Practical Implementation of a 10 Gigahertz Ion Counting Detector Using Conventional Electronics

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Introduction

To address the demand for greater dynamic range in ICP mass spectrometers, a new approach has been developed that extends detector ion counting capability to more than 10 Gigahertz. The new Scaling Pulse Detector allows operation in pulse-counting mode only and can be used with conventional counting electronics.

The new detector attenuates the signal after the ion-to-electron conversion process and so does not introduce any mass-dependent effects.

A control voltage adjusts the ion detection efficiency, which can be dynamically changed from ~90% (for low ion fluxes) down to <0.01% (for high ion fluxes).

Operation

The new discrete-dynode detector is comprised of three functionally distinct parts as shown in Figure 1:

1. an ion conversion section
2. a controllable electron attenuation section, and
3. an amplifying section

Ions entering the detector strike a conversion dynode to convert the signal to electrons. These electrons then undergo a few stages of multiplication to ensure that there is complete separation of the ion-to-electron conversion process from the attenuation process. This is essential in order to minimize mass dependence effects.

In the attenuation section, a control voltage applied to a special electrode adjusts the number of electron-pulses passed to the amplifying section. This allows the effective ion detection efficiency to be adjusted from ~90% (low ion fluxes) down to 1 ion in 10,000 (intense ion fluxes). Even with this very large change in output count rate, the variation in average height of multiplier output pulses is changed by less than a factor of 3.

Electron pulses passed by the attenuation section are then amplified in the final section of the multiplier to yield pulse heights that are typical for normal pulse-counting applications.

In attenuation mode, a smaller fraction of the incident particles produces output pulses thus decreasing the detector output pulse rate. As a result, the effective maximum count-rate is increased by more than 10,000x over that of a standard pulse-counting multiplier.

In the high flux mode, an input ion flux of 5×10^{10} ions per second can typically be reduced to $\sim5\times10^{6}$ Hz output pulse rate — well within the counting capability of conventional electronics used in most commercial ICP mass spectrometers.

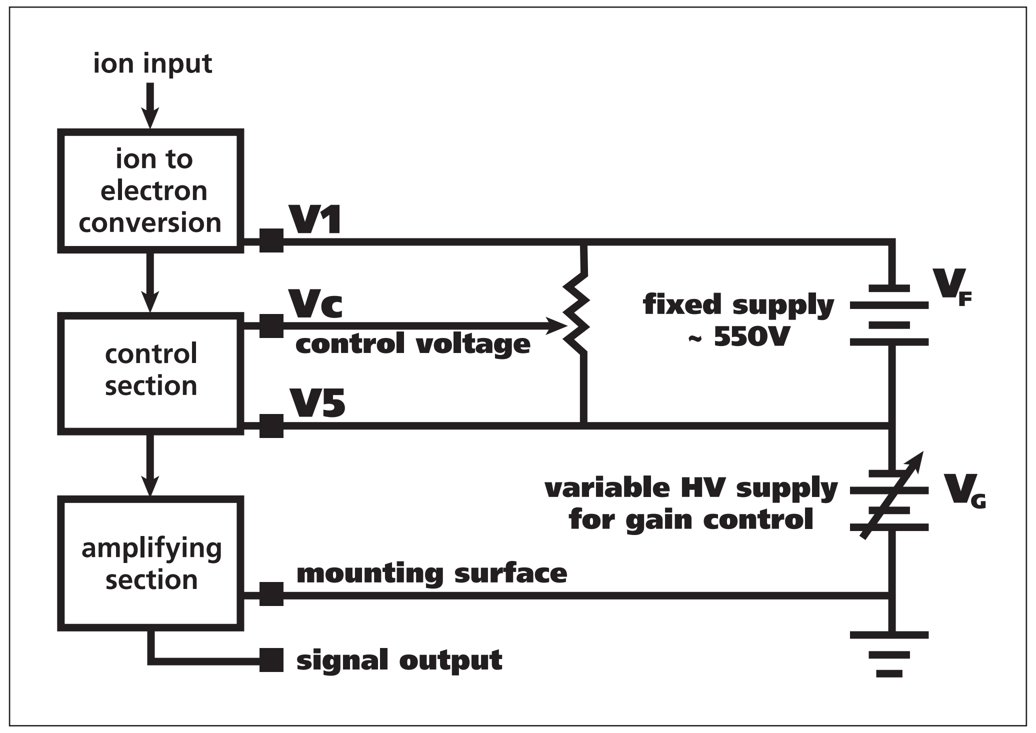
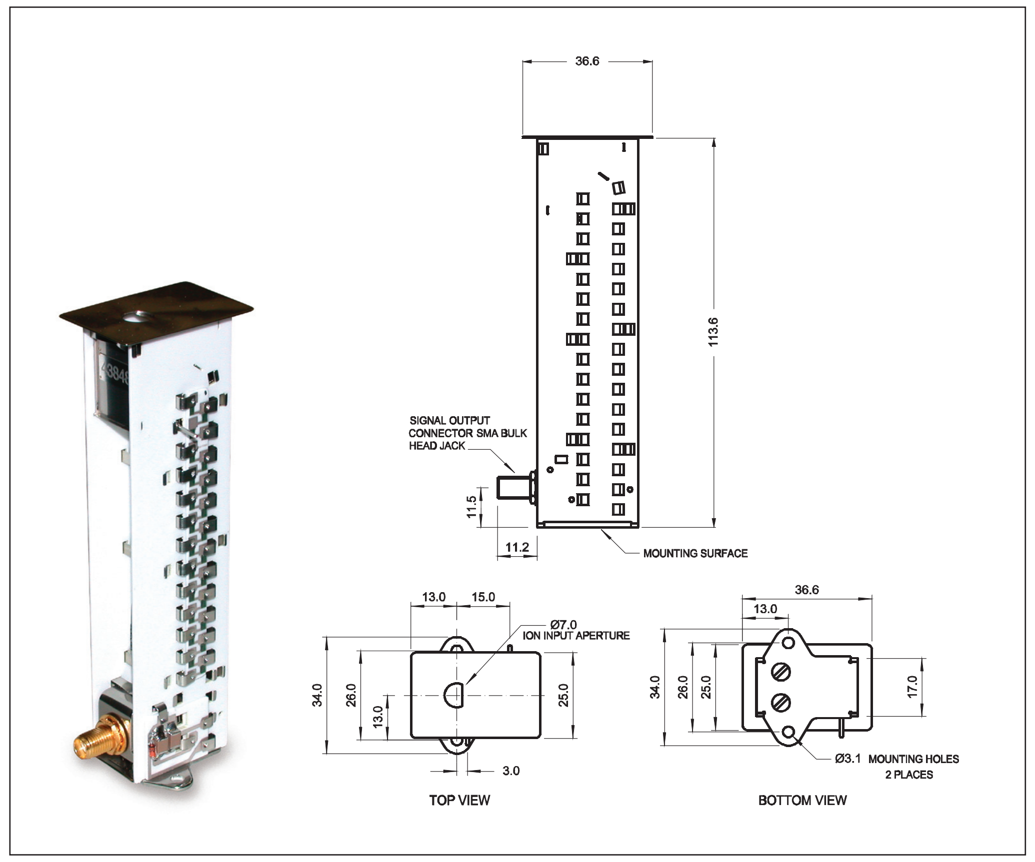


