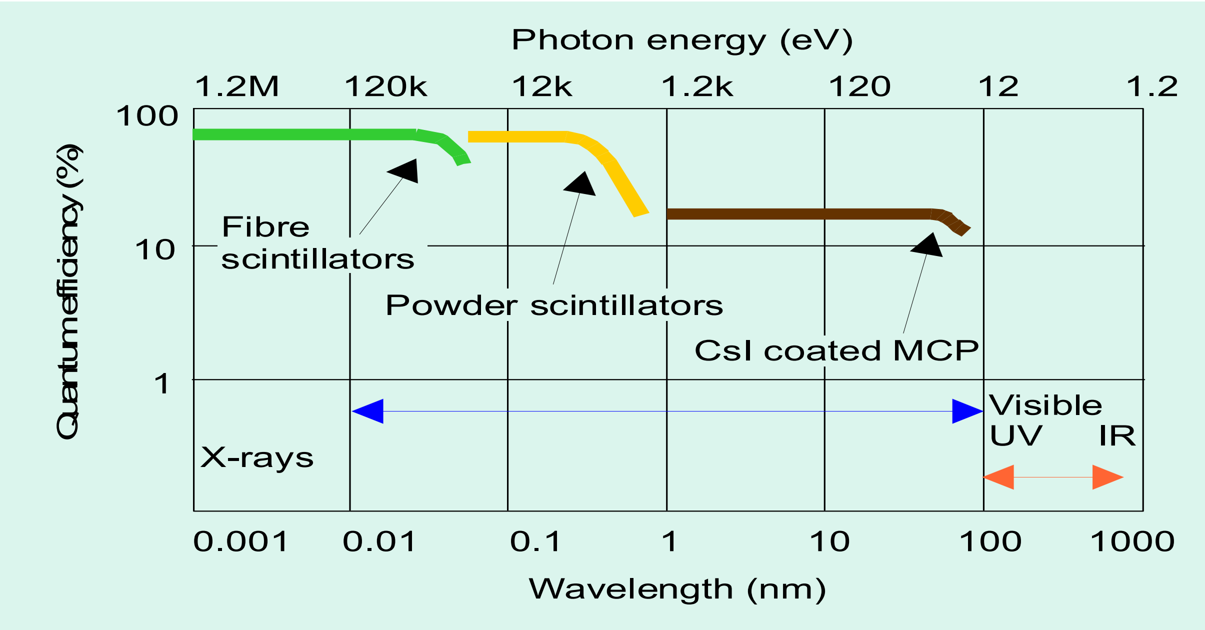
# UV-X-γ-ß AND PARTICLE IMAGING SYSTEMS




## FEATURES

- 25, 40, 80, 150 mm input diameter
- Real time analogue ICCD systems
- Extreme sensitivity photon counting systems
- Vacuum UV
- Scintillator-visible systems with high QE conversion from 5 kv to MeV X-rays
- Neutron and other particle scintillators
- Small, compact, low distortion proximity focus tubes
- User friendly mouse controlled software

## APPLICATIONS

- Non destructive testing
- UV X Spectroscopy
- Astronomy
- X-ray crystallography
- Small angle X-ray crystallography
- Neutron imaging
- γ ray imaging
- ß Auto Radiography
- Nuclear particle track imaging

## General Introduction

Photek manufacturers a wide range of image intensifier from 10 to 150 mm active diameters. These can be coupled to a suitable scintillator to match customers' requirements, and to provide imaging covering the electromagnetic spectrum from UV to high energy gamma rays and particles. Coupling to film backs, CCD cameras and photon counting systems with PC interface and full 32 bit image processing software can also be undertaken. All Photek camera systems are manufactured to individual customer specification and requirement, and are optimised for that purpose.

## Sensitivity/Energy 10 eV – 1 keV (VUV)

Photons in this energy range are strongly attenuated by air, but can be imaged in vacuum by phosphor screens, or micro channel plates. The detection efficiency of a microchannel plate for photons is a functions of incidence and photon energy. Typical efficiency is 10% falling away at both low energy and high energy

The efficiency can be increased to around 20% by coatings such as CsI, but the thickness of this should be optimised for the desired photon energy.

Photek work closely with the Space Science Centre at Leicester University to provide optimally coated photocathodes for micro channel plates.

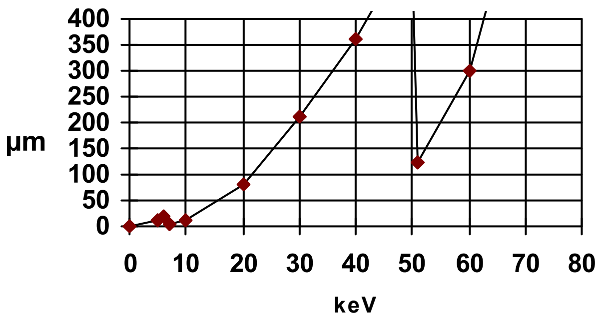



**Figure 1 – Thickness of $Gd_2O_2S$ Required for 90% Absorption**

**1– 50 kV**

Inorganic powder scintillators provide 20 – 30 visible photons per absorbed kV and can be efficiently coupled with a fibre optic block to an image intensifier or photon counting tubes. With a quantum efficiency of typically 10% at the image tube photocathode, it can be seen that every X-ray photon will generate several photoelectrons, ensuring an almost completely efficient detection probability.

At high photon energies the thickness of the scintillator required for good absorption efficiency, increases as shown in Figure 1.

