DATASHEET
DETECTORS
Image Intensifiers

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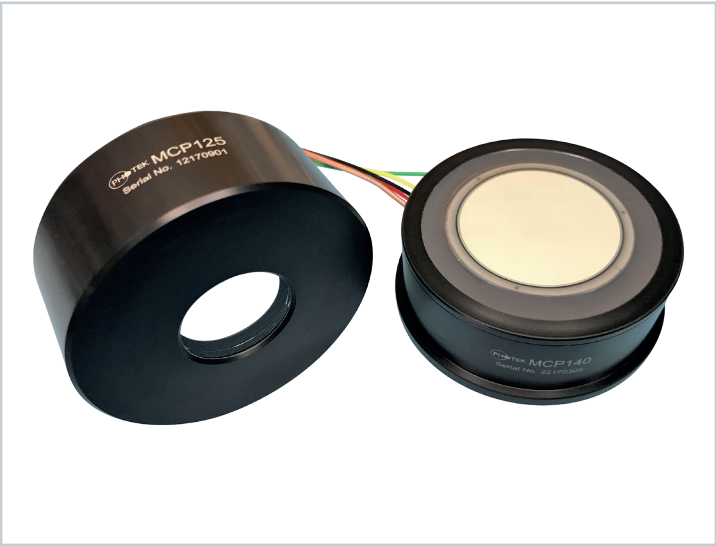
Image Intensifiers

Amplify low light levels



Key Attributes

- 18, 25, 40 and 75 mm active areas available as standard, other sizes available upon request
- Can be customised for specific applications
- Wide range of photocathodes including UV, solar blind, visible and NIR response
- Proximity focussed providing low distortion
- Fast gating to <200 ps
- Able to function in high magnetic field environments

Photek's range of image intensifiers provides the highest performance in terms of resolution, speed of response and in service reliability to deliver photonic measurements for world class scientific research.

Photek manufactures 18, 25, 40 and 75 mm image intensifiers and the world's largest image intensifier with 150 mm active diameter.

A range of photocathodes and input window materials enable a wide choice of spectral responses; UV, visible and NIR, to suit many applications. A variety of MCP configurations satisfies all gain requirements.

Our image intensifiers can be supplied with integral high voltage power supplies and ultra-high speed gate units customised to meet the requirements of your specific application.

Applications

- Bioluminescence
- Corona imaging
- Fluorescence lifetime imaging
- High speed imaging
- Low light level imaging
- Missile warning systems
- Photon counting
- Security detection systems
- Space science
- Spectroscopy
- Threat detection systems
- Time resolved imaging

Principal of Operation

Image Intensifiers are light amplifiers that can detect and image objects at extremely low light levels. The largest application for Image Intensifiers is in nightvision devices, used to “see” at night under moonlight or starlight conditions. Photek specializes in bespoke Image Intensifiers for use in scientific and industrial applications where low noise, high sensitivity and very fast gating down to nanoseconds provide unique capabilities.

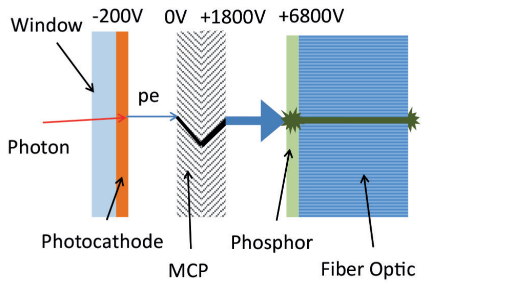


Figure 1: Cross-section of an Image Intensifier and sketch of its operational.

An image intensifier is a vacuum tube having three key components illustrated in Figure 1); an input window with photocathode to detect light and convert it into photo-electrons 2) a microchannel plate to amplify the electron signal and 3) a phosphor screen anode to convert the amplified electron signal back into light. Operation within a vacuum is required to enable the photo-electrons to be accelerated to high speeds without being impeded by gas molecules. Vacuum also enables very low noise amplification, difficult to match with other technologies. Photek Image Intensifiers are available in sizes from 18 mm to 150 mm diameter with millions of resolution elements per image.

