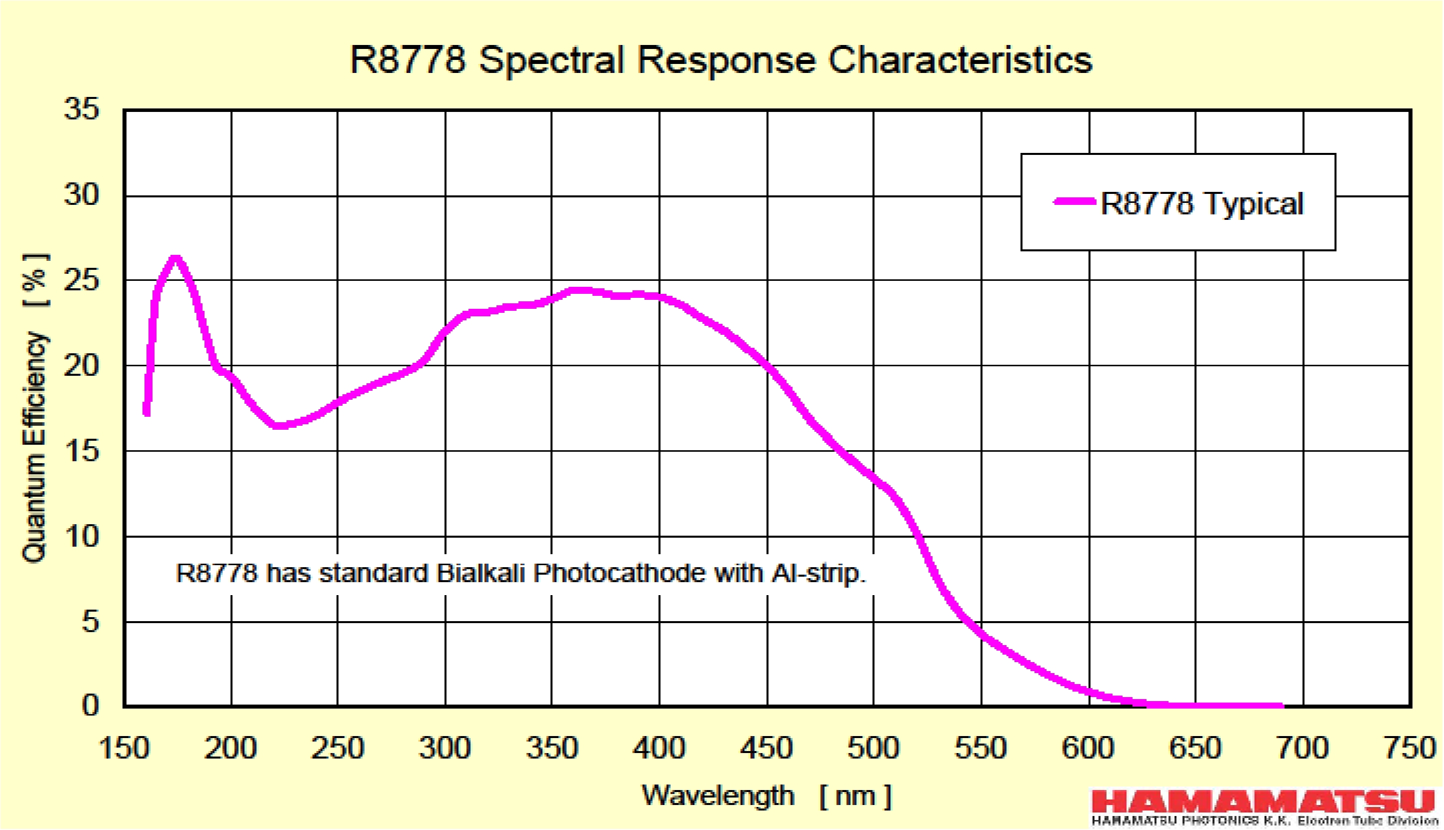
CAN A PHOTON GENERATE MORE THAN ONE ELECTRON?

Jon Howorth

Ralph Powell


R8778 Spectral Response Characteristics
R8778 Typical
R8778 has standard Bialkali Photocathode with Al-strip.
Quantum Efficiency [%]
Wavelength [nm]
0
5
10
15
20
25
30
35
150
200
250
300
350
400
450
500
550
600
650
700
750
HAMAMATSU
HAMAMATSU PHOTONICS K.K. Electron Tube Division

Some Ultraviolet Spectral Sensitivity Characteristics of Broadband Multialkali Photocathodes

