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A NEW ION GATE COMPRISING SMALL ORTHOGONAL TOF ION MIRROR

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OVERVIEW

- The design of a new MALDI orthogonal TOF ion gate is described.
- Unlike axial TOF gates, resolving power is not affected by axial energy spread.
- For MS/MS, fragmentation can be increased by using increased laser fluence.

INTRODUCTION

In MALDI-TOF-TOF instruments, selection of parent ions for MS/MS analysis is achieved using a Bradbury Nielson ion gate (ref. 1) . All ions except those of interest are electrostatically deflected from the axial trajectory. The resolution of parent ion selection is limited by the axial ion energy spread and the ability of the gate to open and close quickly enough and at precisely the right time. A novel ion gate is presented which comprises a small orthogonal TOF with ion mirror (oa-gate). The time of flight orthogonal to the ion beam is largely independent of the axial ion energy spread (or on precise timing of when it is energised) and as such offers significant advantages over the Bradbury Nielson ion gate.

METHODS

Figure 1 illustrates the oa-gate fitted to an experimental orthogonal TOF mass spectrometer (previously described in detail in ref. 3). For MS/MS, ions are accelerated from a MALDI source to approximately 500eV. After a few micro-seconds depending on the precursor mass of interest, ions arrive into the initially field free region of the new orthogonal ion gate (oa-gate). At the approximate TOF for the precursor ion, an electrostatic "pusher" field is energized by applying voltage Vp to the oa-pusher plate (see fig 2), the ions are accelerated orthogonal to their initial direction. They are then reflected back by a short electrostatic mirror. When the ions of interest arrive back in the "pusher" field, the field is de-energised and only ions with the exact orthogonal TOF are redirected along their initial axial direction. Mass selection is determined by the length of time the pusher field is energised (*rather than when it is initially energised*). Only ions of interest for MS/MS are therefore directed along their original trajectory and into the main oa-TOF (TOF2) for mass analysis. In order to determine the precursor ion selection performance (or resolution), the pusher field duration is scanned linearly with time whilst measuring the transmission of a pair of peptides using the oa-TOF.

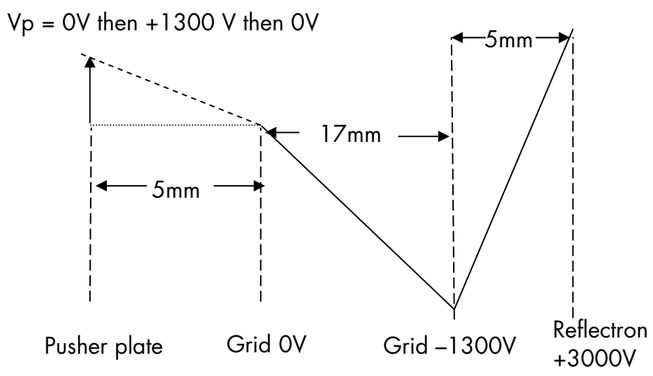

Figure 2. Potential energy diagram for oa-gate

RESULTS

Prior to construction, the oa-gate concept was modeled using SIMION (ref. 2). A distribution of several hundred ions representing a random initial velocity spread (upto 500m/sec) for two masses (MH+ 1000 and 1005) were "flown" as the pusher field duration was scanned. The number of ions transmitted by the oa-gate as a function of pusher duration can be seen in figure 3. The resolution predicted was approximately 200 FWHM. A 1 inch experimental system was constructed and fitted to the oa-TOF shown in Figure 1. The time between energising and de-energising the pusher plate was scanned down from 3.8 usecs at a rate of 4nsecs/sec, each scan on the chromatogram was a 1 second summation of 5 laser shots. By plotting the mass chromatograms the resolution of the ion gate may be measured.

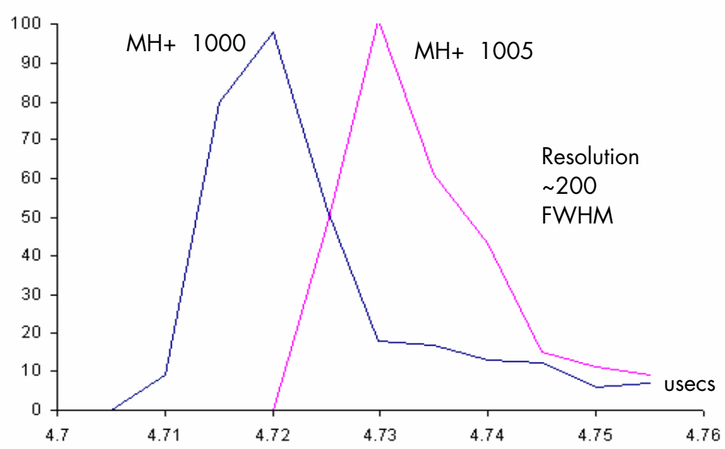

Figure 3. SIMION resolution. Number of ions transmitted versus oa-gate pusher field duration

