Evaluation of Pulse Counting for the Mars Organic Mass Analyzer (MOMA) Ion Trap Detection Scheme

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Novel Aspect: Low-cost, pulse-counting electronic components are used to improve mass spectral quality from an ion trap.

Introduction

The Mars Organic Mass Analyzer is being developed at Goddard Space Flight Center to identify organics and possible biological compounds on Mars. In the process of characterizing mass spectrometer size, weight, and power consumption, the use of pulse counting was considered for ion detection. Pulse counting has advantages over analog-mode amplification of the electron multiplier signal. Some advantages are reduced size of electronic components, low power consumption, ability to remotely characterize detector performance, and avoidance of analog circuit noise. The use of pulse counting as a detection method with ion trap instruments is relatively rare. However, with the recent development of high performance electrical components, this detection method is quite suitable and can demonstrate significant advantages over analog methods.

Methods

A prototype quadrupole ion trap mass spectrometer with an internal electron ionization source was used as a test setup to develop and evaluate the pulse-counting method. The anode signal from the electron multiplier was preamplified. The amplified signal was fed into a fast comparator for pulse-level discrimination. The output of the comparator was fed directly into a Xilinx FPGA development board. Verilog HDL software was written to bin the counts at user-selectable intervals. This system was able to count pulses at rates in the GHz range. The stored ion count number per bin was transferred to custom ion trap control software. Pulse-counting mass spectra were compared with mass spectra obtained using the standard analog-mode ion detection.

Preliminary Data

Preliminary mass spectra have been obtained for both analog mode and pulse-counting mode under several sets of instrument operating conditions. Comparison of the spectra revealed better peak shapes for pulse-counting mode. Noise levels are as good as, or better than, analog-mode detection noise levels. To artificially force ion pile-up conditions, the ion trap was overfilled and ions were ejected at very high scan rates. Pile-up of ions was not significant for the ion trap under investigation even though the ions are ejected in so-called 'ion micro packets'. It was found that pulse-counting mode had higher dynamic range than analog mode, and that the first amplification stage in analog mode can distort mass peaks. The inherent speed of the pulse-counting method also proved to be beneficial to ion trap operation and ion ejection characterization. Very high scan rates were possible with pulse counting since the digital circuitry response time is so much smaller than with the analog method. Careful investigation of the pulse-counting data also allowed observation of the applied resonant ejection frequency during mass analysis. Ejection of ion micro packets could be clearly observed in the binned data. A second oscillation frequency, much lower than the secular frequency, was also observed. Such an effect was earlier attributed to the oscillation of the total plasma cloud in the ion trap. While the components used to implement pulse counting are quite advanced, due to their prevalence in consumer electronics, the cost of this detection system is no more than that of an analog mode system. Total pulse-counting detection system electronics cost is under $250.