A.5.2. Absolute Calibration of Electron Multipliers for Highly Charged Ions--*J. Krása,* and M.P. Stöckli*

Experimental techniques requiring quantitative measurements of ions require calibrated detectors, such as windowless electron multipliers (EMs). They are used for detection of electrons, ions, and VUV, as well as soft x-ray photons in vacuum systems. The calibration of EMs is, however, a complex procedure because the ion-induced emission of electrons from the first dynode depends not only on the quality of a dynode's surface but also on the intercepted ion species and its potential- and kinetic-energy. A serious problem in the accuracy of ion current measurement has been encountered with electron tubes of type 226EM and 119EM equipped with a large cylindrical and Venetian blind first dynode, respectively, when they were calibrated with a narrow ion beam [1,2]. These calibrations showed that the current gain depends on the position where ions bombard the surface of the first dynode.

For the evaluation of the measured data, the current gain (amplification factor) of the electron multipliers tested is defined as the ratio of the amplified current of secondary electrons at the output of the EM, I_{EM}, and the ion current, I_i, which impacts the first dynode: $G_c = I_{EM}/I_i$. For the measurement of an EM's average response to a single ion of the intercepted ion current, the analog particle gain is defined using the charge state q of the ion: $G_a = q\, G_c$. For a description of the EM response to a single ion the efficiency of detection of ions, ε, should be taken into account to determine the pulse counting gain $G_p = G_a/\varepsilon$, which represents the number of electrons at the EM output per single detected ion. G_p is proportional to the total yield of secondary electrons emitted from the first dynode, γ, by a single particle multiplied by the probability that they impact the second dynode, and proportional to the electronic gain G_e, expressing a subsequent multiplication of electrons. Calibrated detectors require the assurance of a constant value of G_e for all measurements. Then G_p should depend only on the number of emitted secondary electrons by a detected single ion.

The highly charged Co^{q+} ($10 \le q \le 26$), Xe^{30+}, and Ta^{q+} ($12 \le q \le 49$) ions used for this measurement were produced with the Kansas State University Cryogenic Electron Beam Ion Source [3]. The accelerating voltage was from 13 kV to 163kV.

The investigated windowless electron multipliers with BeCu dynodes were produced by THORN EMI Electron Tubes Ltd., UK. The 226EM combines a large first dynode with the performance advantages of a linear-focused multiplier. The multiplier has 16 dynodes and a radiation aperture of 17 mm × 17 mm. The 119EM has a Venetian blind structure, with a 10-slat entrance dynode with radiation aperture of 21.6 mm in diameter and a total of 17 dynodes.

Figure 1 shows a scheme of the electron multipliers 226EM and Fig. 2 presents the dependence on the impact position of its current gain. The 226EM's gain decreases strongly when the impact position on the first dynode surface departs from the input window into the second dynode region. This undesirable effect could be ascribed to the decrease in the collection efficiency of the focusing system between the first and the second dynode with increasing distance from the output window of the first dynode region. Figure 3 shows the dependence of the analog particle gain of 226EM on ion incident velocity for Ta^{16+} - Ta^{49+} [5]. The ion beam width of 5 mm was contoured by slits centered with the ion beam axis as well as the radiation aperture of the EM.

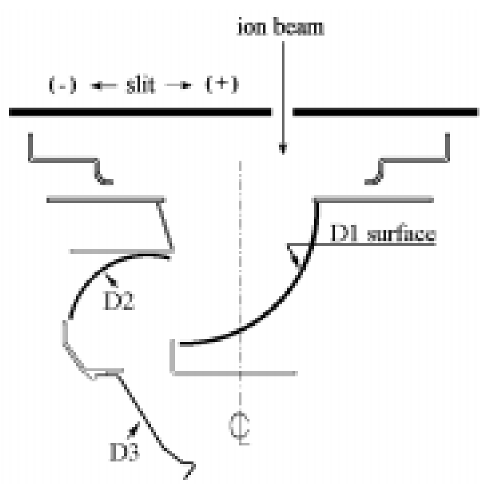

Figure 1. Scheme of the first (D1) to the third (D3) region of 226EM and the movable slit of 2.3 mm width [1].

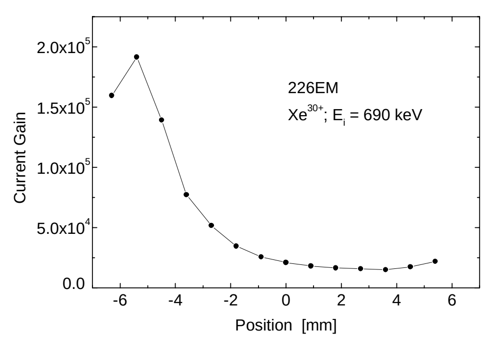

Figure 2. The dependence on the impact position of the current gain of the 226EM for 690 keV Xe^{30+} [1].

