

Generation III based P45 White Phosphor Image Intensifiers

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Video rate imaging at below moonlight illumination levels is a demanding requirement for any imaging sensor. To exploit this capability in aviation, potential sensor candidates have to be capable of being packaged into a wearable goggle configuration. Wearable goggle requirements impose additional system engineering considerations. A wearable goggle design trades off size, weight, power and human factor considerations. Power consumption must be minimized to keep the battery weight down and accommodate extended hours of operation. The use of an off board power source for a goggle system would introduce the complications involved in aircraft modification. Goggles also have to be ergonomically comfortable for long term use without compromising system performance. Part of any goggle requirement is also to provide binocular imaging to enable stereo vision for depth perception. Operational procedures in the use of an aviation goggle must not compromise aircraft flight safety. Alternating between goggle assisted and unaided vision should be operationally straightforward, intuitive, and not interfere with either situational awareness or navigational pilotage.

Surprisingly, there is one imaging technology that can meet all of the above requirements: the image intensifier tube. The image intensifier tube is the key enabling technology for night time aviation goggle systems. As a comparison, a commercial off the shelf wearable solid state system, the Google Glass™ monocular, is a \$1,500 all solid state device. In terms of performance, the 50 gram Google Glass™ has a 640 pixel by 360 pixel resolution OLED display, 1/16 the imaging speed, a 2 hour battery life, and 1/5000 of the light sensitivity of aviation NVG's.



Several features of an image intensifier tube demonstrate why it is an enabling technology that enhances the safety of night time aviation. The first feature is the image intensifier's ambient light amplifying capability, an attribute which particularly stands out under less than full moon illumination conditions. The second feature is the image intensifier's extended spectral sensitivity. Image intensifiers are sensitive to parts of the light spectrum that are invisible to the human eye. These out-of-band wavelengths can provide additional, useful scene information and enhance scene contrast. Any contrast enhancement can assist in identifying night time terrain features. The third standout feature of an image intensifier is the ability to image low light level scenes at a rate of several thousand frames per second (fps). This is an important sensor capability in a low light aviation environment. Typically, solid state cameras operate at a frame rate of 30 to 60 fps under high light level conditions. High frame rates minimize sensor image lag, motion blurring and latency which are relevant concerns in aircraft flight operation. Unlike any other imaging sensor, the high frame rate of image intensifiers is automatically enabled under all lighting conditions, at full resolution with no additional or imposed hardware constraints. Light amplification, added spectral information, and high speed imaging at full resolution are all technical capabilities of the image intensifier. These technical capabilities add to the safety of night time aviation over and above the unaided human eye.

Of equal or greater importance is also how night vision goggles are used while flying at night. The correct operational use of NVG's is a necessary safety component of aviation goggle training. Training in the use of aviation goggles occurs initially in the classroom and is then transitioned to a flying environment. At ASU, the details and concept of operations for NVG's in night aviation is thoroughly covered and training is an important complementary activity to the purchase of aviation night vision goggles.

The core goggle sensor element, the image intensifier, is an integration of several sophisticated subcomponent technologies. The key technological subcomponents are the photocathode, the microchannel plate, the phosphor screen, and a compact, efficient, high voltage power supply. Figure 1 shows a schematic diagram of an image intensifier with these subcomponents identified.