The spatial resolution is approximately equal to twice the thickness of the powder applied, so that, for example at 18 kV the limiting resolution will be 100 microns for a scintillator capable of absorbing 90% of available photons.

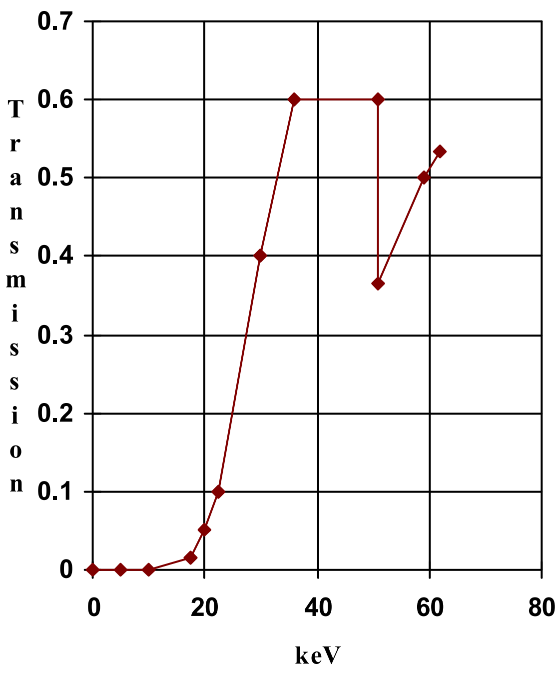



**Figure 2 – Transmission of a 100 Micron Thick $Gd_2 0_2 S$ Scintillator**

**Time Resolution**

The time resolution of image intensifiers and micro channel plates is largely dependent on the readout system. For example, Photek make X-ray sensitive streak camera tubes with resolution down to about 3 ps, and MCP based photomultipliers can achieve pulse width down to 150 ps FWHM with timing jitter down to 40 ps from one pulse to another.

Photomultipliers with beryllium input window are available for timing X-ray pulses in an open environment, or for attaching to vacuum chambers for the vacuum ultra violet and very soft X-ray energy regime.

For systems using a scintillator to convert high energy photons

**10 kV Upwards**

Terbium glass fibre optic scintillators offer an easy solution for X-ray and y-ray detectors at higher energy. The conversion efficiency is lower at around 10 photons per keV, but since all the light is channelled down the 15 micron fibres, the thickness can be made whatever is necessary to achieve efficient absorption. Resolution is typically 50 microns or better, and is largely independent of the photon energy.

Other new glasses are becoming available that are ore efficient that terbium doped material (Reference 1).

**Sensitivity**

Real-time radiographs are easily made with micro focus X-ray sources (40 kV, 100 µA anode current) using single stage intensifier couple to a CCD camera. The energy required is for a single frame with reasonable definition is of the order of 1 milli Rad.Output is proportional to the input flux density for about 3 orders of magnitude from about $10^{-6}$ Rad/cm$^2$. Lower flux density signals can be detected by increasing the integration time (slower frame rate on the camera) or by integrating several images into a computer buffer memory. CCD readout noise is not reduced by either technique and the maximum light/dark ratio that can be reliably achieved with a video readout is approximately 256:1 (8 bits digitisation).

**Resolution**

The resolution at the scintillator is approximately 50 microns. This is the primary limit for 25 and 40 mm systems. With 75 and 150 mm systems the resolution will be limited by readout electronics. For example a 75 mm sensor readout with 768 x 585 CCD results in a pixel size of over 100 microns at the scintillator, so benefit from higher

**Photon Counting Systems**

Photon counting systems are 10,000 times more sensitive than video systems, since they are able to detect signal levels down to 1 photon/pixel/hour. Resolution can also be greater. Photek can supply systems with a resolution of up to 3080 x 2304 pixels by using software interpolation methods developed by ESA and the astronomical community. These cameras can operate in both an analogue (high count rate) and digital (photon counting) mode, giving very high dynamic range and also feature electronic zoom. Photon counting systems are suitable for applications with low flux rates, and at present they are limited to a maximum count rate of 100,000 photons/second (very approximately 10 micron Rad/sec). Nearly all the electronic and tube related noise is removed by the photon counting system, and the accuracy of the data is largely dependent upon the time and patience of the experimentalist. Images to 16 bits are stored in the image processor, and manipulation of this data is accomplished 32 bit imaging software.

**Neutron Imaging**

Thermal neutrons are easily imaged with our cameras using commercially available neutron scintillators such as NE426. This is made from ZnS doped with lithium 6 and has a resolution of about 0.1 mm (Reference 2).

**ß Auto Radiography**

All the scintillators described for X-ray detection can be used for ß particles with similar conversion efficiency expressed in visible photons/keV. The absorption of ß particles is much stronger than X-rays, enabling much thinner scintillators to be used. Photon counting cameras are therefore much more senstive than photographic film and give immediate quantitative data without the need for plate calibration and scanning. Both pathological analysis and living tissues can be studied using radioactive tracers such as carbon, phosphorus tritium etc. (Reference 3).

**Particle Imaging**

Low energy particles such as electrons ions, atoms and molecular fragments are conveniently detected in vacuum by a microchannel plate (References 4 & 5). At higher energy above 100 keV in SEMs etc conventional phosphors are the obvious choice. For nuclear physics, our detectors are conveniently attached to arrays of scintillating plastic optical fibre. Photek image intensifiers and photon counting tubes are used in CERN and are chosen for the ACE explorer satellite system for reading out arrays of scintillating plastic fibre.

**References**

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