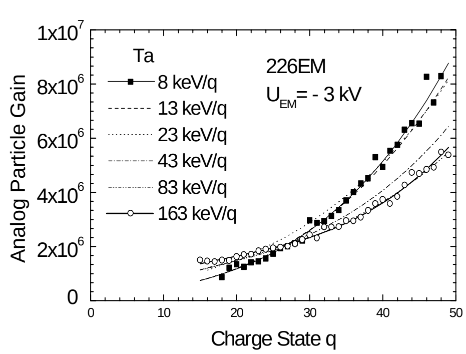

Figure 3. The analog particle gain of the 226EM versus the charge state of Ta ions for 8 - 163 keV/*q* ion energy per charge [5].

A similar effect of the impact position of ions on the EM gain was also found for the 119EM. In this case there is a strong dependence on the impact position of the intercepted ions regardless of the ion species and ion impact energy. The scheme and the position dependence of the 119EM current gain are shown in Figs. 4 and 5, respectively. The normalized $G_{c,nor}$ increases and decreases with a period $\Delta = 2.5$ mm that is equal to the distance between neighboring slats of the Venetian blind. For confirmation of the non-linear properties of this type of electron multiplier, we measured the effect of the 119EM geometry on the ion counting. To minimize the dead time of the ion counting system, we used a flux of 780 keV Ta^{26+} ions that did not exceed 2×10^4 ions/s. The measured position dependence of the detection efficiency of the EM was defined as the ratio of the number of counts to the total number of ions hitting the surface of the first dynode. The detection efficiency varied from about 0.05 to 0.7 and followed the position dependence of the current gain shown in Fig. 5. Also in this case we can deduce from analogy with 226EM [1] that the lowest collection efficiency of electrons is at the input side of the first dynode that is far from the D2 region. The electrons should be most effectively collected from the surface of the D1's output side that is nearby the D2 region.

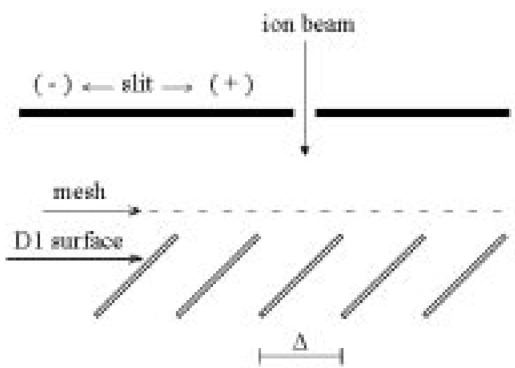

Figure 4. The scheme of the first (D1) dynode region of the 119EM and the movable slit of 0.7 mm width. The distance between neighboring slats Δ=2.5 mm [2].

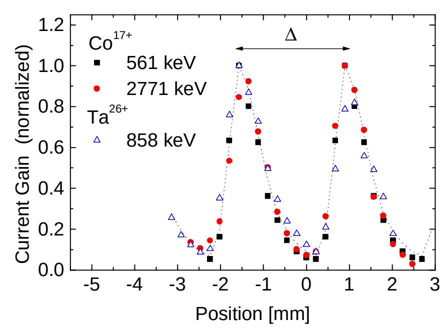

Figure 5. The dependence on the impact position of the normalized current gain of the 119EM for Co^{17+} ions with energy of 561 keV and of 2771 keV and for 858 keV Ta^{26+} ions [2].

We should note that the position dependence might affect also the sensitivity of a photo-multiplier as reported in [4].

The dependence of the gain on impact position implies that any EM equipped with a Venetian blind structure as well as curved first dynodes demands careful use for ion current measurements. If the cross-section of a measured ion beam overlaps the input aperture of the

EM and if the ion distribution across the beam is homogeneous, then a precise measurement of ion current is possible. For ion counting the Venetian blind structure is not very reliable because the detection efficiency of an EM greatly depends on the position where ions hit the surface of the first dynode. It seems that the detrimental effect of the first dynode's geometry on measurement accuracy cannot be lowered by inserting a narrow slit in front of the input window because the distance between neighboring slats of the Venetian blind is only ~ 2.5 mm, and thus the adjustment of a beam on a slat would not be precise.

Figure 6 shows an example of a dependence of the analog particle gain, averaged over a single slat of the first dynode, on both the ion charge state, q, and on the ion kinetic energy, E_i, for Co^{q+} ($10 \le q \le 26$; 13 keV/q < E_i < 163 keV/q) ions. Despite the ion impact position on the EM's first dynode and the complex dependence of secondary electron emission on impinging highly charged ions, the calibration of the windowless electron multipliers with ion beams with well-defined parameters allows us to use them as reliable detectors for ion diagnostics.

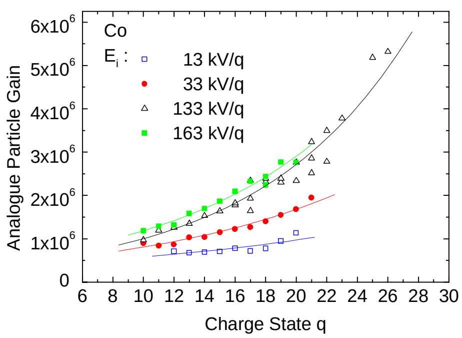

Figure. 6. Analog particle gain of the 119EM vs charge- state of Co ions for 13-163 keV/q ion energy per charge [2].

References

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