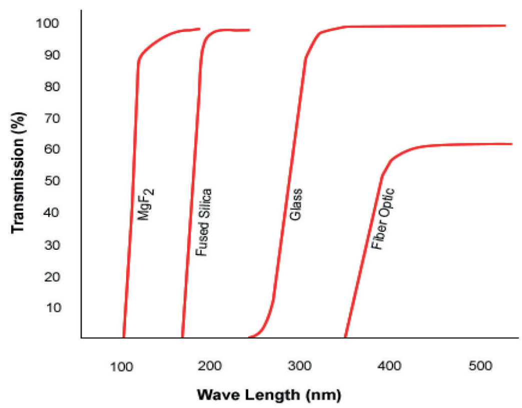


Figure 2: Transmission of input windows.

PHOTOCATHODE

The input window of an image intensifier is selected to have good transmission for the light being imaged and typically determines the short wavelength response of the image intensifier. Example window materials are given in Figure 2. The photocathode is a thin film semi- conductor grown on the inside surface of the glass input window. The photo-cathode material is selected to provide high sensitivity to the light being imaged. When a photon, or quanta of light, is absorbed in the photocathode an electron is freed and can be emitted from the vacuum surface of the photocathode as a photo-electron (pe). The photocathode’s Quantum Efficiency (QE) is defined as the ratio of photoelectrons emitted from the photocathode’s surface (N_{pe}) to the number of photons incident on the photocathode ($N_{photons}$).

$$QE = \frac{N_{pe}}{N_{photons}}$$

The photocathode material also determines the spectral response and sensitivity of the image intensifier. Common types of photocathodes and their spectral responses are given in Figure 3.

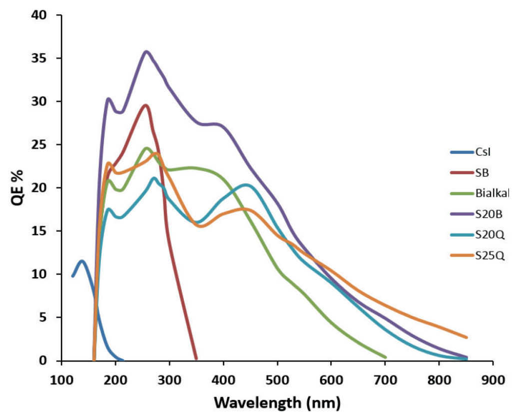


Figure 3: Spectral response of available photocathodes. Note that the underlay on the cathode can affect the QE.

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ELECTRON MULTIPLIER

The photoelectrons are accelerated through a gap to 200V and strike the Micro-Channel Plate (MCP), a glass capillary plate which has been processed to function as an electron multiplier. A typical 25 mm diameter MCP has 6 µm pores on 8 µm centers with a pore Length-to-Diameter (L:D) ratio of 43:1, giving a total thickness of 258 µm.

When a photoelectron strikes the wall of an MCP pore it produces secondary electrons that are accelerated toward the anode by the applied bias voltage of roughly 900V per MCP, striking the pore walls and causing more secondary electrons, with the full electron cascade resulting in a gain of up to 10,000 e^-/pe in a single MCP. With multiple MCPs stacked together gains of up to 10^7 e^-/pe are possible.

PHOSPHOR SCREEN ANODE

The electron cloud leaving the MCP is accelerated through a large voltage, typically +5 kV, to the output phosphor screen, where its energy is converted back into light, completing the light amplification process. Selection of the phosphor is based on its emission efficiency, wavelength and decay time (see Table 1).

The phosphor screen is deposited on one of three main types of output windows; borosilicate glass, fibre optic, or fibre optic taper. A standard glass window is only used when the image intensifier is going to be viewed through a lens system that images the phosphor through the window. A fibre optic window transfers the phosphor image to the output surface of the window where it can be coupled directly to a CCD or a lens system can image it.

