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PERFORMANCE CHARACTERISTICS OF EIGHTEEN POSITRON LIFETIME SPECTROMETERS

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ABSTRACT

Eighteen Positron Lifetime Spectrometers were built and extensively tested both in the USA and in China. Timing resolution varied from 140 to 178 ps with an mean value of 153.3 ps FWHM measured in the USA for a narrow dynamic range of energies. The measurements in China were 141.6 to 179.3 ps with a mean value of 163.3 ps FWHM. Wide dynamic range measurements, more suitable for positron lifetime experiments, gave timing resolutions of 206.5 to 242 ps with an mean value of 225.9 ps FWHM measured in the USA. Corresponding measurements in China were 205.6 to 249.5 ps with an mean value of 237.8 ps FWHM.

INTRODUCTION

A High Rate Positron Lifetime Measurement System was reported by Bedwell and Paulus [1] at ICPA-5. This system is commercially available [2] and has found wide application in positron lifetime studies. Recently, 18 systems of this type were fabricated and delivered to China. This large number of identical systems fabricated and tested at the same time provides an excellent opportunity to review their range of performance characteristics.

POSITRON LIFETIME SPECTROMETER

A block diagram of the Positron Lifetime Spectrometer is shown in figure 1. The detector assemblies consisted of Bicron BC418, 12.9-cc, truncated cone [3] scintillators mounted on a Hamamatsu R1332 or Burle 8850 PMT. The Constant-Fraction Differential Discriminator [4,5], CFDD, provided both the energy selection and the timing pick-off. A 35.5-cm coaxial cable was used for the constant fraction shaping delay. The Fast Coincidence [6] pre-

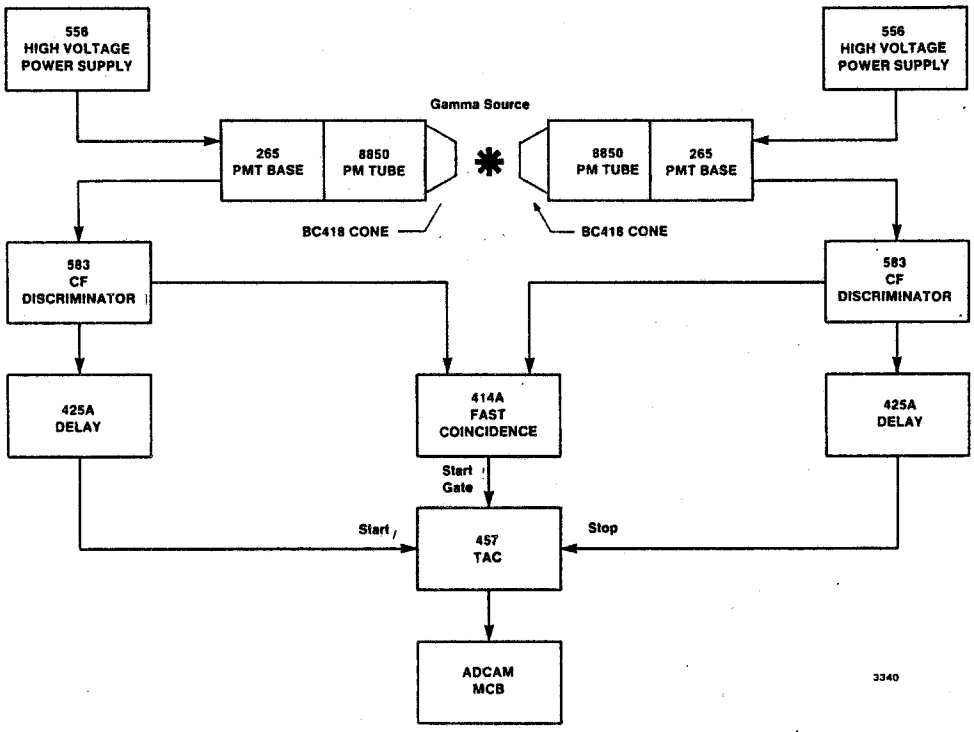

Figure 1. Block Diagram of Positron-Lifetime Spectrometer.

processes the Start and Stop signals to allow only valid events to start a time conversion. The Biased Time-to-Amplitude Converter [7] converts the Start-Stop time difference to a pulse amplitude that is digitized by the Multichannel Buffer [8], MCB. Stable timing resolution as low as 1 ps/channel is possible with this system.

Several instrument settings critically impact the performance of the spectrometer. The PMT high voltage is adjusted to provide sufficient dynamic range without saturating the PMT. This is accomplished by adjusting the high voltage to produce a nominal -2 V pulse from the anode when viewed with a very fast oscilloscope with the scintillator exposed to a ^{22}Na or ^{60}Co source. The Start and Stop thresholds are adjusted to select as high an energy as possible within the range of interest. The CFDD Lower-Level and Upper-Level discriminators are set by gating the energy signal from the detector. The Start thresholds are set to detect the birth gamma-ray and the Stop thresholds are set to detect the annihilation gamma-ray.