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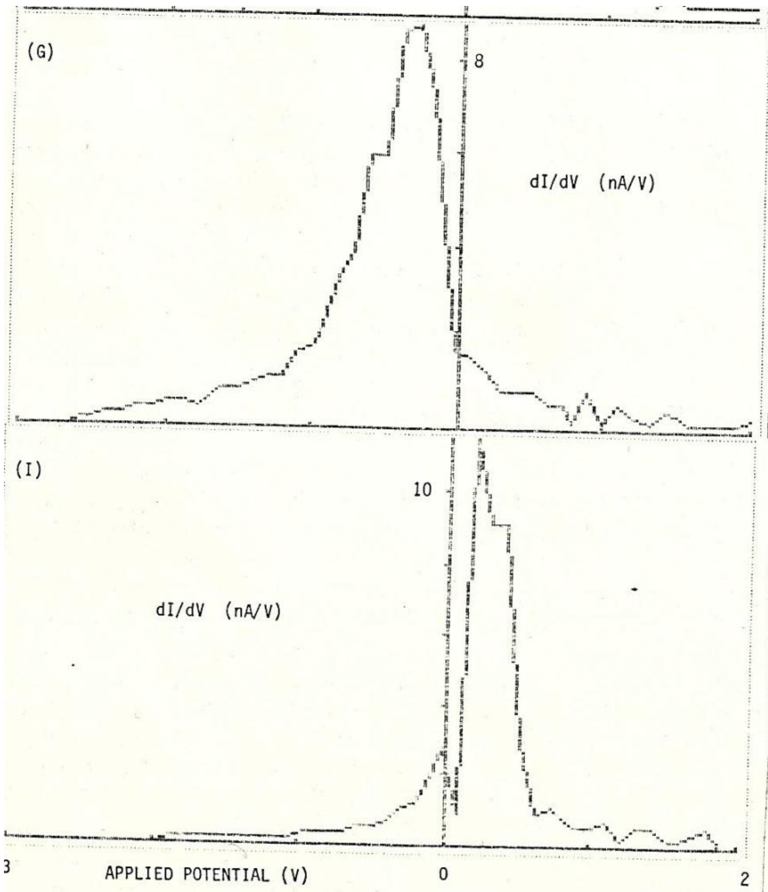
Electron Energies Distribution



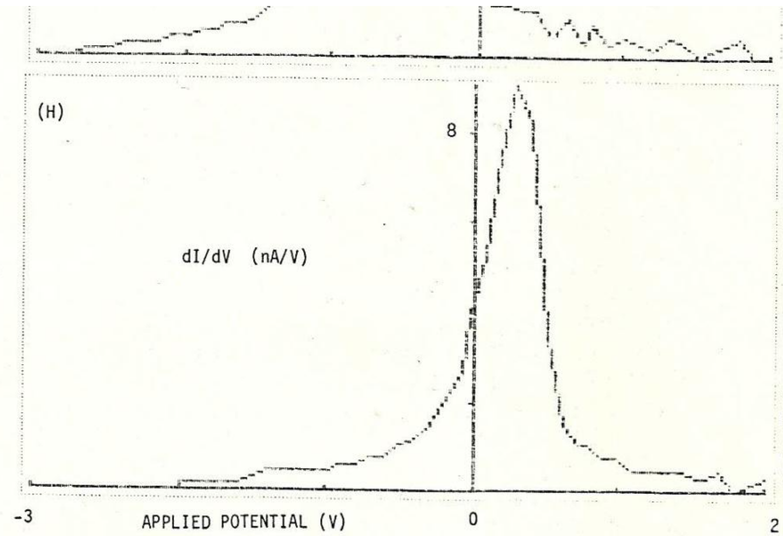


Figure 3. dI/dV versus Diode Applied Potential, tube as described in Fig 2:

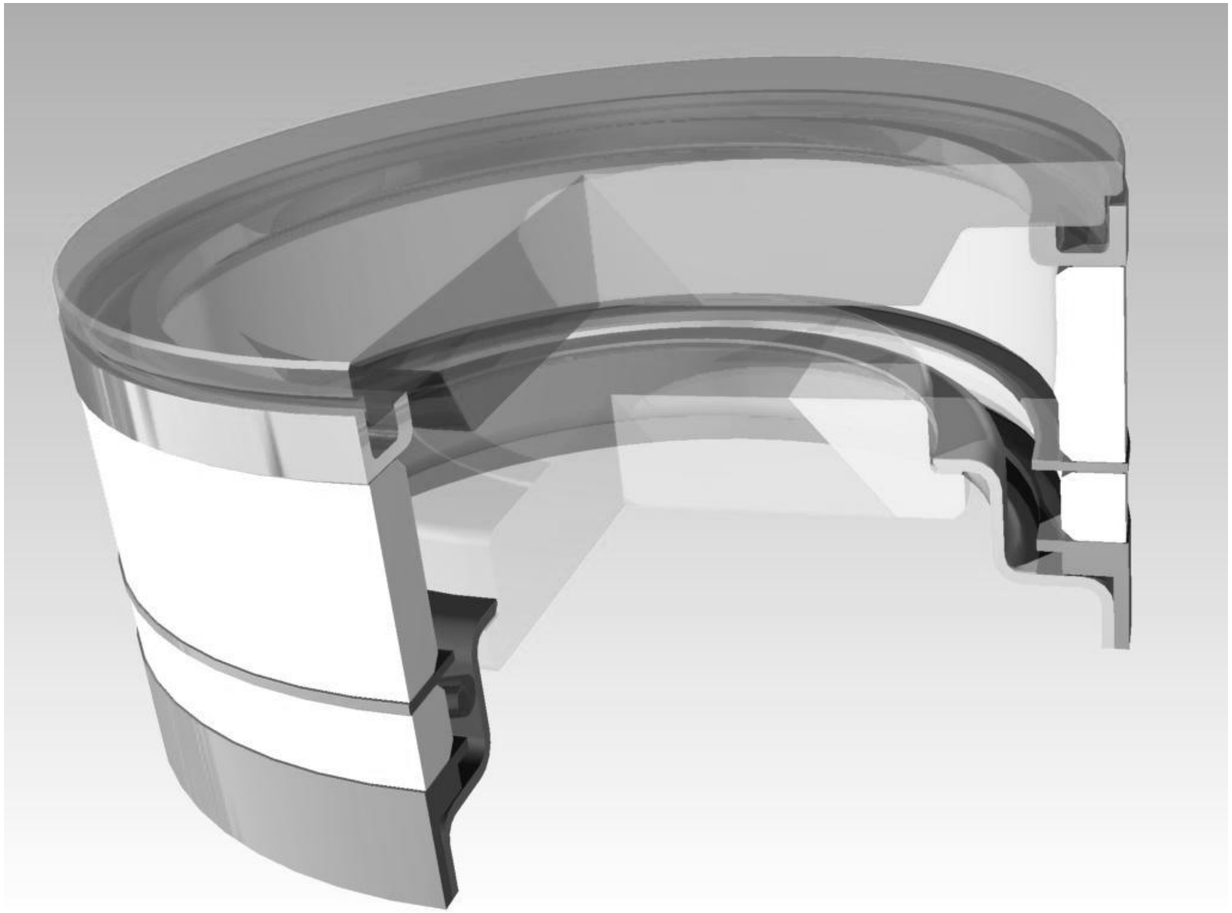
(A) λ = 850 nm, (B) λ = 500 nm, (C) λ = 450 nm,