If the image intensifier is too large to directly couple to a CCD, an integral fiber optic taper can be used as the output window providing demagnification to match the CCD. A transparent conductive film is standard on all fibre optic anodes and is used to discharge static buildup on the anode to ground.

Table 1: Phosphor Screens

Type	Peak Wavelength (nm)	Relative Efficiency	Decay Characteristic
P20	540	1.33	1 ms to 1% with weak long decay component
P43	548	1	1.2 ms/decade, true exponential
P46	530	0.23	300 ns
P47	410	0.27	80 ns

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Spatial Resolution

Spatial Resolution is measured by viewing a series of alternating black and white lines of differing pitch. The pitch at which the contrast between the lines drops to 5% is defined as the limiting resolution and is measure in line pairs per mm (lp/mm). Table 2 gives typical limiting resolution for P43 phosphor on a fibre optic output and for different Image Intensifier sizes and MCP configurations. Since there are a number of contributing factors to this specification, including Photocathode-to-MCP gap, MCP pore size, number of MCPs, the phosphor grain size and thickness, and the output window characteristics it is best to contact Photek for the resolution specification for your configuration.

Table 2: Resolution

Diameter (mm)	Active Area (cm^2)	Typical Limiting Resolution (lp/mm)	
		Single MCP	Dual MCP
18	2.54	50	25
25	4.91	45	23
40	12.6	33	20
75	44.2	16	14
150	177	10	6

Gating Options

An Image Intensifier can be gated on and off by changing the voltage applied between the photocathode and MCP. Normally the input electrode on the front MCP is held at ground potential while the photocathode is at -200V. If the photocathode is reverse biased +50V, electrons are unable to flow to the MCP and the image intensifier is “gated off.”

Photek manufactures a range of gating modules, power supplies and controllers to provide this function. With special underlayers on the input window gating speeds of a few nanoseconds or less can be achieved. Gating can be used as an optical shutter to capture high speed phenomena with excellent clarity, freezing the motion to a few ns. Gating can also be used to quickly turn off the image intensifier to prevent unwanted signal from being detected. The ability to gate the image intensifier synchronized with a laser or other bright light source is unique and one of their most useful features.

Please note that gating performance is a function of cathode type, underlay and area. Larger area detectors gate slower than smaller area detectors. Additionally, cathode type can affect the gating speed. Please contact Photek for further details and advice.

Table 3: Gating Options for 25 mm (S20)

Minimum Gate Width (ns)	Transmission Loss (%)	Notes
500	0	Standard
50	~10%	200 nm - 900 nm
10	~30%	200 nm - 900 nm
< 1	~10%	350 nm - 900 nm TCU
3	~40%	200 nm - 900 nm
< 3	19%	Fine mesh

Photon Counting

A useful property of MCPs, when operated at very high gain, is a phenomenon known as gain saturation. When the electron cloud within a single pore becomes large enough its continued amplification is limited by space charge effects, setting a maximum number of electrons in the pore once saturation is reached. The result is that the distribution of gains for a single photoelectron becomes tighter and a clear peak appears in a pulse height distribution of the output pulse, as illustrated in Figure 4. As additional MCPs are added the distribution becomes more pronounced, and true photon counting operation is achieved.

Another benefit of this high gain operation is that the centroid of the charge cloud produced by a single photoelectron can often be localized to within a pore diameter, better than the quoted limiting resolution. Image intensifiers are unique in their ability to provide photon counting over large areas with high spatial resolution and low noise.

