighter the background illumination. EBI is measured in lumens per square centimeter (lm/cm^2). The lower the value, the better. The EBI level determines the lowest light level at which an image can be detected. Below this light level, objects will be masked by the EBI.

Emission Point: A steady or fluctuating pinpoint of bright light in the image area that does not go away when all light is blocked from the objective lens. The position of an emission point within the field of view will not move. If an emission point disappears or is only faintly visible when viewing under brighter nighttime conditions, it is not indicative of a problem. If the emission point remains bright under all lighting conditions, the system needs to be repaired. Do not confuse an emission point with a point light source in the scene being viewed.

Eye Relief: The distance a person's eyes must be from the last element of an eyepiece in order to achieve the optimal image area.

Fiber Optics Manufacturing Distortions: Two types of fiber optic distortions are most significant to night vision devices: S-distortion and shear distortion.

- **S-Distortion** Results from the twisting operation in manufacturing fiber-optic inverters. Usually S-distortion is very small and is difficult to detect with the unaided eye.
- **Shear Distortion** can occur in any image tube that uses fiber-optic bundles for the phosphor screen. It appears as a cleavage or dislocation in a straight line viewed in the image area, as though the line were "sheared."

Figure of Merit (FOM): Image intensification tube specification used to qualify exportability. Calculated on resolution (line pairs per mm) x signal-to-noise.

Fixed-Pattern Noise (FPN): A faint hexagonal (honeycomb) pattern throughout the image area that most often occurs under high-light conditions. This pattern is inherent in the structure of the microchannel plate and can be seen in virtually all Gen 2 and Gen 3 systems if the light level is high enough.

Footlambert (fL): A non-metric unit of brightness equal to one footcandle at a distance of one foot.

Gain: Also called brightness gain or luminance gain. This is the number of times a night vision device amplifies light input. It is usually measured as tube gain and system gain.

- **Tube gain** is measured as the light output (in fL) divided by the light input (in fc). This figure is usually expressed in values of tens of thousands. If tube gain is pushed too high, the tube will be "noisier" and the signal-to-noise ratio may go down. U.S. military Gen 3 image tubes operate at gains of between 40 000 and 70 000.
- **System gain** is measured as the light output (fL) divided by the light input (also fL) and is what the user actually sees. System gain is usually seen in the thousands. U.S. military systems operate at 2000 to 3000. In any night vision system, the tube gain is reduced by the system's lenses and is affected by the quality of the optics or any filters. Therefore, system gain is a more important measurement to the user.

Gallium Arsenide (GaAs): The semiconductor material used in manufacturing the Gen 3 photocathode. GaAs photocathodes have a very high photosensitivity in the spectral region of about 450 to 950 nm (visible and near-infrared region).

I^2 (Image Intensification): Collects and intensifies the available light in the visible and near-infrared spectrum. Offers a clear, distinguishable image underlow-light conditions.

IR (Infrared): Area outside the visible spectrum that cannot be seen by the human eye (between 700 nm and 1 mm). The visible spectrum is between 400 and 700 nm.

IR Illuminator: Provides a light source (invisible to the unaided human eye) for the night vision system to amplify. Operates at approximately 880 nm.

lp/mm (Line Pairs per mm): Unit used to measure image intensifier resolution. Usually determined from a 1951 U.S. Air Force Resolving Power Test Target. The target is a series of different-sized patterns composed of three horizontal and three vertical lines. A user must be able to distinguish all the horizontal and vertical lines and the spaces between them.

Lumen: A measure of the perceived power of light. The lumen can be thought of casually as a measure of the total "amount" of visible light emitted.

mA/W (milliampere per watt): The measure of electrical current (mA) produced by a photocathode when exposed to a specified wavelength of light at a given radiant power (watt).

MCP (Microchannel Plate): A metal-coated glass disk that multiplies the electrons produced by the photocathode. An MCP is found only in Gen 2 and Gen 3 systems. MCPs eliminate the distortion characteristic of Gen 0 and Gen 1 systems. The number of holes (channels) in an MCP is a major factor in determining resolution. ITT's MCPs have 10.6 million holes or channels compared to the previous standard of 3.14 million.

Modulation Transfer Function (MTF): A measurement of the ability of an optical system to reproduce (transfer) various levels of detail from the object to the image, as shown by the degree of contrast (modulation) in the image.

Near-Infrared: The shortest wavelengths of the infrared region, nominally 750 to 2500 nm. Also see IR (infrared).

Photocathode: The input surface of an image intensifier tube that absorbs light energy (photons) and in turn releases electrical energy (electrons) in the form of an image. The type of material used is a distinguishing characteristic of the different generations.