Figure 1. Schematic diagram of multiplier operation.



Photograph of a DM169 prototype Scaling Pulse Detector and schematic showing mechanical detail.

Performance

The operating point is determined by obtaining a plateau curve for the multiplier. This is done by increasing the multiplier HV and plotting the measured output count rate. The operating point is typically set just above the knee of the plateau curve. Figure 2 shows a typical set of plateau curves for the new multiplier taken over a range of attenuation factors. The knee of the attenuating plateau curves occurs at VG ~2850V. The knee of the non-attenuating plateau curve occurs at VG ~2750V. It is important to note that the plateaus on these curves have a wide region of overlap so an operating point can be selected to suit both the unattenuated and attenuated modes of operation.

Figure 3 shows attenuation of the count rate caused by varying the voltage applied to the control electrode. This demonstrates that attenuation of the detected ion count rate can be adjusted to be greater than 1 in 10,000.

Conclusions

A Scaling Pulse Detector has been developed that can handle input ion rates in excess of 10^{10} per second.

- The output count rate of the multiplier stays within normal limits ($<10^{7}$ cps) and conventional pulse-counting electronics can be used
- Attenuation of the count rate occurs after the ion-to-electron conversion, minimizing any mass-dependent effects
- Plateau curves obtained for attenuated and unattenuated modes of operation have a wide region of plateau-overlap. This allows a single operating point to be used for both modes of operation