(D) λ = 340 nm, (E) λ = 290 nm, (F) λ = 280 nm,

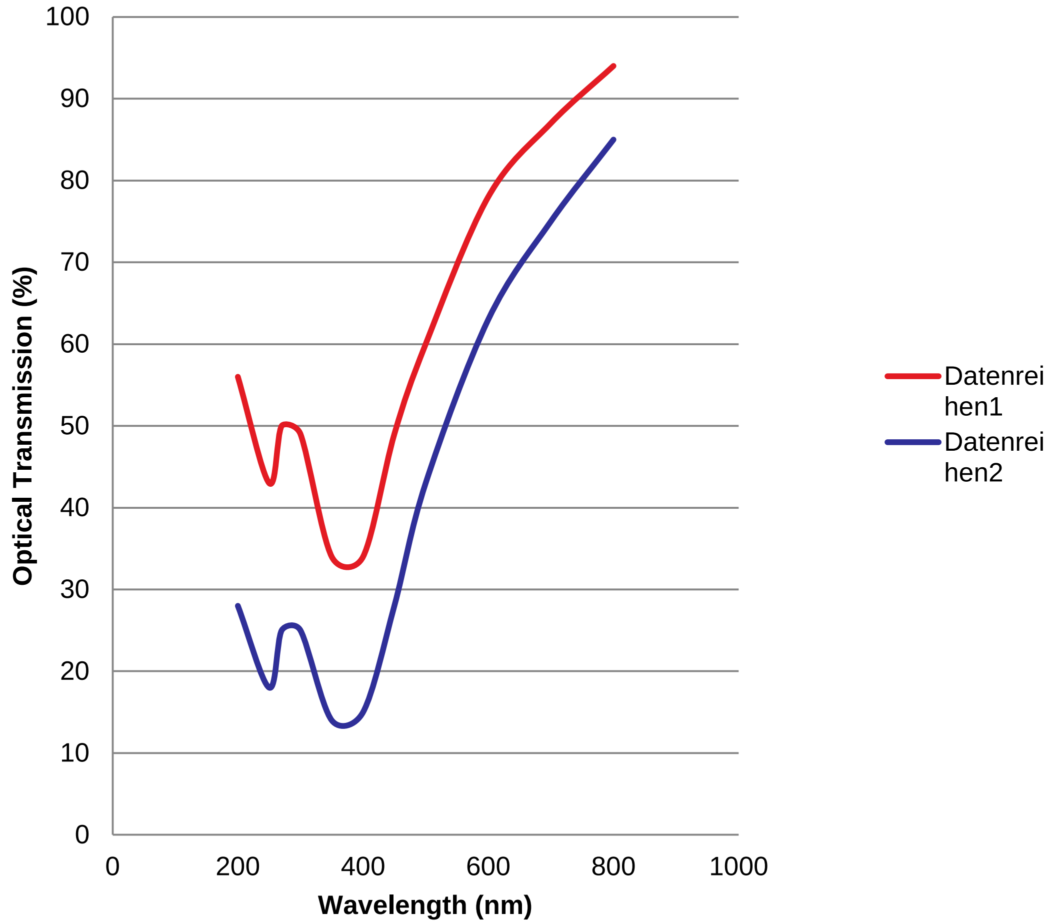
(G) λ = 270 nm, (H) λ = 250 nm, (I) λ = 221.4 nm

We first formulated the following simple physical model to explain this behavior. Low energy photons, near the threshold of photoemission, impact with enough energy to excite valence band electrons into the conduction band with sufficient excess energy to overcome the electron affinity at the photocathode-to-vacuum interface and escape into the vacuum. As the photon energy increases more electrons are excited into the conduction band in greater numbers and with greater energies, and the photocurrent increases. This trend continues with increasing photon energy until electrons arrive at the conduction band with sufficient energy to generate additional hole-electron pairs at collisions with the lattice. These inelastic collisions produce two slow electrons that have a lower combined probability to escape into the vacuum, and the photocurrent begins to fall with increased photon energy. As the photon energy continues to increase, a point is reached for which the primary and secondary electrons have sufficient combined energies to escape from the photocathode in sufficient numbers to cause the photocurrent to increase to a second maximum, ie n = 3. At the next maximum, two hole-electron pairs are generated by the primary high-energy electron, and the resulting three slower electrons have a combined lower probability to escape, and the photocurrent drops as the photon energy increases.

