RF-Only Mode, Frequency Focusing and Gated Trapping for In-Field MALDI FTMS: Operation Considerations


Department of Chemistry, Washington University, 1 Brookings Drive, St. Louis, MO, 63130-4899

Gated trapping with high voltage pulses can (at least theoretically) stop within the FTMS trap in-field MALDI generated ions, which have wide ranges of mass and velocity. Evidence shows substantial detection performance improvement for in-field LD and MALDI might be achieved with trap frequency focusing (compensation) and a high voltage RF-only-mode event. The trapping plate supply which implements the three strategy combination, however, introduces mass dependence into the detection sensitivity and holds the potential for destruction of instrument components. The difficulties and dangers are removed through the use of devices which include pneumatically operated switches. Additionally, the combined strategy of trap compensation and the use of an RF-only-mode event for detection performance improvement of in-field LD produced ions in a solenoid magnet is shown for the first time.

Additions were made to the existing configuration of a 3-Tesla Finnigan T30 FT/MS mass spectrometer including a radio coil and a switch array that intercepts the analog drives normally connected to the trapping plates. The two 47.6-mm cubic trapping plates were previously segmented into an electrically independent 23.8-mm center disk and an outer segment. Ions are generated by LD of C_{60} with the third harmonic from a Quanta Ray DCR-2(10) Nd:YAG laser aimed down the trap z-axis and located opposite from probe positioned 4 mm from the trap. For the results reported here, the sample was depleted by use of the laser until signal was not observed when compensation was used by itself.

Asymptotic stability over a wide mass range (100 to 7.5E+4 m/z) [ASMS 1999] during the RF-only-mode event requires the application of a 4.8-kV base-to-peak 0.885-MHz sine wave. This goal has been met with a coil that resonates with the network of stray capacities of the trap and its leads. A 2.0-kV base-to-peak 0.9037-MHz sine wave was used for results reported here.

Because the trap detection plates are involved in this network through capacitive coupling in the trap, the equivalent circuit for the preamp input necessarily includes this resonance, which distorts the preamp's sensitivity to ion signals as a function of mass (see Fig. 1). A switch was place across each of the eight windings that make up the secondary of the coil to short out the coil inductance and remove its effects on the preamp. Pneumatic operation at 20 psi of the switches permits their operation in the fringe field of the solenoid magnet and opens the switch for the RF-only-mode event in about 10 ms.

The preamp's input's involvement in the network of stray capacities exposes it to excessive currents during the RF-only-mode event and gated trapping voltage transitions and that high current can damage the low-signal FETs of the preamp input stage. Accordingly, the preamp inputs are protected by switches that short the inputs to ground at all times in the sequence except for the detection event. Each switch adds less than 1 pF to the preamp input and pneumatic operation makes complete isolation from outside electrical interference possible.

In the sequence, the RF was extended beyond the time during which the He is introduced into the trap to minimize radial diffusion while the He pumps away. The experiment is relatively insensitive to changes in this “stretch” time from 5 s to 20 s.

The RF is applied (2000 Vb-p at 903.7 Khz) together with the introduction of He gas (2 to 2.5 x 10^{-5} Torr) to pressure focus the ions to the center of the trap during the “He time”. The cumulative improvement in signal (~10x) from 5 s to 320 s suggests ions continue to be focused over long times.

In experiments that used a 80-s He time and a 20-s stretch time, a comparison of the various combinations of strategies shows that compensation together with the RF-only-mode gives a clear improvement in detection and resolving power as shown in Fig. 2. The trap segment voltages were 0.89 V for the outer segments and 0.5 V for the disks during excitation and detection.
Figure 1. Preamplifier response vs frequency as affected by the RF coil in the trap voltage supply circuit. Shorting the coil with switches restores the uniform response of the preamplifier to ion signals as a function of mass.

Figure 2. A comparison of strategies for improving the performance of FTMS. The combined utilization of compensation and the RF-only-mode event in the sequence provides the best outcome in the comparison.