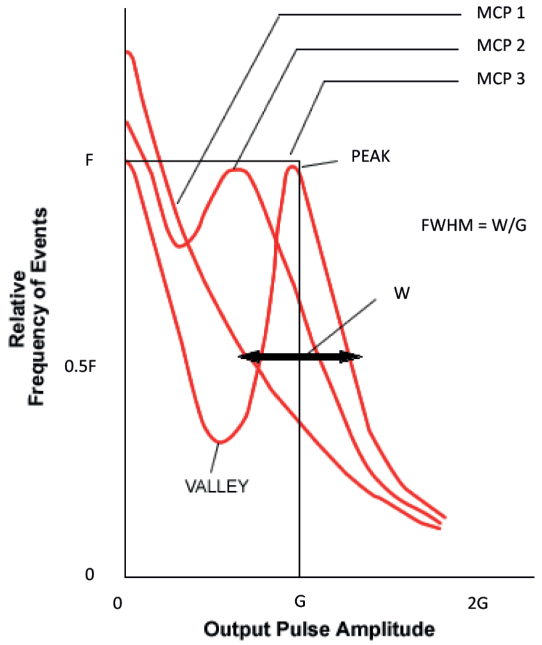
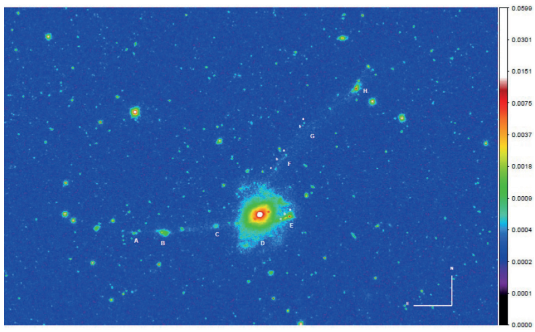


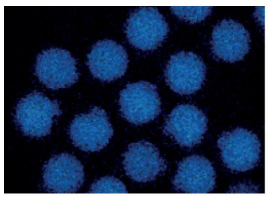
Figure 4: Single photoelectron pulse height distribution for different MCP configurations.

Application Examples

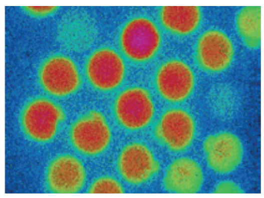
Composite Near Ultra Violet (NUV) and Far Ultra Violet (FUV) image of the post-merger galaxy NGC7252 as observed by the UV Imaging Telescope (UVIT) on board the Indian astronomy satellite ASTROSAT (George, K. et. al. 2018, A&A, 613, L9.) UVIT uses three Photek 40 mm dual MCP Image Intensifiers covering wavelengths ranges of FUV (130 - 180 nm), NUV (200 -300 nm) and VIS (320 - 550nm) fiber optically coupled to CMOS image sensors.



Accumulated photons emitted from mouse eggs for a 10 minute window during an experiment that lasted several hours. The chemiluminescent light is from a luciferase fusion protein (PLCz-luciferase) that is expressed in the eggs and shown in the left image. The right image is the fluorescent light emitted during epifluorescent illumination at 490 nm of a Ca2+ sensitive fluorescent dye loaded into the same eggs.



Chemiluminescence of luciferase



Fluorescence of Ca^{2+} dye

Images courtesy of K Swann - Cardiff University School of Medicine.

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Table 4: Typical Performance

Photocathode	Spectral Range [1] (nm)	Peak Wavelength (nm)	QE Quantum Efficiency [2] (%)	Gγ Photon Gain [3] (ph/ph)		EBI [4] (typical max)	
						ph/cm^2s	lux
S20	175 - 800	440	20	1 MCP	1×10^4	2000	2×10^{-7}
				2 MCP	2×10^6		
S20B	175 - 800	260	35	1 MCP	2×10^4	5000	2×10^{-7}
				2 MCP	4×10^6		
Bi-alkali	175 - 700	350	22	1 MCP	1×10^4	50	2×10^{-7}
				2 MCP	3×10^6		
S25	175 - 950	460	17	1 MCP	1×10^4	20,000	2×10^{-6}
				2 MCP	2×10^6		
Solar Blind	175 - 340	260	30	1 MCP	2×10^4	5	n/a
				2 MCP	3×10^6		
CsI	115 - 200	130	10	1 MCP	7×10^3	5	n/a
				2 MCP	1×10^6		

All specifications quoted are typical for a 25 mm tube with a Fused Silica input window having no gating under-layer and P43 phosphor on a fiber optic output window.

