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TITLE: THE PROSPECTS OF USING LARGE VACUUM PHOTODIODES WITH GAS SCINTILLATION PROPORTIONAL COUNTERS

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THE PROSPECTS OF USING LARGE VACUUM PHOTODIODES WITH GAS SCINTILLATION PROPORTIONAL COUNTERS

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The photomultiplier tube (PMT) has been a limiting factor in the development of large area gas scintillation proportional counters (GSPC). The large quartz PMTs needed are expensive, bulky, fragile, often have long term instabilities, and are available only in a limited number of sizes. The largest such tube available has a photocathode of only 11 cm diameter.

It has been demonstrated by Van Staden, et.al.[1] that a vacuum photodiode can be used as the sensing element for gas scintillators. The advantages of photodiodes are that they can be made less expensively than PMTs, they are compact, rugged, and very stable. Unfortunately, the commercially available photodiodes are small and have peak quantum efficiencies of 20% or less. Thus, they are not yet competitive with PMTs.

We have explored two photocathode materials that appear promising for the detection of the UV light from noble gas scintillators. These are CsI reported on by Di Stefano and Spicer[2], and Cs_2Te reported on by Fisher, et.al.[3]

Figure 1 shows the quantum efficiencies of these two photocathode materials[2,3] as a function of photon wavelength superimposed over the emission spectra of xenon, krypton, and argon.[4] The quantum efficiency of a spectrosil PMT and window with a bialkali photocathode is also shown. The integrated quantum efficiencies of these photo-cathodes are given for the three gases in Table I.

Assuming no geometric factors to degrade resolution, the fluctuation in the pulse amplitude of a GSPC with a photodiode detecting monoenergetic x-rays of energy, E_x:

is

$$\left(\frac{\sigma_P}{\overline{P}}\right)^2 = \left\{\frac{(F + f)W}{E_x} + \frac{1}{N^2} \quad (N + n^2)\right\} \tag{1}$$

where $\overline{P}$ is the mean pulse height, F is the Fano factor, f is the variance associated with charge multiplication of one primary electron and W is the mean energy to produce one ion pair. N is the mean number of photons detected by the photodiode and n is the rms noise (measured in electrons) of the amplifier used. The full width half maximum resolution of the counter is

$$R(FWHM) = 2.35\frac{\sigma}{\overline{P}}. \tag{2}$$

For xenon $F \approx .13$[5] and $W = 21.9$ eV. Normally, a GSPC is operated with $f \approx 0$. Assuming an instrument that produces 3×10^4 photons/keV/atm into 4π sr, a Cs_2Te photodiode that subtends a solid angle of π sr, and a window transmission of 80%, the expected resolution can be calculated as a function of x-ray energy. Table II shows the expected resolution for such an instrument for N=200 and 400 electrons rms and 1 and 1-1/2 atm fillings of xenon. The response of a PMT system with a resolution of 8% FWHM for 6 keV x rays and one atm of xenon is also included as a comparison. The amplifier with N=200 electrons gives resolutions better than the PMT for x-ray energies >5 keV and the 400 electrons noise amplifier is better than the PMT above 15 and 10 keV for 1 and 1-1/2 atm fillings respectively.

The construction of the large Cs_2Te vacuum photodiodes needed to detect xenon light in GSPCs will require some development. A means must be developed to coat a large surface with Te and then transfer it to the photodiode structure while still in a vacuum. Once large photodiodes are developed, larger GSPCs will be possible with greater resolution and reduced cost. Associated problems with PMTs are also eliminated.

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TABLE I

QUANTUM EFFICIENCY OF VARIOUS PHOTON DETECTOR SYSTEMS

System	Quantum Efficiency (%) Xe	Kr	Ar
Cs_2Te+	29.3	12.5	57.6
CsI+	12.8	37.5	12.3
PMT*	6.1	-	-

+The absorption of the window on the vacuum photodiode is not included.

*This assumes a Spectrosil PMT with a bialkali photocathode and a 4 mm Spectrosil GSPC window.