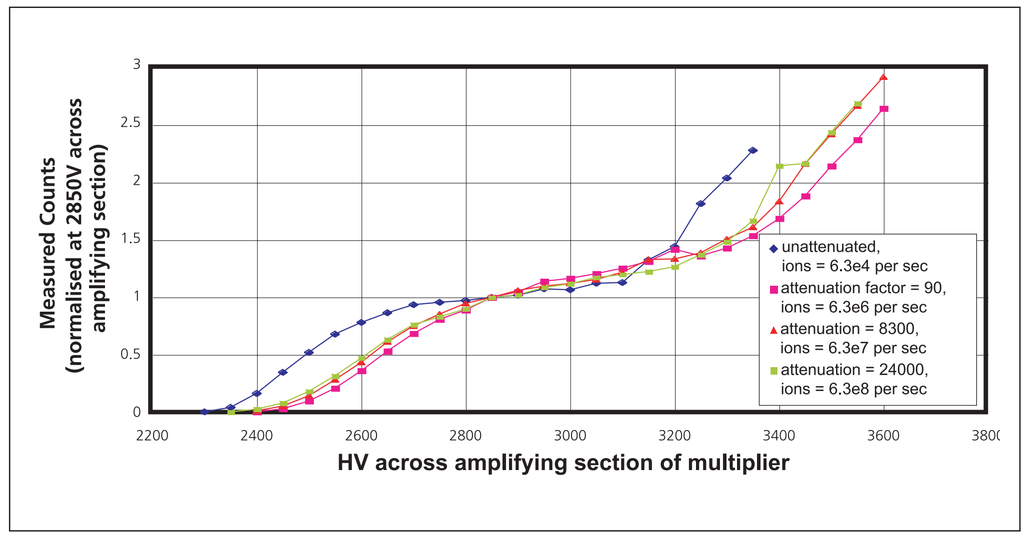


Figure 2. Plateau curves obtained at attenuation factors of ~1, ~90, ~8300 and ~24000. Datas were recorded with a discriminator level of 1.0mV.

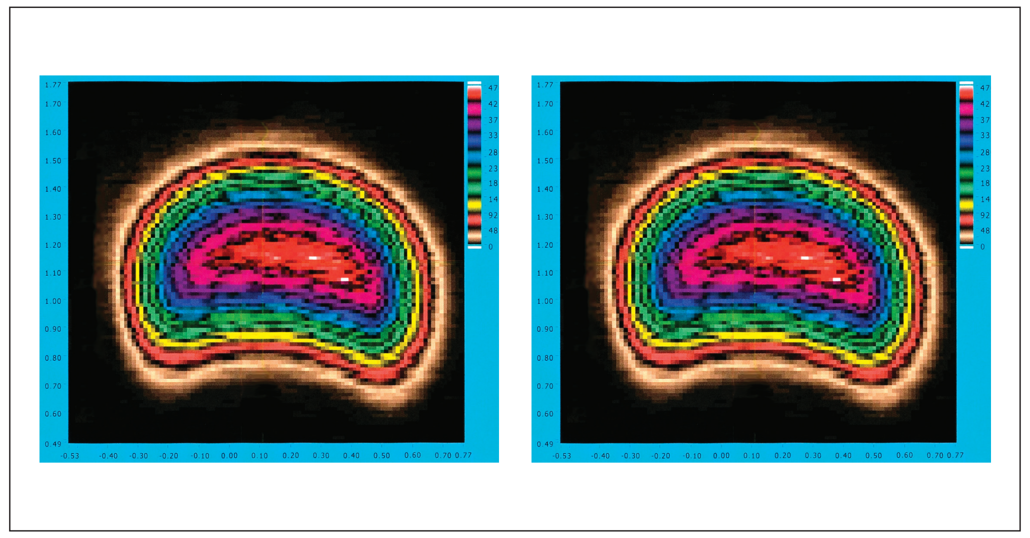


Figure 4. A contour plot of the spatial sensitivity within the aperture of a DM169 Scaling Pulse Detector (dark lines are 10% sensitivity contours). The aperture scan was produced by rastering a ~2mm diameter beam of air ions across the multiplier aperture. Little change is seen between the attenuated and unattenuated modes of operation. This indicates that the attenuation process does not alter the input optics and so will introduce minimal mass dependent effects.

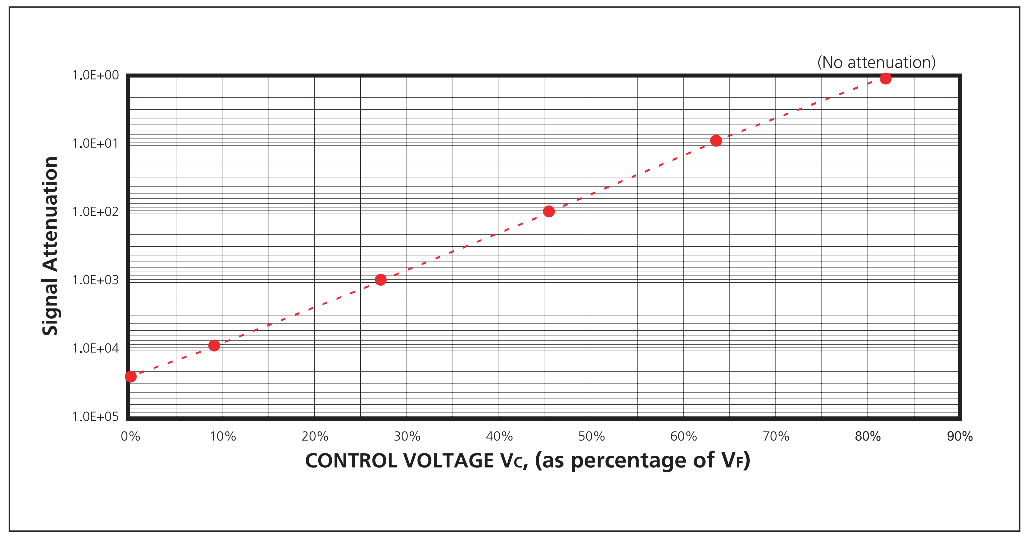


Figure 3. Attenuation of the measured output pulse rate of a DM169 Scaling pulse Detector as a function of the control voltage, VC.

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