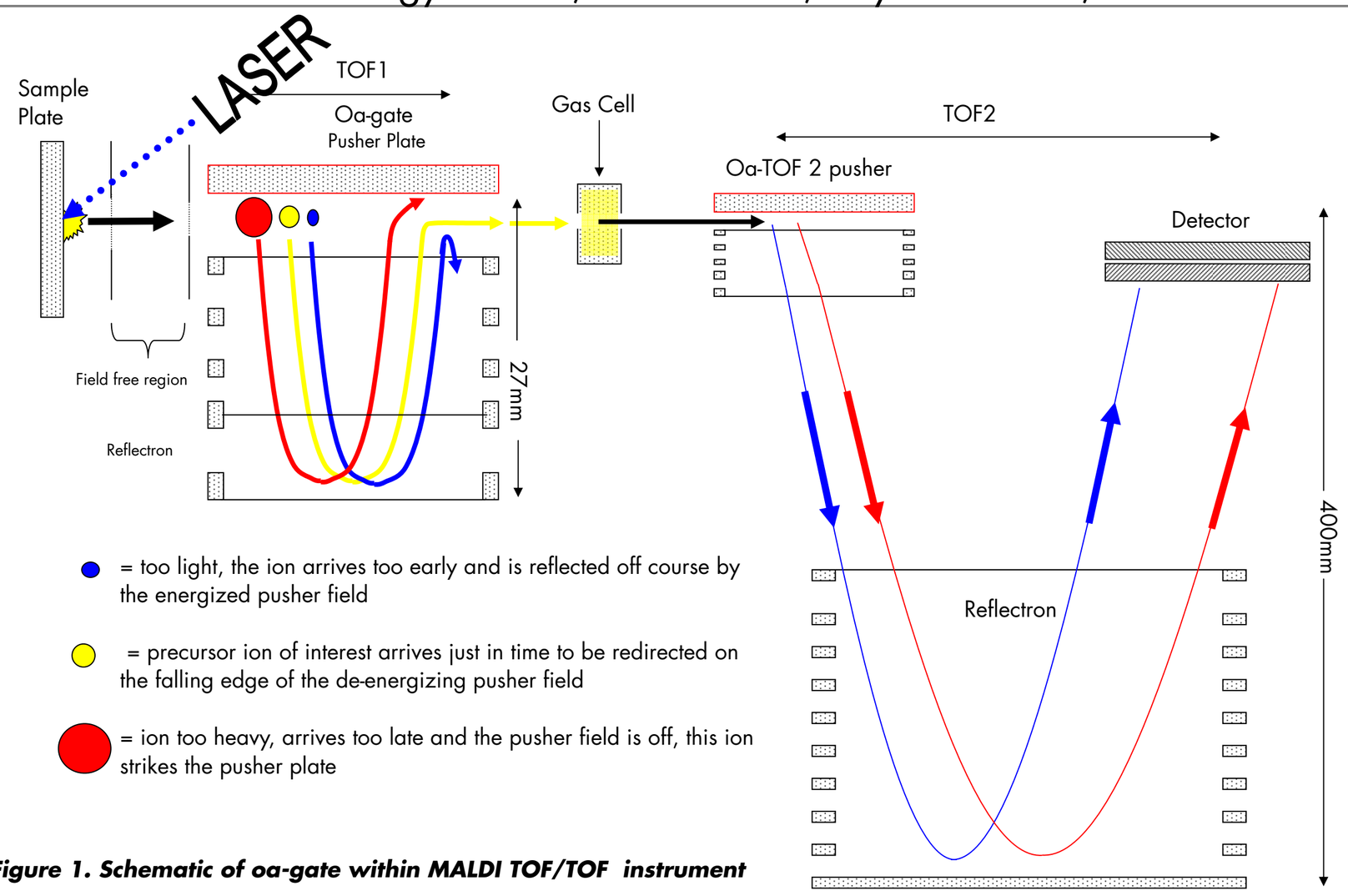

Figure 1. Schematic of oa-gate within MALDI TOF/TOF instrument

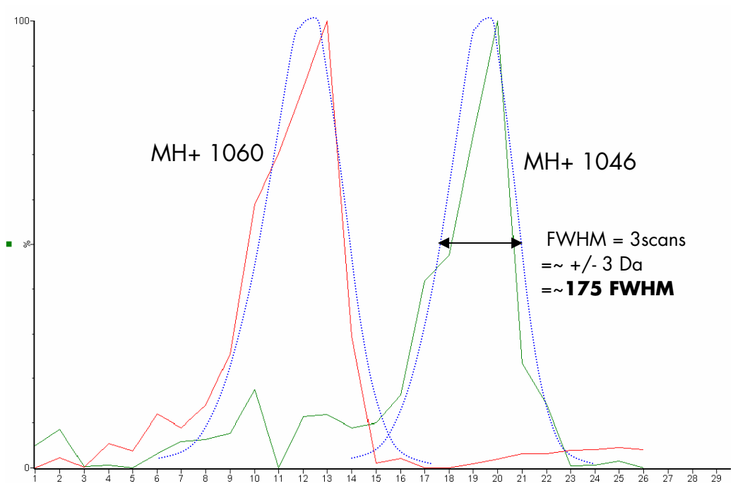

Figure 4. Separation of Angiotensin II and Bradykinin by scanning the oa-gate pulse duration

Figure 4 shows the mass chromatograms of ions transmitted by the oa-gate from an equimolar mixture of 100fm Angiotensin II (MH+1046.5) and Bradykinin (MH+1060.5) as the pusher duration is scanned.

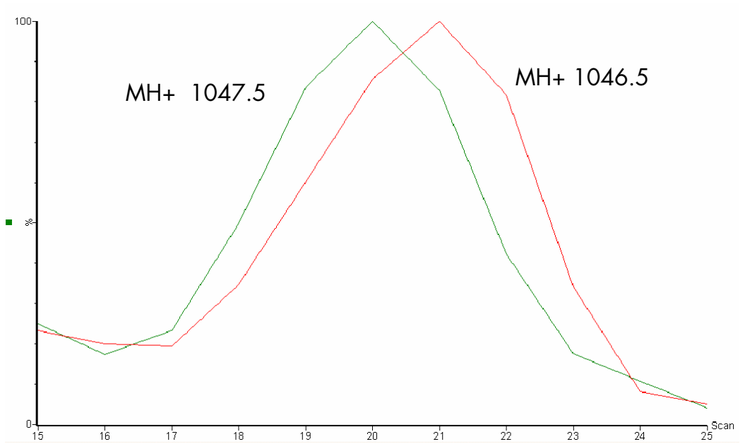

Figure 5. Partial separation of adjacent isotopes from Angiotensin II by scanning the oa-gate pulse duration