TABLE II

ENERGY RESOLUTION FOR A GSPC USING Cs_2Te VACUUM PHOTODIODES AND A PMT

	Resolution (% fwhm)					
	1 atm xenon			1.5 atm xenon		
Ex (keV)	N= 200	N-400	PMT	N=200	N=400	PMT
5	8.1	12.3	8.8	7.0	9.3	7.8
10	5.1	6.9	6.2	4.6	5.5	5.6
15	4.0	5.0	5.0	3.7	4.2	4.5
20	3.4	4.1	4.4	3.1	3.5	3.9
25	3.0	3.5	3.9	2.8	3.0	3.5
30	2.7	3.1	3.6	2.5	2.7	3.2

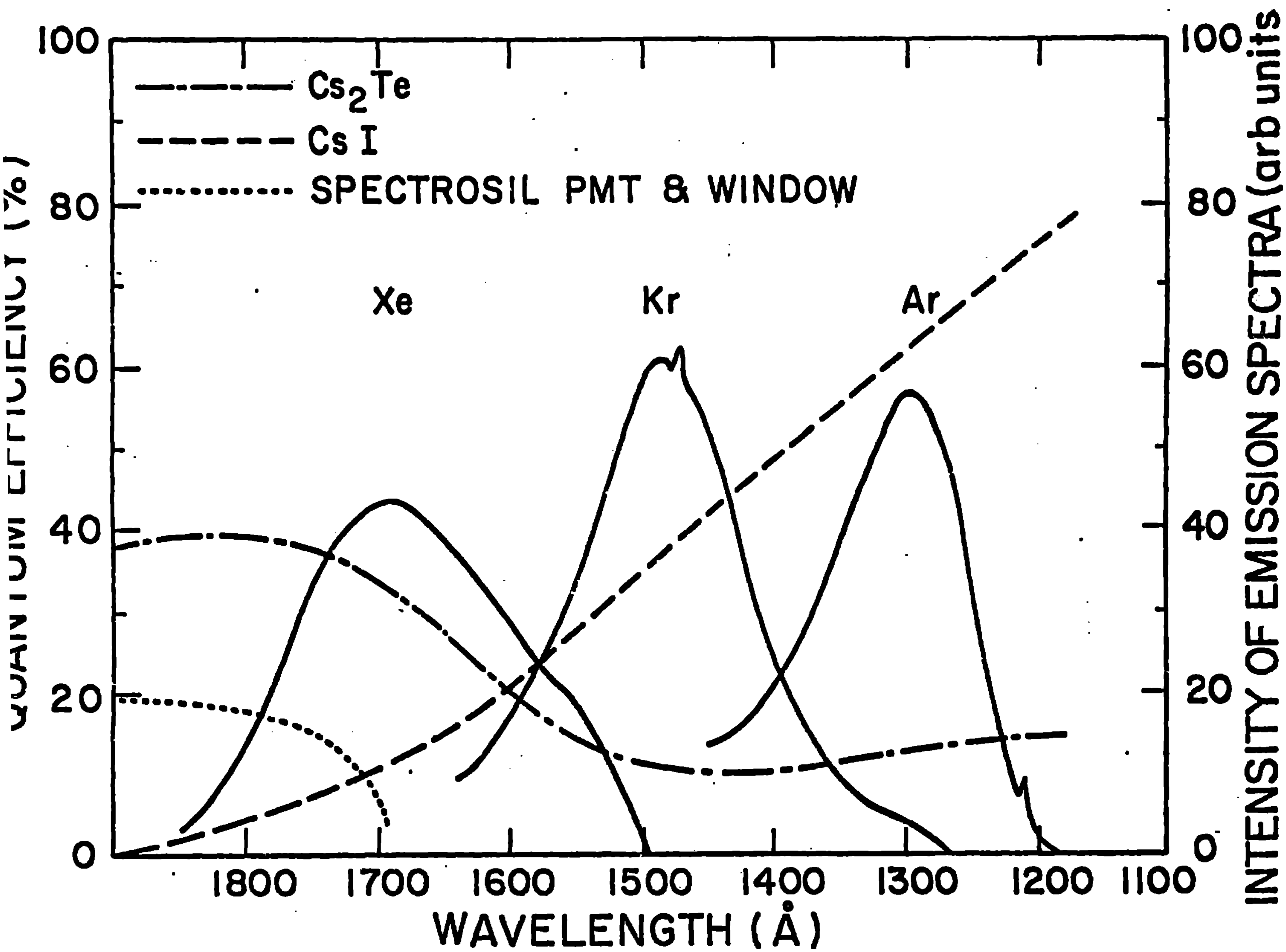

Fig. 1. Quantum efficiency of a Cs_2Te photodiode, CsI photodiode and a Spectrosil PMT with a bialkali photocathode as a function of photon wavelength. The emission spectra of xenon, krypton, and argon are also included.