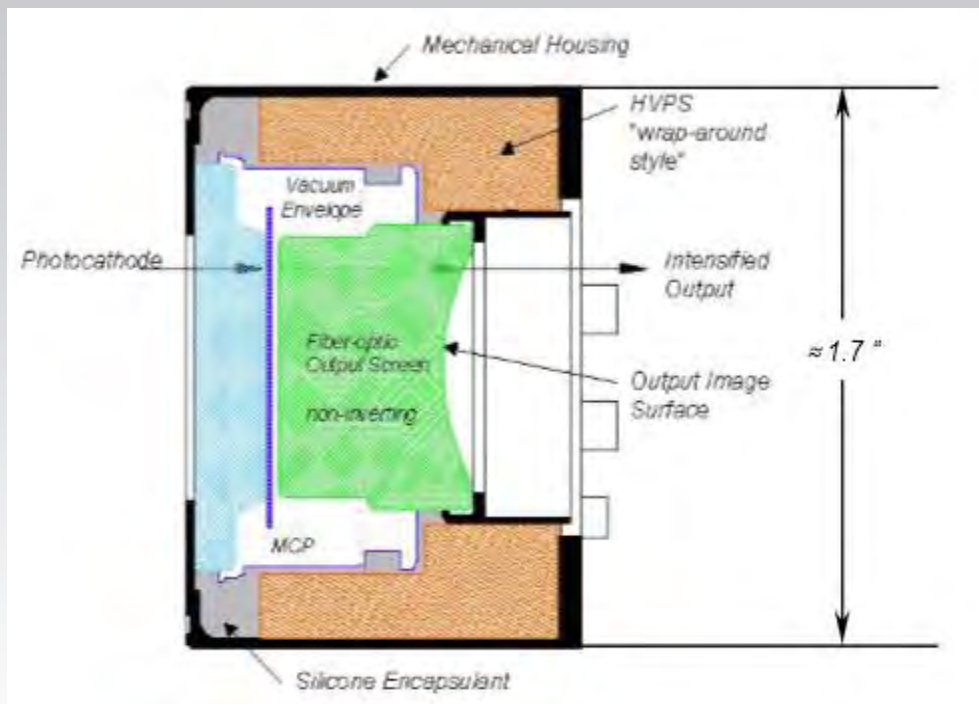


Figure 1. Schematic diagram of an image intensifier.

The goggle optics focuses light on the photocathode. The photocathode is a precisely fabricated thin layer of semiconductor material that absorbs light in a wide band from the near infrared through the visible to the ultraviolet. The photocathode is engineered to utilize as much as possible, the night spectrum of starlight, reflected sunlight and artificial lighting.

The light illuminating the photocathode layer is converted into an electrical current. The photocathode output current is directed to the input side of another component, the microchannel plate. The microchannel plate is an array of millions of conductive, small glass channels. Each microchannel plate channel amplifies the photocathode current. The output of the microchannel array is focused on the phosphor screen, which converts the amplified current back into light.

The phosphor screen is also another sophisticated, engineered component subject to several tradeoffs. Screen phosphors have to efficiently produce light from high voltage electron bombardment over thousands of hours with minimal decrease in output intensity. The screen phosphor material is filtered and sorted to produce a powder which is made up of micron sized particles having a very narrow range

of sizes. The phosphor powder is then deposited on glass to form a layer of uniform thickness. The phosphor screen thickness is a key parameter. If the screen layer is too thick, the screen resolution decreases. If the screen layer is too thin, the output brightness also decreases. The narrow range of particle sizes is important in order to have a uniform phosphor layer across the screen with the ability to resolve fine image detail.

Not all phosphor materials are suitable for image intensifier applications. In applications where it is important to image rapid changes in scene illumination, the light output of any potential phosphor candidate has to change fast enough in order to prevent image smearing. Potential phosphor candidates have to be commercially available and of high quality. The P45 white phosphor meets the above technical requirements for component insertion into image intensifiers. The P45 phosphor also has a product track record in mission critical applications as the phosphor of choice for medical diagnostic displays.

One benefit of using P45 white phosphor in image intensifiers is that it exploits the efficiency of the human visual system in processing black and white images. P45 phosphor has further advantages which are a result of its broad spectral light output. Figure 1 shows the light output spectrum of the P43 and P45 phosphors.