Figure 5 shows the mass chromatograms for two adjacent isotopes from Angiotensin II. The dotted line in Figure 4 represents a Gaussian fit of the transmission profile for the oa-gate. This is overlayed onto the spectra in Figure 6 which shows both the unresolved mixture (a) (gate off) and the individually selected peptides (b) and (c) where the oa-gate pusher duration was set to transmit the individual peptides.

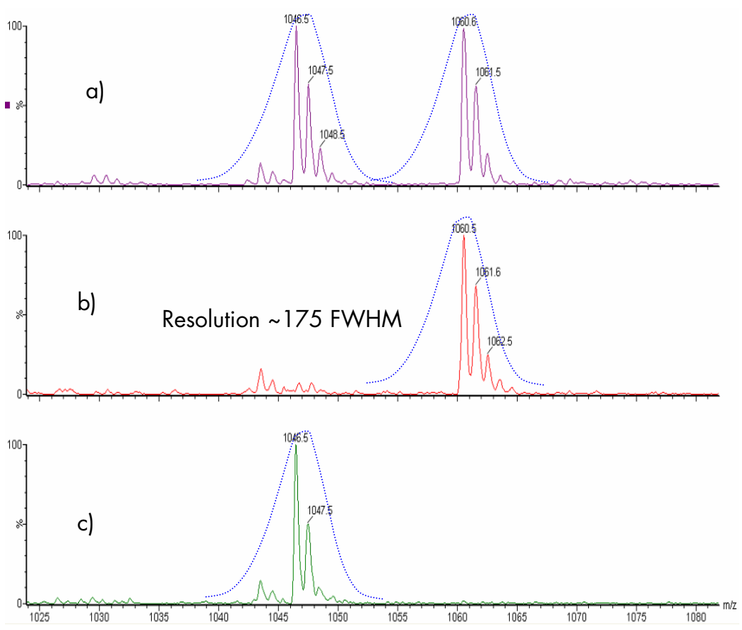

Figure 6. a) oa-gate off, mix of Angiotensin II and Bradykinin, and b) oa-gate selection of Bradykinin and c) Angiotensin II.

