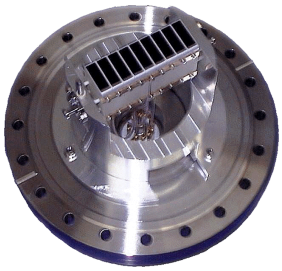
Linearity of the PHOIBOS Channel Electron Multiplier (CEM) detection system

Application Notes

Detection electronics PCU 300



CEM array with feedthrough

Introduction

Inadequate design may cause the intensity measuring system in electron analyzers to show non-linearities. For an ideal counter with a non-extended dead time t the measured count rate N′ and the true count rate N is given by

$$N' = N / (1 + N t).$$

We have measured for a PHOIBOS SCD analyzer the count rates as a function of the Auger electron beam current. For the analysis, standard and extended dynamic range CEMs were used.
It can be shown that for a non-extended dead time counter the spectral ratio N'_1 / N'_2 of two spectra N'_1 and N'_2 (measured at two different beam currents A × I and I) is given by

$$N'_1 / N'_2 = A + (1 - A) \times t \times N'_1$$

Therefore, from a spectral ratio plot the dead time can be determined. The detection efficiency N'_1 / N_1 can now be calculated

$$N'_1 / N_1 = N'_1 / N'_2 \times (1 - N'_2 t) / A.$$

Experiment

The PHOIBOS SCD and a modified EQ 22 electron gun were installed on a UHV system without bakeout (base pressure 2 × 10^{-7} mbar). A copper sample was cleaned by sputtering with Ar^+ ions. The sample current was measured with a Picoammeter and a +90 V bias voltage.
For different beam currents the count rate was measured with the standard PCU 300 detection electronics and the SPECSLAB software in the fixed kinetic energy mode.
In a second experiment the AES low kinetic energy region of the sample was measured with two different beam currents.

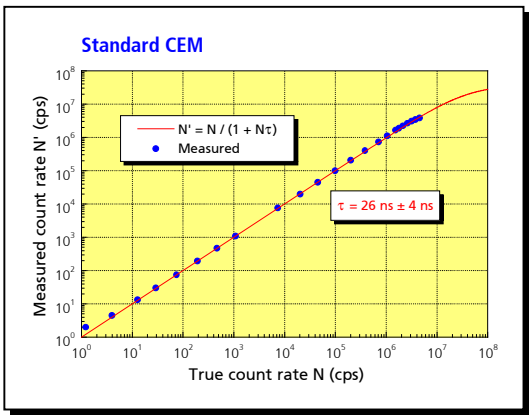


Figure 1: The count rate N′ was measured for different beam currents I. From the low count rate region we have calculated the conversion factor a
(N = a × I).

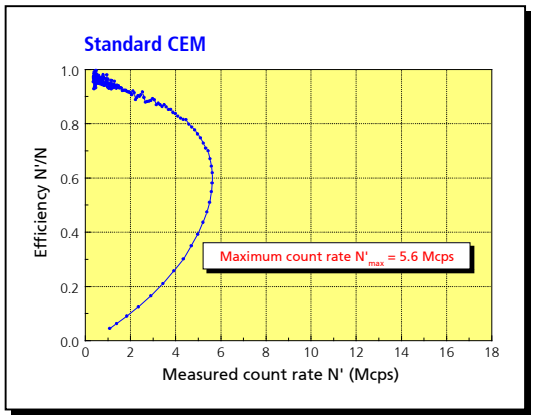


Figure 2: From a spectral ratio plot of two spectra measured at different beam currents the detector efficiency N′ / N was calculated. With increasing count rate the mean gain of the pulse height distribution will decrease. For some critical value the distribution starts to fall below the discriminator threshold.

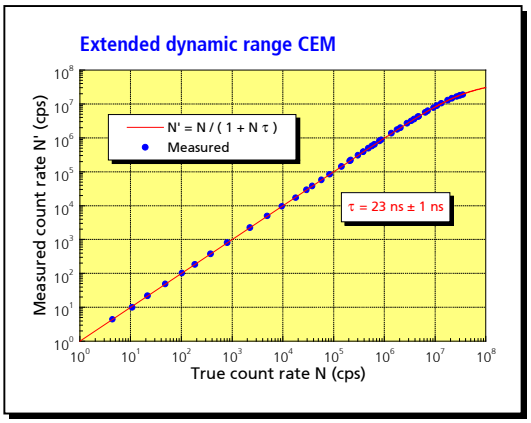


Figure 3: Linearity plot for the new Extended Range CEM

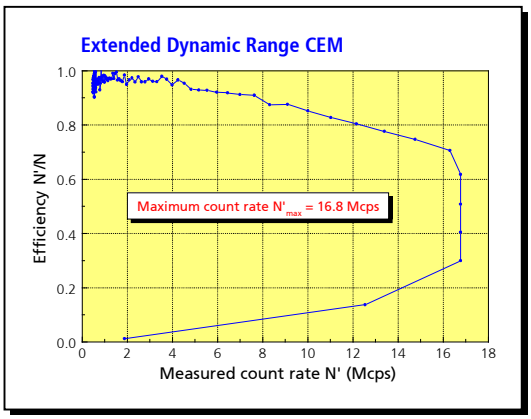


Figure 4: Efficiency plot for the new Extended Range CEM

Conclusions

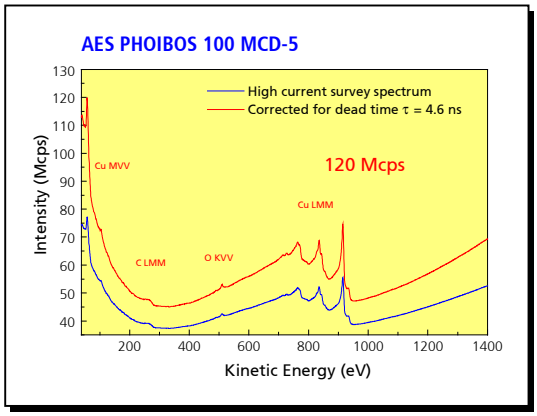
- The maximum (measured) count rate detectable is 5.6 Mcps per channel for the standard CEMs and 16.8 Mcps for the extended range CEMs.

- We have verified the linearity and the non-extended dead time behavior for the standard CEMs up to 1 Mcps and for the extended range CEMs up to 10 Mcps true count rate. Up to these count rates no significant deviation from linearity could be observed with the PHOIBOS detection system (CEMs and PCU 300 detection electronics).

- From pulse height distribution measurements we find that the mean gain from the extended range CEMs is much less sensitive towards increasing the true count rate. This is the reason for the extended working range.

- The detector voltage required to operate the extended range type CEMs is 300 V higher than that of the standard CEMs.

- The high current AES survey spectrum shows the high count rate capability of the PHOIBOS detection system with the extended dynamic range CEMs.



References

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[4] Linearity in Electron Counting and Detection Systems, M.P. Seah et al., Surf. Interface Anal. 18, 1992, 240-246.

SPECS GmbH
Surface Analysis
and Computer Technology
Voltastrasse 5, 13355 Berlin
Germany

Phone: +49 30 467824 - 0
Fax: +49 30 4642083
E-mail: support@specs.de
http://www.specs.de