SYSTEM PERFORMANCE CHARACTERISTICS

All 18 Positron Lifetime Spectrometers were extensively tested using ^{60}Co to determine their performance characteristics. The Test results are summarized in Table 1. Each system was tested at EG&G ORTEC, Oak Ridge, TN, USA, and in China. Table 1 shows excellent agreement between the two sets of measurements.

TABLE 1. Performance of 18 Positron Lifetime Systems Using ^{60}Co.

	Narrow Dynamic Range Start: 1050-1150 keV Stop: 900-1000 keV		Wide Dynamic Range Start: 500-1000 keV Stop: 200- 380 keV	
	Timing FWHM (ps)		Timing FWHM (ps)	
System	ORTEC	China	ORTEC	China
N403	151.8	158.8	211.5	237.3
N409	150.8	157.1	223.1	232.9
N410	178.0	173.3	212.8	240.2
N411	145.4	141.6	216.8	226.0
N416	160.6	168.0	231.0	217.2
N422	159.0	170.6	232.6	249.5
N425	158.1	173.3	234.9	235.6
N426	140.1	142.9	212.3	205.6
N427	157.3	179.3	238.1	236.2
N433	154.9	149.5	239.6	226.9
N434	149.4	170.7	233.6	236.5
N437	144.1	171.4	206.5	219.4
N439	163.0	165.5	242.0	243.6
N422	156.6	160.4	231.6	235.6
N443	148.1	166.0	217.0	239.0
N448	152.4	157.2	237.0	227.6
N453	146.0	155.1	234.6	247.3
N457	152.6	177.8	210.5	233.4
Minimum	140.0	141.6	206.5	205.6
Maximum	178.0	179.3	242.0	249.5
Mean	153.8	163.3	225.9	232.8
Range	37.9	37.7	35.5	43.9
Std Dev	8.4	10.9	11.5	10.6

A narrow dynamic range of energies was selected to determine the ultimate timing performance of each system. The Start thresholds were set for the energy range from 1050 to 1150 keV, and the Stop thresholds were set for the energy range from 900 to 1000 keV. Timing resolution measured at ORTEC ranged from 140.1 to 178 ps with an mean value of 153.8 ps. The mean resolution measured in China was 163.3 ps FWHM.

Each system was also tested over a wide dynamic range of energies more typical of those used in positron lifetime measurements. In the wide dynamic range measurements, the Start thresholds were set for the energy range from 500 to 1000 keV and the Stop thresholds were set for 200 to 380 keV. Timing resolution measured at ORTEC ranged from 206.5 to 242 ps with an mean value of 225.9 ps FWHM. The mean resolution measured in China was 237.8 ps FWHM.

One objective of performing all measurements in a consistent manner was to determine which parameters affected system perfor-

mance. The major difference among the systems was the individual PMTs. Important parameters such as transient time spread and cathode to first dynode gain are not specified for individual PMTs. Table 2 lists some of the parameters that are measured including the Peak-to-Valley ratio, Dark Current, and Dark Pulse Sum. These parameters are listed in order of the wide dynamic range timing resolution. No obvious correlation between system performance and PMT parameter values can be observed.

TABLE 2. Photomultiplier Tube Characteristics.

	START PMT			STOP PMT		
Wide FWHM (ps)	P/V Ratio	Dark Current (nA)	Dark Pulse Sum (cps)	P/V Ratio	Dark Current (nA)	Dark Pulse Sum (cps)
206.5	1.48	0.6	462	1.73	0.7	591
210.5	2.00	0.4	224	1.73	0.3	185
211.5	1.86	0.4	262	1.42	0.4	234
212.3	2.11	0.4	667	2.00	0.6	460
212.8	-	-	-	1.54	2.2	145
216.8	1.90	2.0	667	2.16	0.4	177
217.0	1.90	0.5	463	1.95	0.5	274
223.1	1.95	0.4	115	1.54	1.0	420
231.0	1.60	1.4	160	2.05	1.5	455
231.6	2.28	0.3	155	-	-	-
232.6	1.95	0.6	283	2.05	0.3	148
233.6	1.95	0.3	140	1.56	0.4	230
234.6	1.95	0.4	100	1.70	0.4	230
234.9	1.70	0.5	375	1.81	0.3	162
237.0	2.11	0.4	422	-	-	-
238.1	1.95	0.7	654	2.05	0.4	155
239.6	1.95	0.5	207	1.73	0.4	249
242.0	1.60	2.4	213	1.70	0.4	245

CONCLUSIONS

The timing performance of 18 Positron Lifetime Systems was measured for both narrow and wide dynamic ranges. Consistent results were obtained from system-to-system and location-to-location. This data is representative of that obtainable using available commercial equipment.

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4) Bedwell, M. O. and Paulus, T. J.: CFDD, IEEE Trans. on Nucl. Sci., Vol. NS-26, No. 1, 1979.
5) EG&G ORTEC Model 583 CFDD.
6) EG&G ORTEC Model 414A Fast Coincidence Unit.
7) EG&G ORTEC Model 457 Biased Time-to-Amplitude Converter.
8) EG&G ORTEC 918A ADCAM Multichannel Buffer.