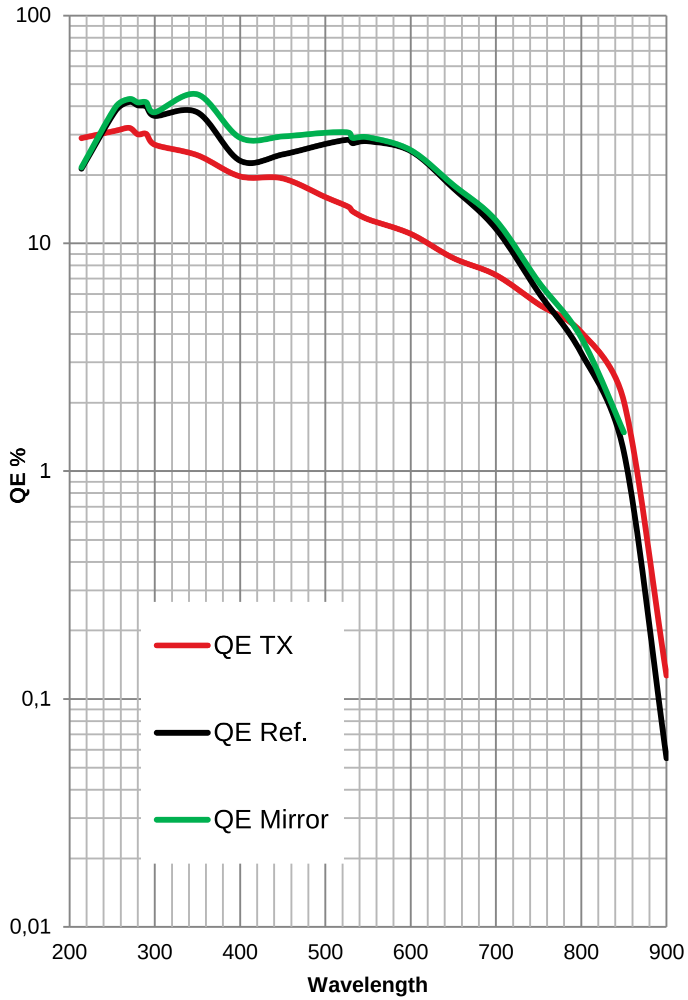
Test Cell

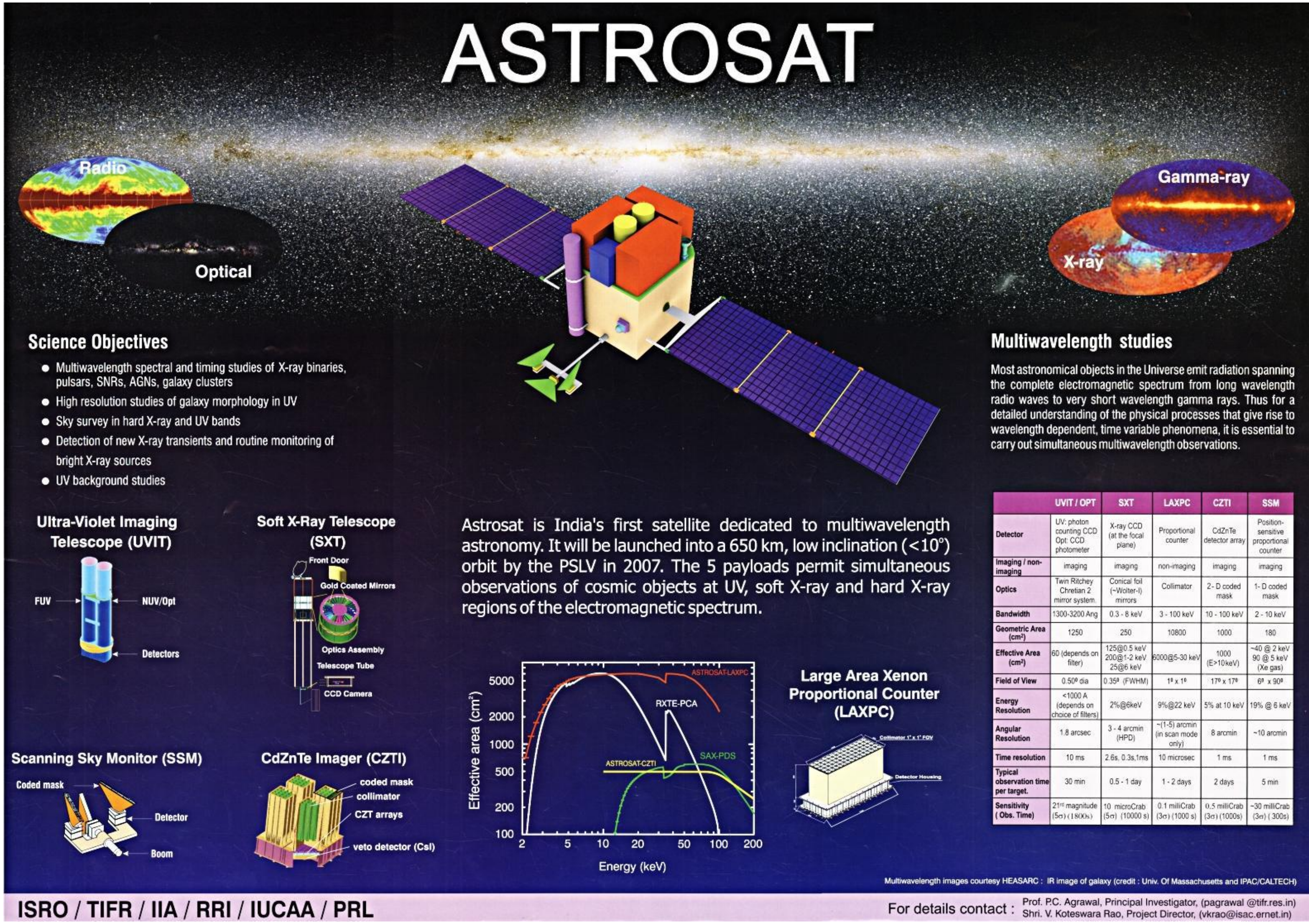


OPTICAL TRANSMISSION S-20 PHOTOCATHODES



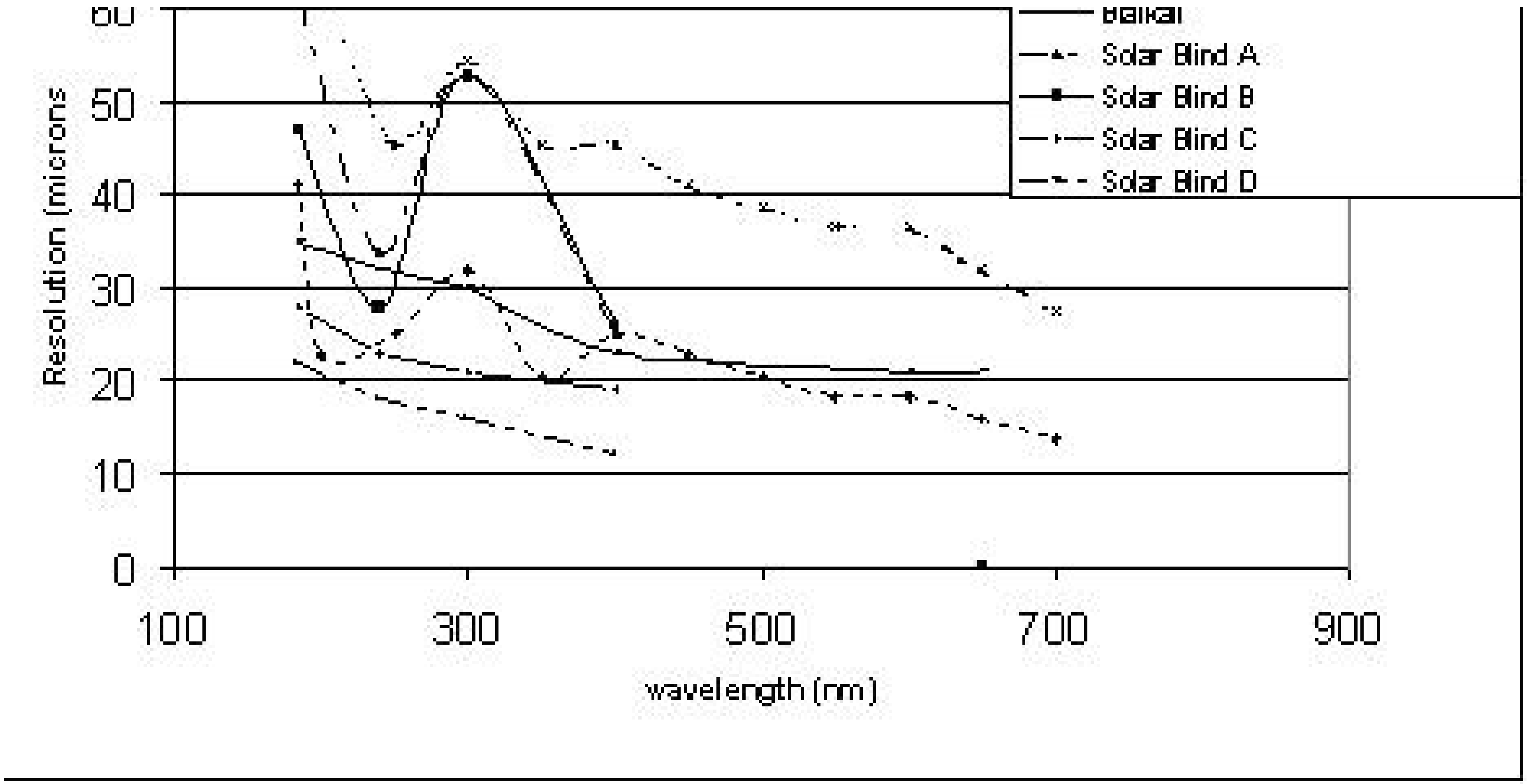
Reflection/Transmission Test Cell





	UVIT / OPT	SXT	LAXPC	CZTI	SSM
Detector	UV: photon counting CCD Opt: CCD photometer	X-ray CCD (at the focal plane)	Proportional counter	CdZnTe detector array	Position-sensitive proportional counter
Imaging / non-imaging	imaging	imaging	non-imaging	imaging	imaging
Optics	Twin Ritchey Chretian 2 mirror system.	Conical foil (~Wolter-I) mirrors	Collimator	2- D coded mask	1- D coded mask
Bandwidth	1300-3200 Ang	0.3 - 8 keV	3 - 100 keV	10 - 100 keV	2 - 10 keV
