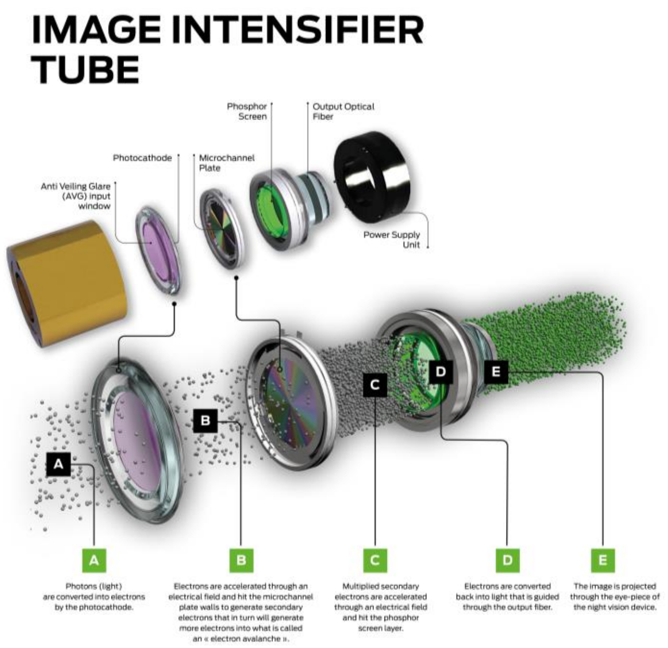
Differences between Gen3 and 4G image intensification technology

Although the image intensifier (I^2) technology originates from well before the second world war (1934), it was only in the 1970s, that night vision experienced a technological breakthrough with the then Generation 2 (Gen2); the image intensification within a vacuum tube from then on is conducted in three stages: 1. A photocathode catching photons (light) and transferring those into electrons, 2. a micro channel plate (MCP) multiplying the electrons (this was the innovation with Gen2), 3. a phosphor screen transferring the (multiplied) electrons back into photons (light). In most (but not all) cases a fiber optic twister was used to turn the picture 180 degrees (saving a heavy lens to do so). And in all cases a power supply unit (PSU), that functions on a small battery (in the night vision device), enables and controls the whole process of the image intensifier.



This is the key (engine) component of any night vision device.

Although the functioning of each of these 3 stages and the PSU is substantiated differently by each manufacturer, nowadays all image intensifiers still work on this very same, above described (Gen2), principle!

In 2001, the United States Government concluded that the "Generation" indicator of an Image Intensifier sensor (or night vision I^2 device), be it Gen 2, Gen 3 or whatever, was not a determinant factor in an image intensifier's performance, confirming the "Generation" indicator as completely irrelevant in determining the performance of an image intensifier. For that matter the US Government also eliminated the term "Generation" as a base for its export regulations, ITAR Cat XII, part (e), §7. Instead the figure of merit (FOM) became key in determining the export feasibility.

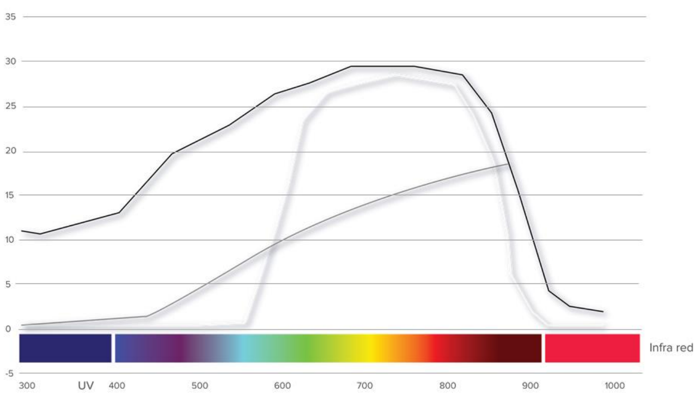
The US and the EU each have different rules for exports to third countries. The US ITAR in general only allows a FoM less than 1800 to be exported to non-NATO Armies (and require elaborate administration on the whereabouts of each tube at all times) while Photonis is allowed to provide any FoM to the ROK Army (and doesn't impose any logistic/administrative burdens).

Differences in the 3 Stages and PSU

What really does make the difference is how each of the 3 described stages and the PSU together result in the overall performance of the image intensifier. The composition of (and the production methods for) each and all of the elements that constitute a stage within an image intensifier are highly complex (and secretive) and differ between manufacturers. Nevertheless, the most important differences will be described in as much detail as possible.