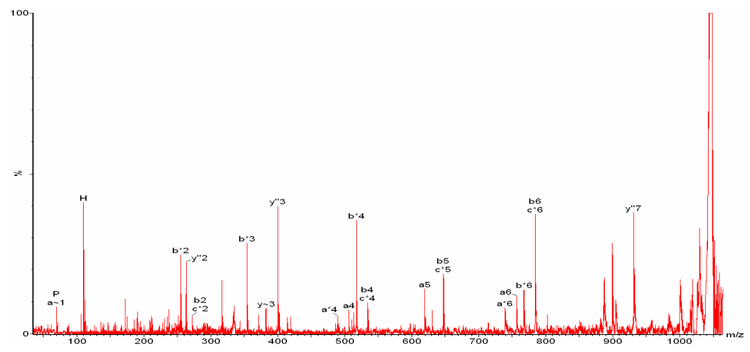

Figure 7. MS/MS spectrum of Angiotensin II selected

In order to investigate the MS/MS data quality, precursor ions and their post source decay (PSD) fragment ions were recorded by the oa-TOF. Figure 7 shows an MS/MS spectrum where Angiotensin II was selected from the mixture above. The annotated fragment ions are clearly attributed to Angiotensin II and not Bradykinin. To check the transmission and sensitivity of the ion gate, a 2fmole loading of GluFibrinopeptide was analysed by MS/MS both *without* and *with* the ion gate selecting the precursor (see Figure 8). It is interesting to observe that the oa-gate significantly improves the signal:noise of the fragment ions because it only allows the precursor ion through and rejects other chemical noise peaks such as matrix adducts/fragments and sample impurity fragments.

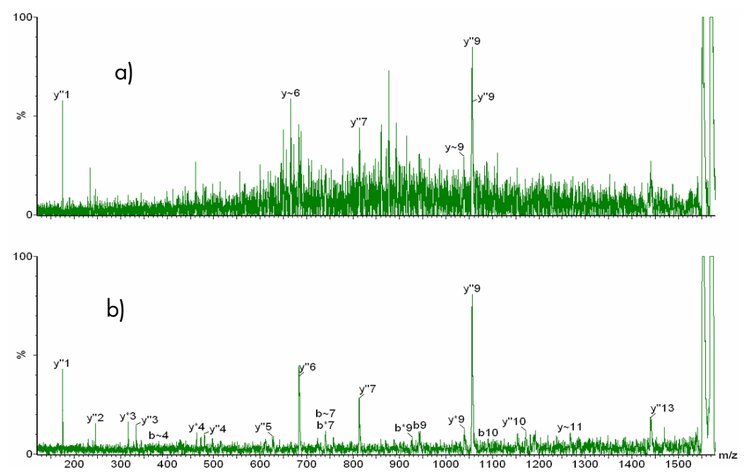

Figure 8. 2fmole GluFibrinopeptide MS/MS spectra with oa-gate switched a) OFF and b) ON.

DISCUSSION

The oa-gate has a number of advantages over the traditional BN ion gate. It is not dependant upon the location of the device, the use of a delayed extraction ion source or the laser fluence, therefore increased laser fluence may be used to promote ion fragmentation. Also, for the precursor ion, no loss in ion transmission occurs through the oa-gate with the gate deactivated as there are no wires occluding the ion beam. When the oa-gate is active, the ions pass through four 90% transmission grids however no reduction in transmission is observed (simulations have indicated that this could be due to the reduction in phase space volume).

CONCLUSION

- A small orthogonal TOF ion gate concept has been proven.
- The data show the clear selection of precursor ions using a short (~1inch) oa-TOF. The results were close to those predicted by SIMION.
- The transmission through the gate is high (~100%) and improves signal to noise of the MS/MS data.
- The precursor ion selection window using the small oa-gate is ~+/- 3Da at m/z 1060 (~175 FWHM).
- Since the ion gate is orthogonal, a greater range of laser fluence can be used to promote ion fragmentation without loss of precursor ion resolution.

References

1. N. E. Bradbury and R. A. Nielson, Phys. Rev. 33, 605 ,1936
2. SIMION 7.0 - David Dahl at Idaho National Lab (INL)
3. ASMS 2005, San Antonio, Poster 265 ("A Novel MALDI Orthogonal Time of Flight Mass Spectrometer").

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