1. Lower wavelength cut-off is determined by the input window given in Figure 2, Fused Silica is assumed except for CsI which uses MgF2.

2. Quantum Efficiency measured at stated peak wavelength with no gating under-layer, see Figure 3 for wavelength dependence and Table 3 for gating options.

3. Photon Gain is typical maximum photon gain at stated peak wavelength for single MCP and dual MCP tubes respectively, measured as P43 photons generated per incident photon at the peak wavelength.

4. EBI is the Equivalent Background Illumination. Under normal operation an Image Intensifier output has background emission from the phosphor, even when no light is applied. Most of this background is due to thermal excitation of the photocathode. The first column gives the input photon flux at the peak wavelength required to generate signal equivalent to the background, measured in units of photons/cm2s. In addition we give the Luminous EBI measured in lux, a common measurement used for direct view applications. The EBI is provided for 20°C operation and at the stated Photon Gain. For photon counting applications the EBI is equal to the maximum dark count rate.

Typical maximum photon gain for a specific input wavelength and phosphor screen is given by

$$G\gamma(\lambda) = G\gamma(\lambda_{max}) \times \frac{QE(\lambda)}{QE(\lambda_{max})} \times \eta_{phosphor} \quad (Eq.1)$$

where $G\gamma(\lambda_{max})$ and $QE(\lambda_{max})$ are given in Table 4, $QE(\lambda)$ is taken from Figure 3 and $\eta_{phosphor}$ is the relative efficiency from Table 1.

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Radiant and Luminous Response

Contact Photek for more information on specifications of Image Intensifier performance including Radiant and Luminous response as well as details on spatial resolution and gating.

Quality Specifications

UNIFORMITY

Non-uniformity is mainly caused by gain variations in the MCP and can be removed by digitisation in photon counting applications. Uniformity can be measured by scans across the complete tube in x-y axis, or in a defined zone using a standard Deviation/Mean measurement - see Table 5.

BLEMISHES

Most of Photek image intensifiers are sold for applications with CCD or CMOS sensors and employ a square or rectangular quality zone.

No bright spots are allowed inside the quality zone. Typical specification for dark spots within the quality zones are shown in Table 6.

Table 5: Uniformity

Size	X-Y Scan (Typical)	Standard Deviation
18 mm	±10%	7%
25 mm	±12%	10%
40 mm	±15%	12%
75 mm	±17%	15%

Table 6: Blemishes

Size	MCPs	Dark Spots	
		75-100 µm	101-150 µm
25 µm	1	< 3	< 2
25 µm	2	3	2
40 µm	1	4	2
40 µm	2	6	2
75 µm	1	10	5

Part Numbers

Image intensifier part numbers start with MCP and are built up as follows:

MCP	Size	Input	Cathode	Phosphor	Output
1	18	**F** (fibre)	CsI	P20	**IFO** (fibre optic)
2	25	**Q** (fused silica)	SB	P43	**GL** (glass)
3	40	**G** (glass)	BI	P46	**ITA** (fibre taper)
	75	**M** (MgF_2)	S20B	P47	
	150	**S** (sapphire)	S20	FS	
			S25		

Example:

MCP125/Q/S20/P43/IFO
is a 25 mm diameter single MCP Image Intensifier with a fused silica input window, S20 photocathode, and P43 phosphor on a fibre optic output window.