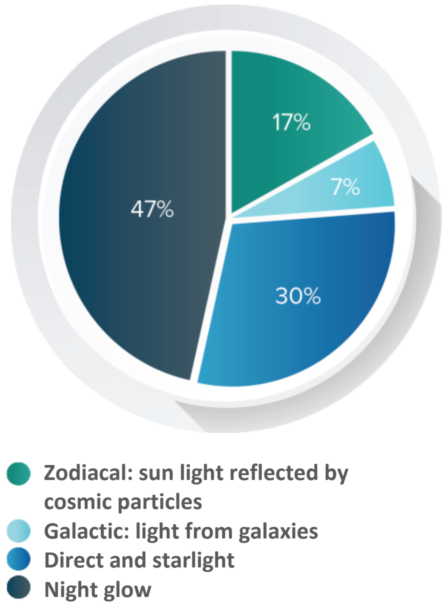
The photocathode nowadays mainly consists of either Gallium Arsenide, GaAs (as produced by L3-Harris and ELBIT USA, and against all odds still branded as Gen3) or a Hybrid Multi-Alkali, HyMa (as produced by Photonis, branded as 4G). Over time both photocathodes characteristics have been further developed and improved; and that process will definitely continue in the coming decades.

Photonis' branded 4G technology (as introduced into the market in 2014) uses a patented nanostructured photocathode providing it with a diffracted based sensitivity, increasing electro-optical absorption and broadening level of energetic acceptance of the photocathode element.

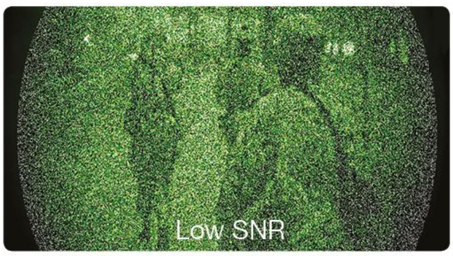


The main difference between GaAs and HyMa photocathodes is the bandwidth, or spectral range. In other words, the scope of types of light (from UV-blue to IR-red) that the photocathode is able to "absorb" and to transfer into electrons substantially differs. The bandwidth of GaAs is approx. 500 (blue-ish) to 900 (red-ish) nanometers. The bandwidth of HyMa is approx. 350 (UV) to 1100 (IR) nanometers. It is clear that the bandwidth, or spectral range, of an image intensifier with a HyMa photocathode is significantly extended (wider) than that of an image intensifier with a GaAs photocathode.

That extended bandwidth, spectral range of a HyMa photocathode has two important operational consequences. First of all, it ensures that the image intensifier performs at its very best in all types of light that come in different theatres worldwide. From the desert-like high 'blue/UV spectrum' to the jungle-like high 'red/IR' sky illumination. The later by the way, is highly dependent on night-glow (particles in the atmosphere) which, contrary to the more UV-starlight residue, is not always present! Secondly, it provides the ability to see light sources outside the visual spectrum (and thus see light that the image intensifiers with GaAs photocathodes can't see). Of course all image intensifiers can image the beam and target point of conventional individual soldier's IR laser pointers (800-950 nm). But only the wider bandwidth of a HyMa photocathode allows it to also see the 1064-laser-target designator (used by JTAC units), which the GaAs tube can't. And the HyMa photocathode also provides other options (both on the UV as well as the IR side of the spectrum) to exploit for tactical use (next-generation lasers, illuminators, pointers and beacons, like the French CILAS DHY208 or US ELBIT AN/PEQ-17). This can help the soldier to remain stealthy and thus less vulnerable.



GaAs was initially thought to be a more efficient material but that was back 30 years ago (transferring light, photons into more electrons). Now it is accepted that the signal-to-noise ratio (SNR) is the parameter describing how efficient the image intensifier deals with low light level. An image intensifier with a better signal to noise ratio will provide a better image in low light level condition than one with a lower SNR, irrespective of the photocathode material or "Generation".



