Taming the Jitter in a Discrete Dynode TOF Detector

Dick Stresau, Wayne Sheils, Kevin Hunter
ETP Pty. Ltd. Ermington, Australia

Presented at the 49th ASMS Conference on Mass Spectroscopy and Allied Topics
May 27-31, 2001, Chicago, Illinois

INTRODUCTION

Discrete dynode TOF detectors offer major advantages over MCP's. These include large dynamic range and both mechanical and operational robustness. However, they usually have the disadvantage of significant detector jitter. Detector jitter is a result of differing transit times for ions striking different portions of the ion impact plate. This causes output pulse broadening for multiple ion events.

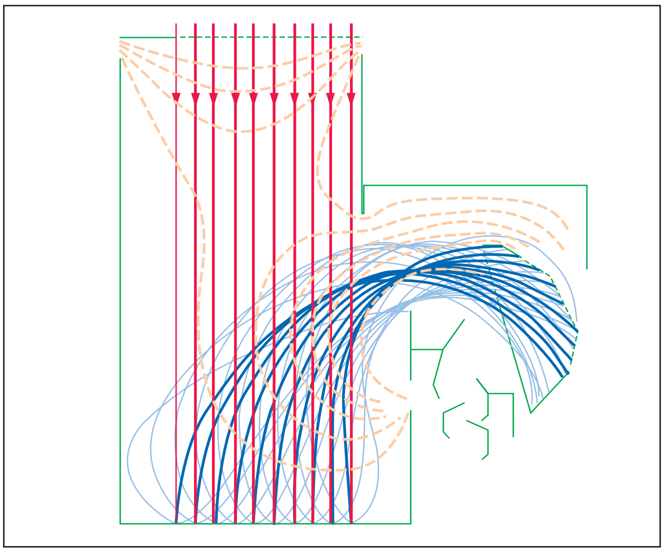
The mechanisms causing jitter in a fast discrete dynode TOF detector have been studied in detail. The analytical methods devised for this study have been used to develop a design that reduces the jitter to minimal levels. The new design resulting from this study offers a combination of narrow pulse width and large dynamic range in a robust TOF detector.

DEFINING THE ISSUE

The details of the discrete dynode TOF detector shown in Figure 1 illustrate the mechanism causing jitter: Ions (shown as red trajectory lines) must transit the area between the entry grid and impact plate before conversion to electrons at the impact plate. Ions traversing this area on the left side of the diagram encounter significantly less field variation (shown by the equipotentials) than ions on the right of the diagram. As a result the 'left side' ions take less time to reach the impact plate than 'right side' ions (if they are positive ions). The opposite is true if they are negative ions. There is also a 'left-to-right' variation in transit time for electrons traversing from the impact plate to the electron multiplier input dynode. In some cases the electron transit time variation will compensate for the ion variation and result in negligible jitter.

In Figure 1, the ion input optics of the conventional discrete dynode TOF detector showing: the basic electrode structure, incoming ions (with arrows), electron trajectories from impact plate to multiplier input dynode (left to right), and equipotentials (dotted lines).

Figure 1



ANALYSIS METHOD

A series of steps were followed to arrive at a detailed analysis of jitter for a range of ion species and for each detector design (jitter is a strong function of ion mass, energy and polarity). Trajectory times were calculated in a three-dimensional model of the detector structure for both incoming ions and the resulting secondary electrons. Appropriately weighted Monte Carlo selection was used to choose the input position for each ion and electron. This method was also used to select the characteristics of the emitted electrons to accurately simulate secondary electron emission. The surface of the impact plate was divided into 400 segments.

For each segment the average ion transit time was added to the transit time of electrons emitted from that segment. The detector's jitter was then expressed as a histogram of the electron (plus ion) transit times. 100,000 ion and electron trajectories were calculated for each structure to ensure an accurate analysis.

RESULTS

The above method was used to design and evaluate a very effective jitter compensation electrode. Each of the histograms generated by the method is essentially a calculation of the multiple ion pulse width that should be expected from the first two stages of the detector. Measuring the pulse's width at half maximum gives a convenient, quantitative method of expressing each analysis result as a single number. To calculate the expected total-detector pulse width (Figure 2, 3 and 4) the calculated pulse width of the detector's first two stages (jitter) has been added in quadrature to the detector's experimentally measured single ion pulse width:

$$W_T = ((W_J)^2+(W_{SI})^2)$$

Figure 2, 3 & 4 show the variation in multiple ion pulse width as a function of ion mass and polarity for both the original design and the jitter compensated design. In the original design, the variation of electron transit time from impact plate to multiplier dynode compensates for the jitter caused by low-mass, positive ions, but causes greater jitter for negative ions.