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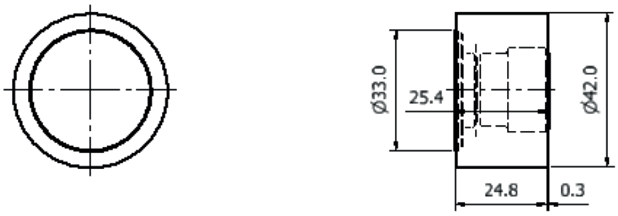
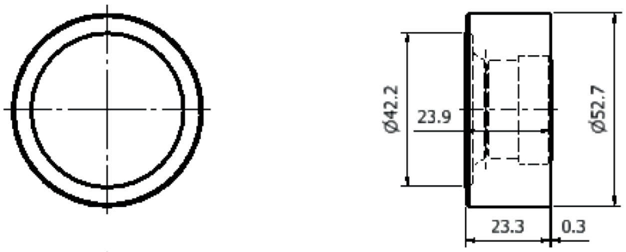
Mechanical

OUTLINE DRAWING

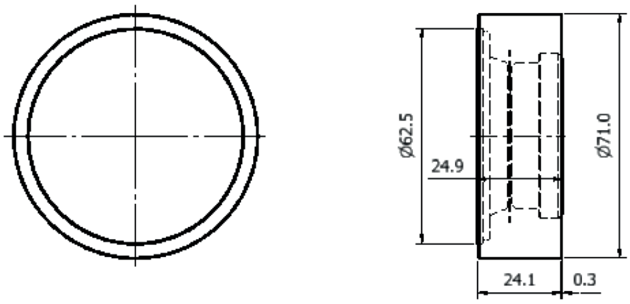
18 mm



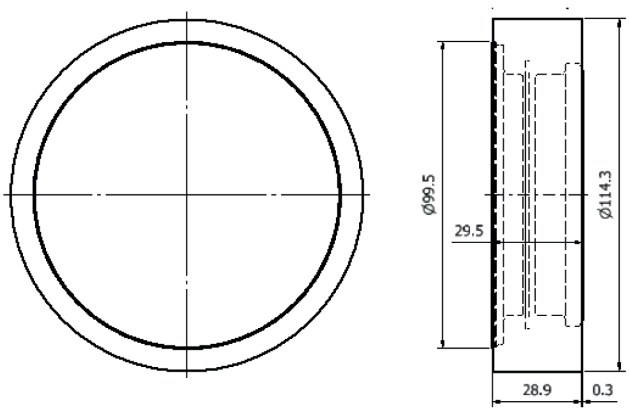
25 mm



40 mm



75 mm



Dimensions are indicative and may very depending on the optics, number of MCPs and housing required.

Environmental

Operational Limits: -40°C to +45°C
Storage: -40°C to +60°C

Note: Contact Photek for extreme temperature solutions.

ENVIRONMENTAL TESTING

For applications where the image intensifier is exposed to temperature and shock conditions Photek has the appropriate facilities to offer environmental stress screening. Our vibration system offers shock, sine, random, and sine-on-random testing. Our thermal chamber has a temperature range of -75°C to +160°C and can control humidity from 10% to 98%.

Power Supply & Gate Units

Photek designs and manufactures a range of power supplies and gate modules for our image intensifiers. Our power supplies use the very latest in power supply design and are available in either flat pack or wrap around formats.

Our gate modules can gate down to 3 ns with a 200 KHz repetition rate (model dependant) and are used for high brightness or fast optical shutter applications.

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About Photek

Photek is a specialist manufacturer of vacuum based tubes and camera systems for photon detection.

Our product range includes; Camera Systems, Image Intensifiers, Photomultiplier Tubes, Streak Tubes plus a range of associated electronics.

We are experts in large area and ultra-high speed imaging and advanced photon counting camera systems.

Our continuing success is built upon continuous innovation and product development, and by harnessing and applying knowledge to find solutions for all of our customers' applications.

Photek is accredited to ISO 9001 and ISO 14001.

Contact Us

Our team of specialist engineers and scientists are ready to discuss your application requirements in depth.

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