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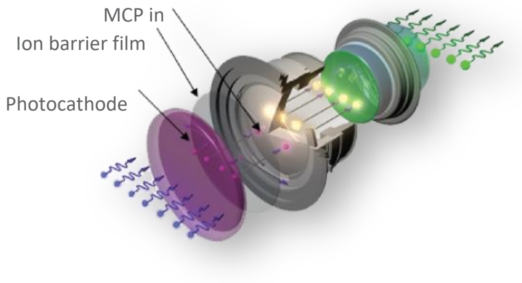
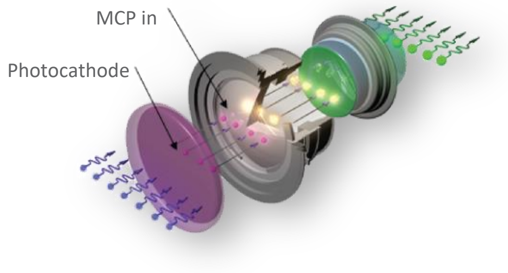
It also became evident that the GaAs material is much more fragile, losing its essential capability quite quickly, reducing the lifetime of the image intensifier drastically. To protect the GaAs photocathode from deteriorating, a ion-barrier film needed to be installed on the MCP (that is not required with a HyMa photocathode; all Photonis tubes are filmless) to protect the GaAs photocathode layer from ion feedback.

This results in two operational consequences. First of all, it makes the image intensifiers with a GaAs photocathode extremely susceptible to laser burns, causing irreversible damages. The cesium-coated GaAs surface of the photocathode is much more sensitive to damage by over exposure and especially to laser beams than the filmless HyMa photocathode as cesium chemically binds with HyMa and not with GaAs.



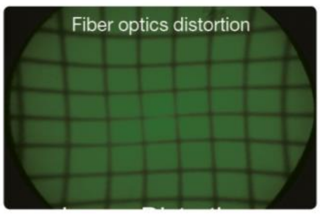


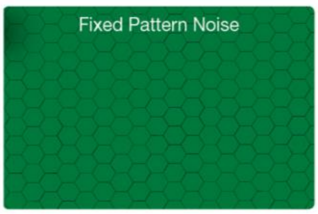
Secondly, image intensifiers with a GaAs photocathode results in bigger halos. Halos are round bright areas around the brightest spots in a scene, for example; street lights or car headlights; disturbing the overall image quality by ‘whiting out’ part or the entire image. A halo in an Image Intensifier with a GaAs photocathode would typically be around 1 mm, while the filmless 4G Image Intensifier would typically generate a halo of 0,7 mm. The smaller the halo, the better the capability to identify a possible threat (especially in urban environments). The reduced halo size in the 4G image intensifier provides clearer (less obscured) view on targets in or with light sources.

HALO 4G Technology

HALO Gen3 Technology

The 4G MCP is secret in its composition and construction but provides the highest possible focused electron multiplication, contributing to the unique, high quality, image of the 4G image intensifier. It enables higher figures of merit (higher resolution and lower noise). Photonis can provide 4G image intensifiers with 1800 FOM and far beyond. By the way, one should mind that Photonis, as a European company, is not bound by ITAR (like its competitors in the USA) and will thus provide image intensifiers which each and all at least will meet the stated values (and not the maximum values as the US competitors have to abide by). Also the image quality of 4G tube, thanks to its MCP, is far superior to that of Gen.3 tubes in terms of Fixed Pattern Noise (FPN). FPN is the disturbing honeycomb structure pattern that appears in a Gen.3 tube image when the light level becomes higher (for example an helicopter flying above a city).





The 4G power supply unit (PSU) holds a super-fast Auto-Gating (SFATG). ATG is an electronic feature that gates the voltage applied to the photocathode and MCP in such order that the optimum performance of the image intensifier is maintained in all light conditions.

The operator needs an image intensifier that performs optimally under all light conditions (in the widest possible luminance dynamic range), including dynamic light conditions (e.g. extreme light bursts of an explosion, flame bursts during shooting, a sudden illumination in a dark room, and pinpointed light such as a streetlight). That applies particularly when operating on the battlefield, in an urban environments and/or in closed buildings. The ATG enables the image intensifier to reveal mission critical details (allow non-disrupted “eyes on target”) at all times; a clear image in both dark nights and twilight (or even day time) conditions.

The benefits of the high-quality 4G SFATG can easily be seen, not only during day-night-day transitions, but also under dynamic lighting conditions when rapidly changing from low light to high light conditions such as sudden illumination in a dark room. The typical advantage of the 4G SFATG is best felt when using a weapon sight which experiences a flame burst during shooting. SFATG will avoid the temporary blindness experienced with standard image intensifiers and allow the soldier to continuously maintain “eyes on target”.