Geometric Area (cm^2)	1250	250	10800	1000	180
Effective Area (cm^2)	60 (depends on filter)	125@0.5 keV 200@1-2 keV 25@6 keV	6000@5-30 keV	1000 (E>10keV)	~40 @ 2 keV 90 @ 5 keV (Xe gas)
Field of View	0.50° dia	0.35° (FWHM)	1° x 1°	17° x 17°	6° x 90°
Energy Resolution	<1000 A (depends on choice of filters)	2%@6keV	9%@22 keV	5% at 10 keV	19% @ 6 keV
Angular Resolution	1.8 arcsec	3 - 4 arcmin (HPD)	~(1-5) arcmin (in scan mode only)	8 arcmin	~10 arcmin
Time resolution	10 ms	2.6s, 0.3s,1ms	10 microsec	1 ms	1 ms
Typical observation time per target.	30 min	0.5 - 1 day	1 - 2 days	2 days	5 min
Sensitivity (Obs. Time)	21rd magnitude (5σ) (1800s)	10 microCrab (5σ) (10000 s)	0.1 milliCrab (3σ) (1000 s)	0.5 milliCrab (3σ) (1000s)	~30 milliCrab (3σ) (300s)

Resolution/Wavelength



Summary for S-20

- Electron Energy Distribution-marked change about 270nm
- Optical Absorption peaks at 370nm and a secondary peak at 270nm
- Not an Interference Effect!
- QE peaks at 370nm (45%) and 260nm
- Spatial Resolution improves at 260nm

Do Other Cathodes show a similar Effect

- SB cathodes show a dip in QE
- Our Electron energy distribution and Spatial Resolution measurements were inconclusive

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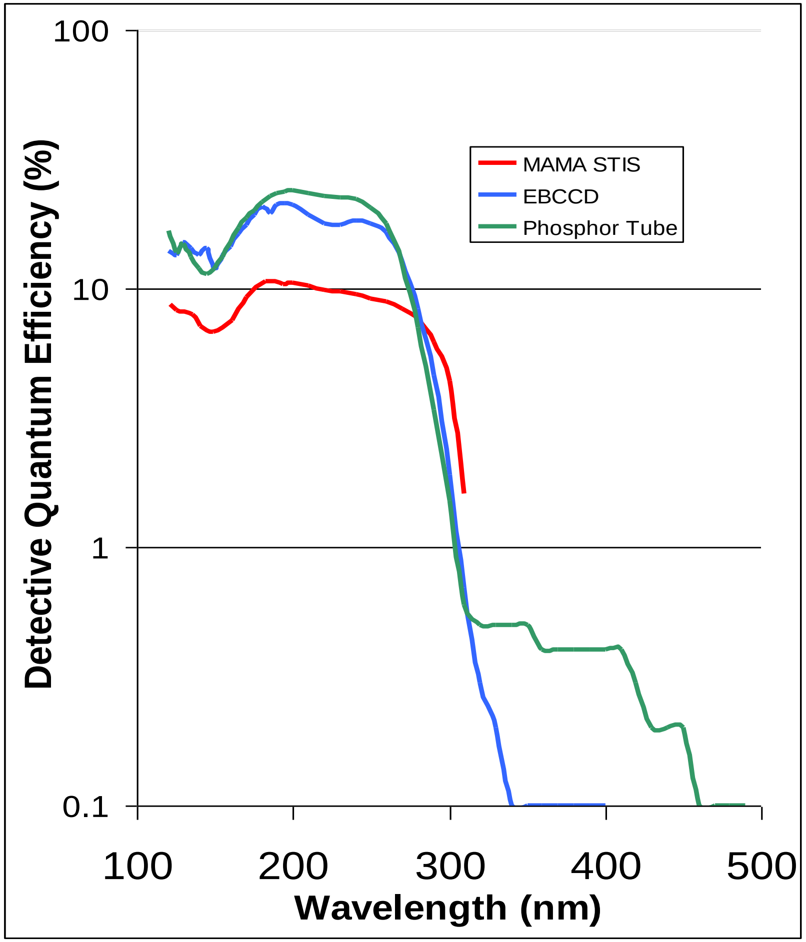
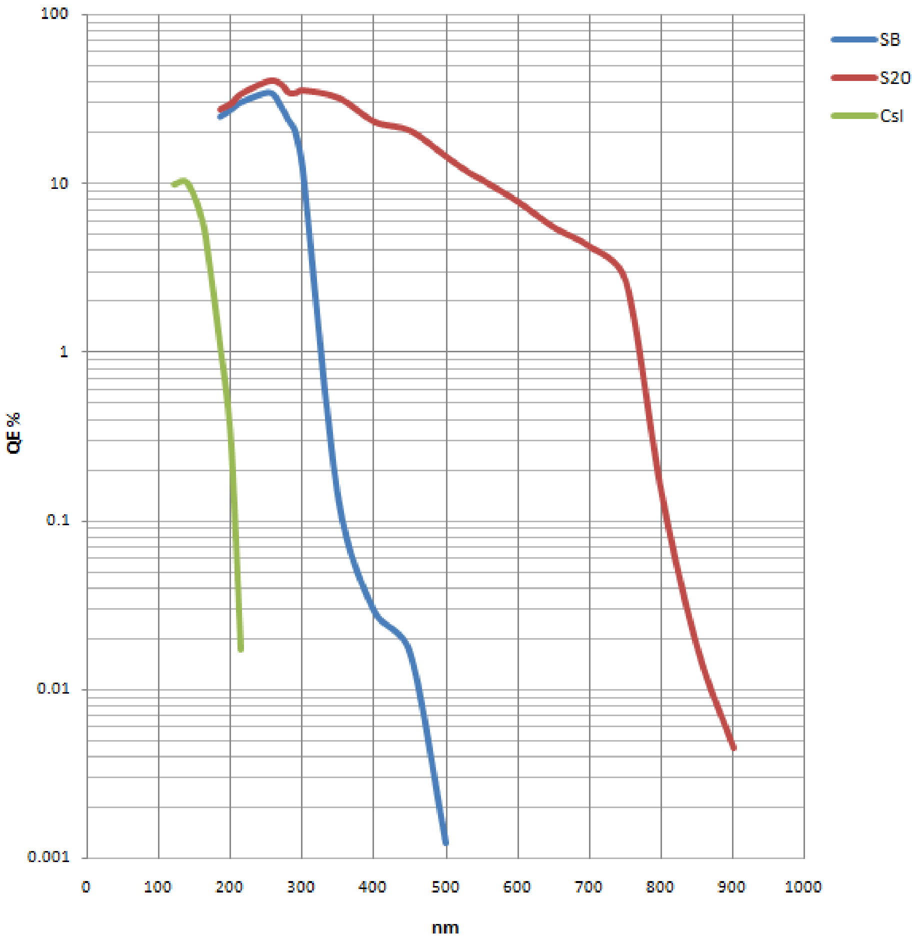