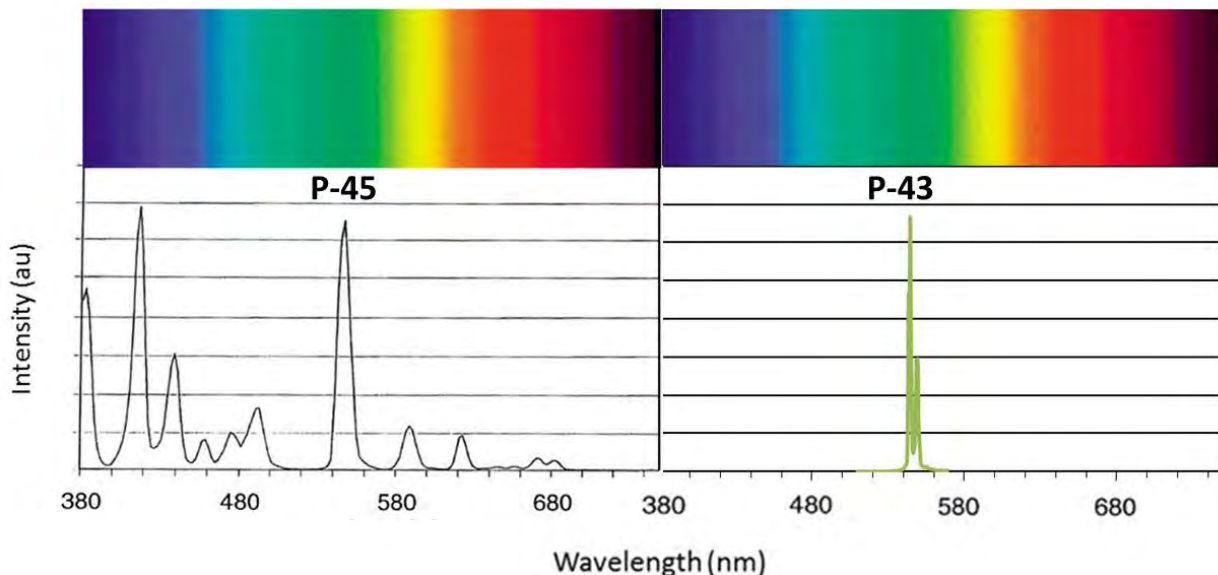


Figure 1. Side by side comparison of P45 and P43 phosphor light output by wavelength.

The light output of the P45 phosphor ranges in wavelength from violet to red, with a large fraction of the light energy in the violet to green (380nm to 500 nm) range. The P45 light energy from 380 nm to 500 nm engages the most sensitive detectors in the eye, the rod cells. In this wavelength range, the rod cells are about 3 to 10 times more sensitive than the cone cells at low light levels.

As shown by figure 2, the output of P43 which peaks at 550 nm falls short of the scotopic maximum.

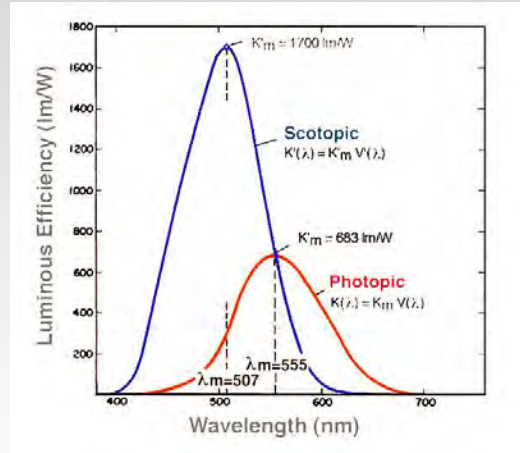


Figure 2. Luminous efficiency of the eye under scotopic(low light) and photopic conditions. (Figure 9 in Psychophysics of Vision by Michael Kalloniatis and Charles Luu

P45 exploits the low light(scotopic) sensitivity maximum at 500 nm. This effectively can increase the optical gain of the combined eye-goggle system by up to a factor of 2+ at low phosphor screen output intensities. This difference further improves scene dynamic range and contrast at low light levels. Another benefit in engaging the rod cells is in enhancing peripheral vision, because the rod cells dominate peripheral vision in the human eye.

Another potential gain in the use of P45 is a reduction in eyestrain. The P43 phosphor has a very narrow wavelength output. In an optical system, the focus is not only a matter of distance to the image but the image focus also depends on wavelength. This is an issue for the eye optics. The problem then with the narrow wavelength output P43 phosphor is that the eye optics must continually compensate for any slight movements to keep the scene in focus. With a broad spectral output such as provided by the P45 phosphor, the strain in compensating for changes in the eye focus distance should be reduced.

White phosphor night vision aviation goggles offer all of the advantages of image intensifier technology along with the visual benefits of P45 white phosphor. The advantages of P45 white phosphor is that it engages the efficiency of the human visual system in processing black and white images. The spectral output also illuminates the rods in the human eye at the peak in their spectral sensitivity. The rods are not only most sensitive photoreceptor in the eye, but also dominate human peripheral vision. Finally, the broad band nature of the P45 phosphor light output should reduce eyestrain in maintaining focus.