Although the jitter compensation is very effective, it is clear that the original design configuration will give better TOF performance in a system limited to positive ions and an energy dependant mass range (up to a mass of 6000 amu for 10 keV ions).

The ion's contribution to jitter is a function of its velocity. Therefore, the jitter is a strong function of ion mass and energy.

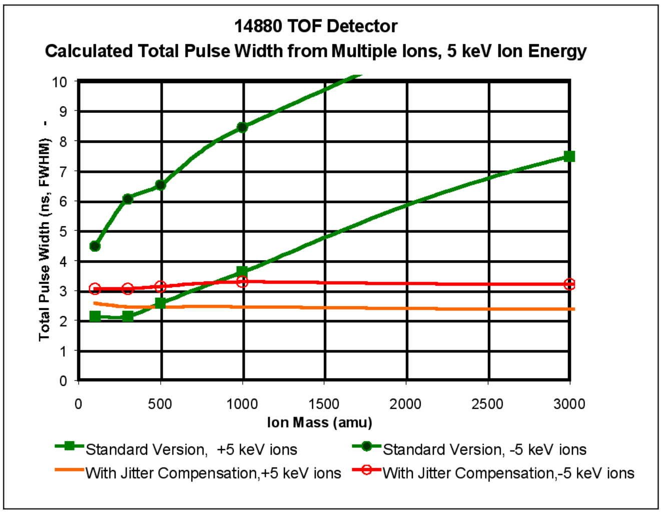


Figure 2

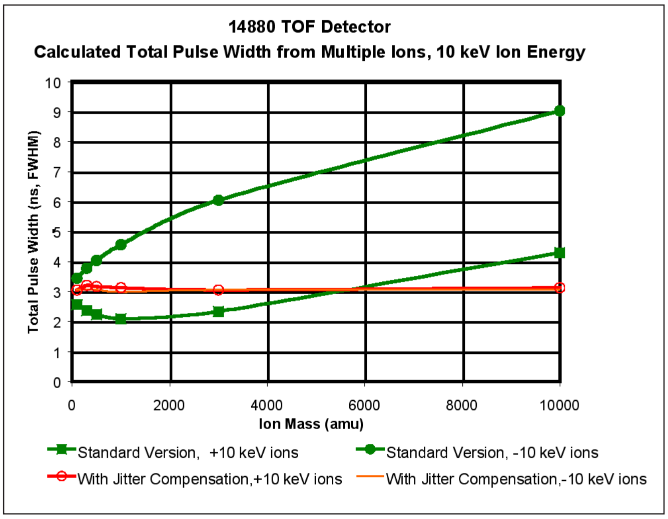


Figure 3

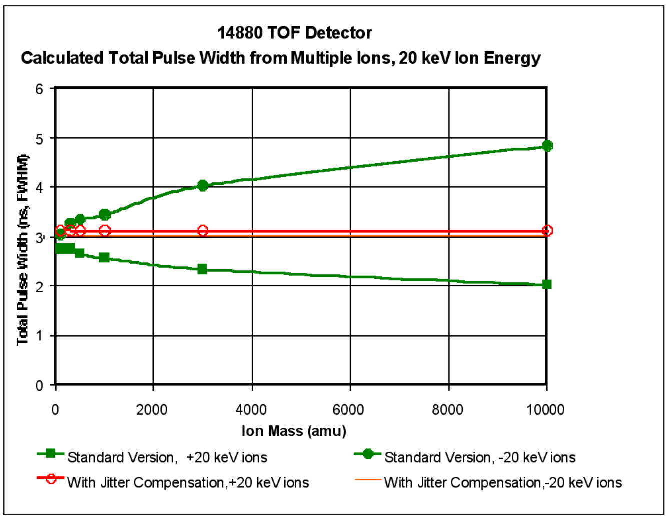


Figure 4

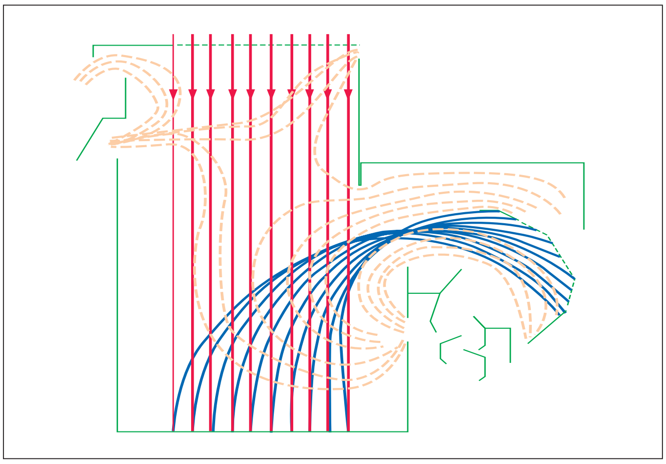


Figure 5

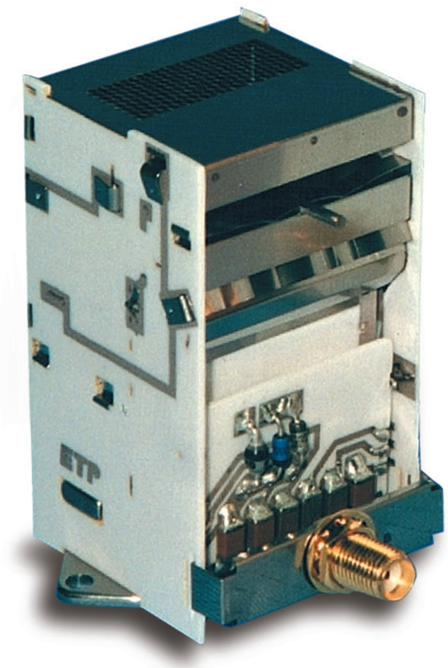
Figure 5 shows the ion input optics of the jitter compensated discrete dynode TOF detector. Note how all incoming ions traverse similar field variations due to the compensation electrode (upper left).

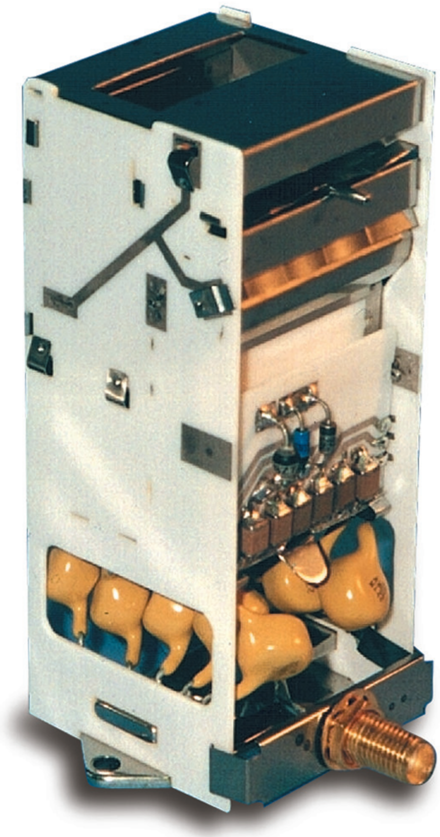
CONCLUSIONS

Inclusion of a jitter compensation electrode in a discrete dynode TOF detector has reduced multiple ion pulse width to ~3 nanoseconds for all ion masses and energies. The original (uncompensated) version TOF detector will give better TOF performance for most positive ion applications. Improved performance for negative ion applications will extend the discrete dynode TOF detector's use as the preferred detector in a wider range of TOF applications, affording greater detector robustness and dynamic range in systems previously restricted to MCP detectors.

ACKNOWLEDGMENTS

We would like to thank Alexander Makarov, Thermo Masslabs Ltd. (formerly of HD Technologies), whose initial suggestions lead to this development project.





The 14880 discrete dynode TOF detector (below left) used in this study (available either with or without jitter compensation). The 14882 (below right) is a floating version of the 14880 that has the signal isolated from the detector output through 10kV decoupling capacitors.

ETP electron multipliers

ETP Electron Multipliers
ABN: 35 078 955 521
Address: 31 Hope Street,
Melrose Park NSW 2114
Australia
Tel: +61 (0)2 8876 0100
Fax: +61 (0)2 8876 0199
Email: info@etp-ms.com
Web: www.etp-ms.com