Image of explosion with super-fast Auto-Gating

Image of explosion with conventional Auto-Gating

The SFATG developed and produced by Photonis for 4G, is not only the fastest available on the market now, it is tuned in such unique way that it ensures that the nominal MTF and resolution will remain at its highest quality, even at higher night levels unlike what happens on Gen.3 tubes that see their high light level resolution drop drastically.

Even if there is an explosion the 4G SFATG can react fast, so it is not a problem as it is transparent. Regular or poor/slow ATG image intensifiers would be bloomed full white and unusable and one has to wait for it to transition for a second or so. Now 4G SFATG can do this in tens of milliseconds, it is closer to normal eye perception.

Given their special missions, SOF and Anti Terrorists Teams do appreciate this unique electronic 4G SFATG feature highly. But with operations in urban areas and/or on a dynamic battlefield, this feature is beneficiary to the operational effectiveness and safety of the regular (marine or infantry) soldier as well. Operators regularly have to move from dark or low light conditions into brighter environments such as exiting/entering a building. Yet another advance of the 4G SFATG is it provides the ability to see in lighter light conditions.

Last but not least, 4G as well as Gen.3 image intensifiers have made some nice improvement in terms of lifetime in the past decade. All tubes offer guaranteed lifetime characteristics of more than 10000 hours according to the same Mil-Spec criteria with limited performance decrease over time. As far as 4G is concerned, and as recently again proven independently by the renown Fraunhofer Institute, the SNR characteristics have a typical values drop of less than 5% over the full lifetime which largely supersedes the US MIL-SPEC

Conclusions

All current image intensifiers work on the very same principle of 3 stages with a PSU. The Generation indication is (confirmed by US Government) obsolete to indicate performance. What really is determinative, is how each of the 3 stages and the PSU together result in the overall performance of the image intensifier. And that performance can be determined in laboratories by measuring parameters like Figure of Merit, Signal to Noise Ratio, Limiting Resolution, Modular Transfer Function, Lay-out Autogating, etc, etc.

Photonis' 4G technology provides new capabilities that, based on performance specifications, not only outperform current (US) Gen3 image intensifiers, but could be used in ways that render existing Gen3 night vision blind to significant existing and evolving threats on the battlefield.

Photonis' 4G image intensifiers feature a wide spectral sensitivity from 350nm to 1100nm, a minimum Figure-of-Merit (FoM) of 1,800 and up to 2400 (without any ITAR limitations), a high light resolution higher than 57 lp/mm and a halo size of less than 0.7 millimetres. The Super-Fast ATG ensures optimum functioning in all (dynamic) light conditions.

It is not just about new technology invented in factories or theoretical criteria measured at laboratories; the proof of the pudding is in the fight. Photonis first and foremost continues to provide the end user with better operational performance; increased detection, recognition and identification (DRI) ranges, enabling the soldier to see at greater range into deeper darkness. Ultimately enabling the soldier to operate more effectively and safely than any adversary; enable him "to be the first to see".

All NATO countries have undergone the modernization of their Army Night Vision Goggles fleets since a few years, with notably a large preference towards binoculars goggles (with 2 tubes) that provide a much better image by night with depth perception. Large programs are ongoing in Germany, UK, France, Denmark, USA, Canada, Poland (but also UAE, Jordan, Morocco, KSA notably) to go for better FOM tubes, lighter equipment (less than 450g) and lower power consumption. Old equipment using XD-4 or Gen.III are usually being used for training purposes while the new gear is provided for combat and operations.

Photonis has been providing the tubes for the locally produced night vision systems for more than a decade for the Korean Defense Forces. At the start of that decade those tubes and systems were highly innovative, however more than a decade later newer better performing tubes and systems are available. The newest development (apart from further performance improvements) is the low weight, small size 16mm tubes that allow for a 30% smaller and lighter system.

Photonis hopes to deepen its long standing partnership with the Korean Defense Forces (and adjacent agencies) in the coming years, providing tubes that meet the highest standards at a reasonable price. Systems are already manufactured locally, completely by EOSYSTEMS, and Photonis is open for discussions on collaboration on further R&D on the tubes (e.g. regarding the power supply unit) and final construction of its tubes.

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