100
10
1
0.1
Detective Quantum Efficiency (%)
MAMA STIS
EBCCD
Phosphor Tube
100
200
300
400
500
Wavelength (nm)

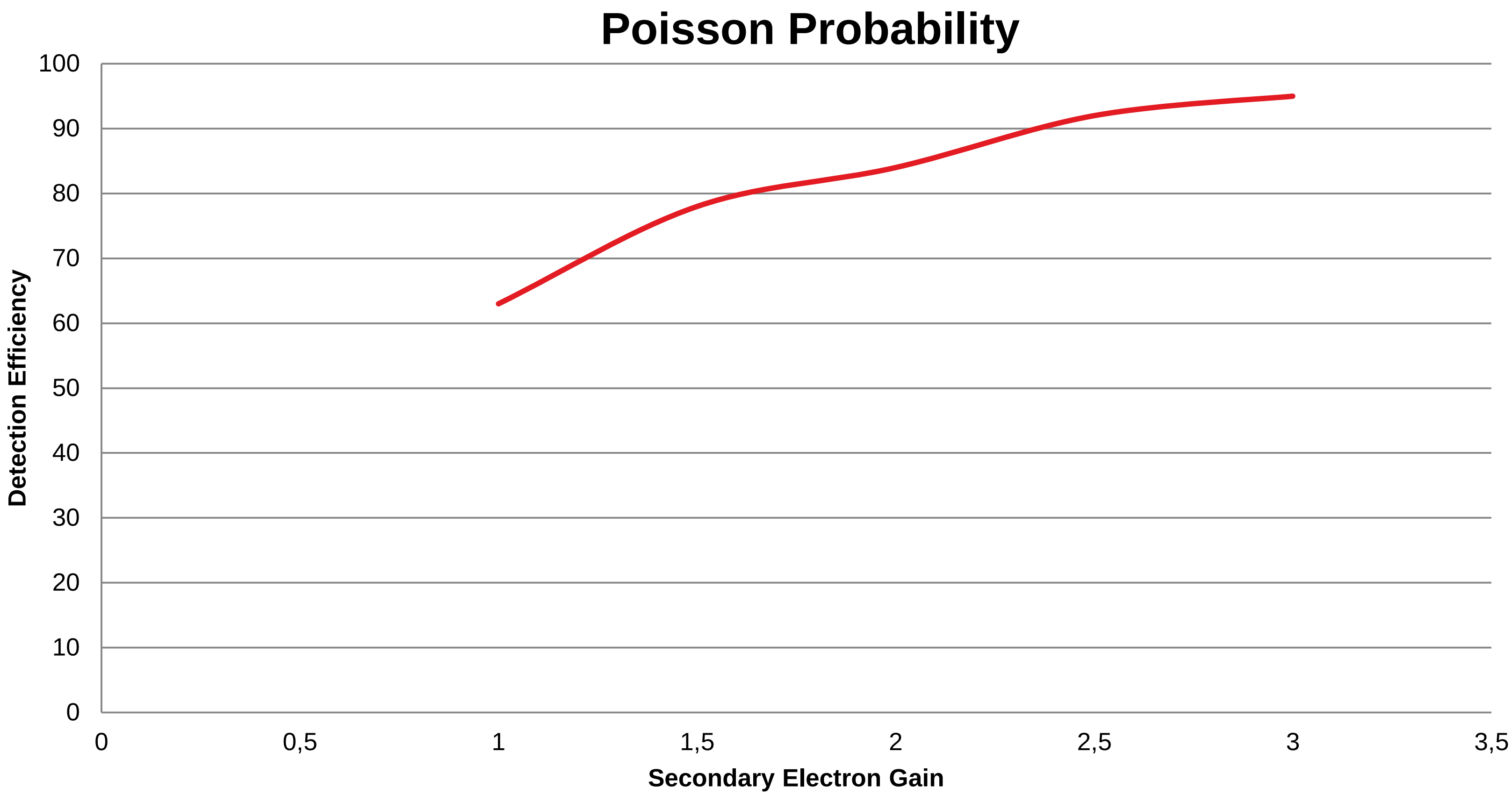
Standard Spectral Responses



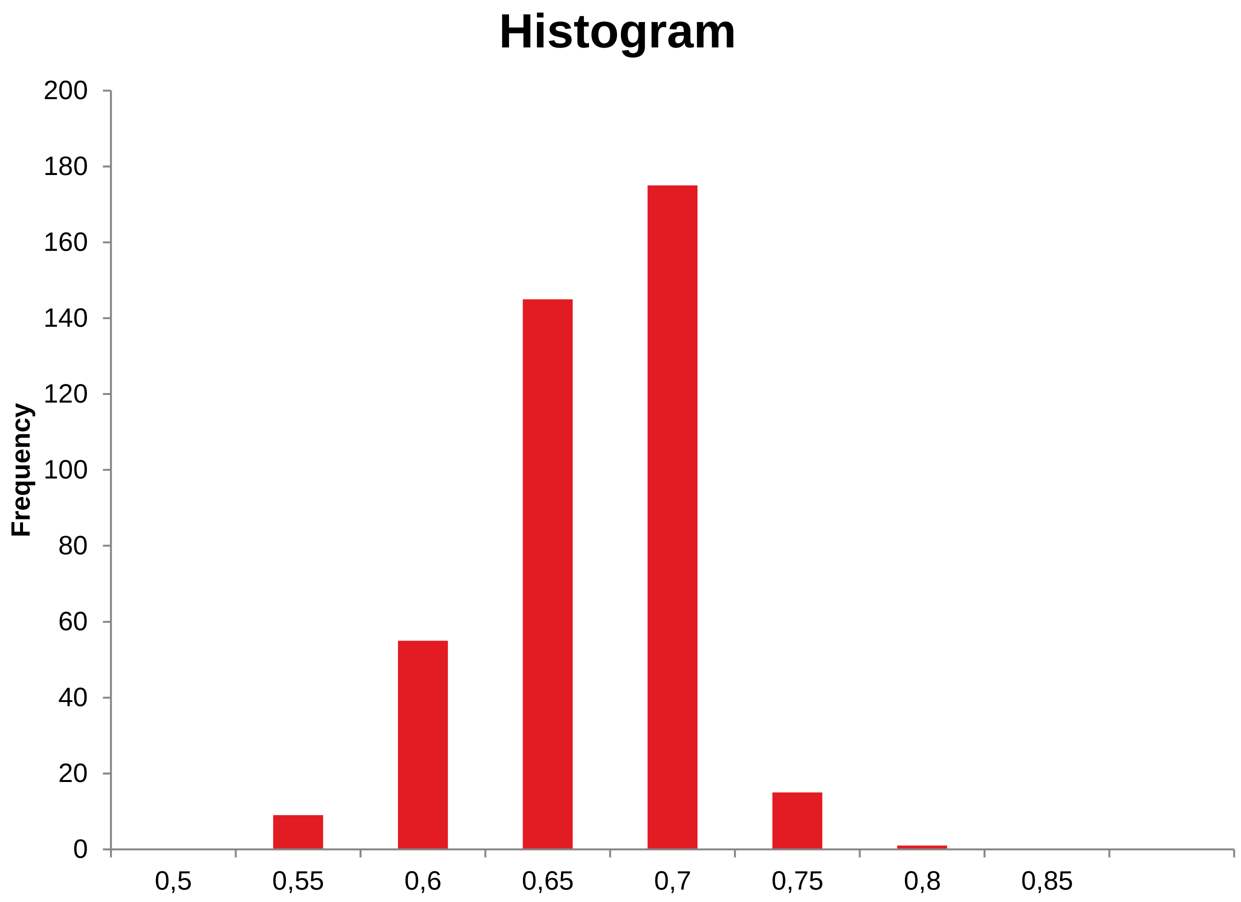
Counting Efficiency

1. Some Electrons are reflected (depends on Z)
2. Poisson Distribution
3. Geometrical Losses (e.g. OAR)

Counting Efficiency



Counting Efficiency of MCPs



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Does It Matter?

- DQE=QE×CE×number of electrons/photon
- If CE is 50%, and we have 2 electrons/photon, the net result is similar to a photocathode with a cathode that only gives one electron/photon
- If CE is high, the same cathode that reads high QE because it is 2 electrons/photon has not the expected superior SNR

Thank you for listening

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