Photocathode Sensitivity: Photocathode sensitivity is a measure of how well the image intensifier tube converts light into an electronic signal so it can be amplified. The units of photocathode sensitivity are micro-ampere/lumen (µA/lm). A lumen is a scientific unit that measures light at wavelengths the human eye sees (violet through red). Since image intensifier tubes see light that the eye does not, it is important to know the spectral (color) content of the light used in testing photocathode sensitivity. Photocathode sensitivity is measured using a light source with a color spectrum similar to a theoretical black body operating at 2856 K (2856 kelvin). This light source was chosen because it has a color spectrum similar to the color of a night sky illuminated only by stars. Photocathode sensitivity measured with a different color spectrum light source will yield different readings.

Resolution: The ability of an image intensifier or night vision system to distinguish between objects close together. Image intensifier tube resolution is measured in line pairs per millimeter (lp/mm) while system resolution is measured in cycles per milliradian. For any particular night vision system, the tube resolution will remain constant while the system resolution can be affected by altering the objective or eyepiece optics and by adding magnification filters or relay lenses. Often the resolution in the same night vision device is very different when measured at the center of the image and at the periphery of the image. This is especially important for devices selected for photography or video where the resolution of the entire image is important.

Scintillation: A faint, random, sparkling effect throughout the image area. Scintillation, sometimes called "video noise," is a normal characteristic of MCP image intensifiers and is more pronounced under low-light conditions. Do not confuse scintillation with emission points.

Signal-to-Noise Ratio (SNR): SNR is a ratio of the magnitude of the signal to the magnitude of the noise. If the noise in the scene (see "scintillation" definition) is as bright and as large as the intensified image, you cannot see the image. SNR changes with light level because the noise remains constant but the signal increases (higher light levels). The higher the SNR, the darker the scene can be and the device still performs. The effect of SNR in I^2 devices is similar to that of a television set. At long distances from the station, the TV picture becomes noisy, and the "snow" blocks the picture.

Spectrum: The range of electromagnetic energy from cosmic rays to extra-low frequency, including light and infra-red.

Thermal Imaging: Senses radiation and temperature differentiation from the 7,5 to 13,5 µm range and creates a thermal picture (image of emitted heat energy). Better for detection than recognition.

µA/lm (microampere per lumen): The measure of electrical current (µA) produced by a photocathode when it is exposed to a measured amount of light (lumen).

Further Terms

Source: https://www.pro-lite.co.uk/File/light_measurement_glossary.php downloaded 2020-04-21

Scotopic vision defined by the spectral luminous efficiency function for scotopic vision V'(l). Between 380 and 780 nm, peaking at 507 nm.

Photopic vision (cones) active when $L_V \geq 3$ cd/m^2, scotopic vision when $L_V < 0{,}01$ cd/m^2. Mesopic vision in between (both rods and cones in operation).

UVA: 315 to 400 nm
UVB: 280 to 315 nm
UVC: 100 to 280 nm

Units for Measuring Light

Characteristic		Standard (SI) Units		Mericun Units	
Name	**Symbol**	**Name**	**Symbol**	**Name**	**Symbol**
Luminuous flux	Φ_V	lumen	lm		
Luminous intensity	I_V	candela	cd (= lm/sr)		
Luminous energy	Q_V	lumen-second	lm.s		
Luminance	L_V	candela per sq. metre	cd/m^2	foot-lambert nit	fL nit
Illuminance	E_V	lux	lx (= lm/m^2)	footcandle nox lumen per sq foot	fc, ftc nx lm/ft^2
Luminous exitance/emittance	M_V	lux	lx (= m.cd) (= cd.sr/m^2)		
Luminous exposure	H_V	lux-second	lx.s		
Luminous energy density	ω_V	lumen-second per cubic metre	lm.s/m^3		
Luminous efficacy	H	lumen per watt	lm/W		
Luminous efficiency	V				
Temperature	T	kelvin	K	degrees Fahrenheit	°F

Conversions

1 lx = 0,0929 ftc   1 ftc = 10,764 lx

1 lm/ft^2 = 10,76 lx

1 W/cm2 = 6,83 klx (defined at 555 nm = 540 THz)

1 fL = 1/π cd/ft^2 = 3,426 cd/m^2

1 nit = 1 cd/m^2

Definition of Lumen

https://en.wikipedia.org/wiki/Lumen_(unit)

The **lumen** (symbol: **lm**) is the SI derived unit of luminous flux, a measure of the total quantity of visible light emitted by a source per unit of time. Luminous flux differs from power (*radiant flux*) in that radiant flux includes all electromagnetic waves emitted, while luminous flux is weighted according to a model (a "luminosity function") of the human eye's sensitivity to various wavelengths. Lumens are related to lux in that one lux is one lumen per square meter.

The lumen is defined in relation to the candela as

1 lm = 1 cd · sr.

A full sphere has a solid angle of 4π steradians,[1] so a light source that uniformly radiates one candela in all directions has a total luminous flux of 1 cd × 4π sr = 4π cd·sr ≈ 12.57 lumen