# STEPWAVE

## Enhancing MS Sensitivity and Robustness

## INTRODUCTION

Of the key analytical requirements for any experiment, sensitivity is typically of primary concern. Having the selectivity to uncover an analyte within a complex matrix is inconsequential without the presence of sufficient ions of interest to detect.

Based on stacked-ring ion guide technology, Waters® StepWave™ is an elegant device designed to maximize ion transmission from the source to the mass analyzer. Through its unique design, StepWave also allows for the active removal of neutral contaminants, providing an enhancement to overall signal-to-noise, while importantly extending the robustness of the system.

### Principles of operation

When sampling ions from an atmospheric pressure ion source, a significant quantity of gas enters the vacuum system. It is essential to remove the accompanying gas from the ions prior to the mass analyzer. The configuration of an off-axis ion guide featuring conjoined stacked rings enables the active separation of ions from the gas flow.

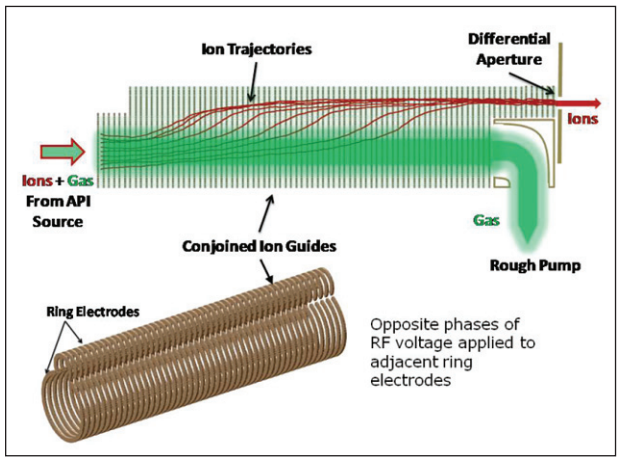



*Figure 1. Diagrams of the conjoined stacked ring ion guides.*

Figure 1 shows a schematic of a conjoined ion guide. The ions enter the larger diameter ion guide and are directed into the upper ion guide using a differential voltage; this focuses them into a narrow beam for transport into the mass analyzer. Gas, neutral species, and any non-desolvated material are directed to the rough pump inlet. The gap between the lower and upper guides allows the clear passage of ions without impact on the lenses, as shown in Figure 2. A reverse travelling wave on the lower guide ensures ions are not swept out with the high gas flow and have time to transfer into the upper guide. Once captured, they are propelled by T-Wave into the next stage.

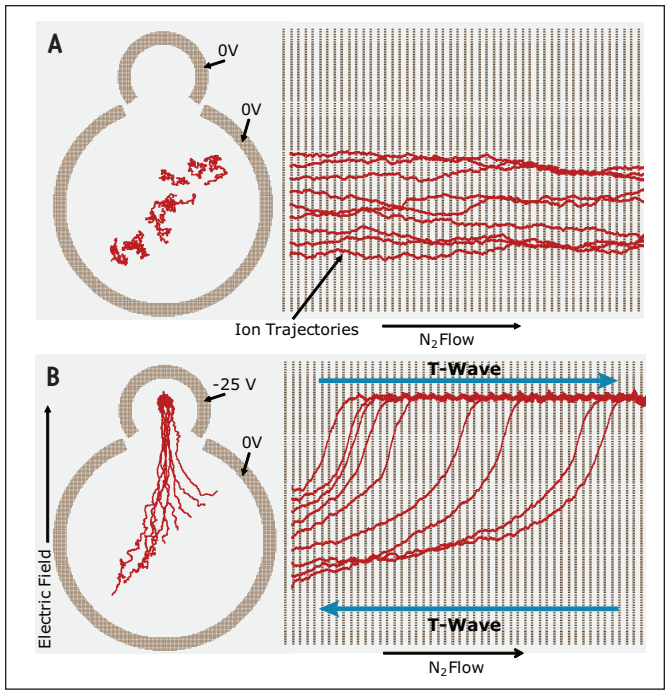



*Figure 2. SIMION simulation of ion transit through the conjoined ion guide device: (a) with no potential difference between the sections (b) with 25 V.*

### Maximizing sensitivity

StepWave's design allows the handling of much larger gas loads into the instrument, permitting the use of a larger sampling orifice to capture significantly more ions from the source. Signal transmission is consequently increased more than 25X over the standard single ion guide designs, directly contributing to greater sensitivity across the mass range, as shown in Figure 3. Chemical noise is an undesirable consequence of the larger orifice; however StepWave can improve signal-to-noise compared to expected ratios, due to the active removal of the neutral or large cluster species.

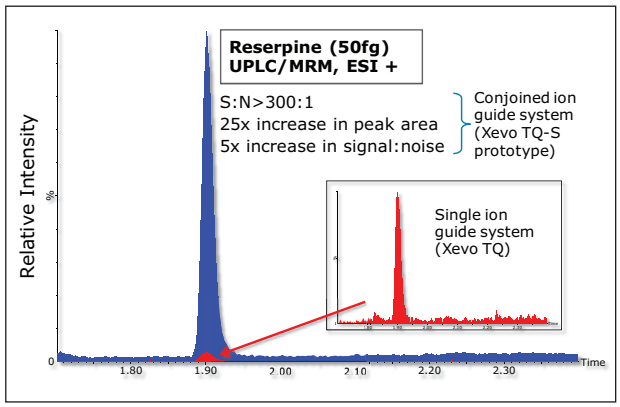



*Figure 3. Reserpine, 50 fg on-column. 800 µL/min gradient elution on a 50 x 2.1 mm BEH $C_{18}$ Column.*

"When compared to earlier generation mass spectrometer models, MicroConstants experienced a forty-fold increase in sensitivity with compounds tested internally in negative electrospray ionization mode. The significant increase in sensitivity can be attributed primarily to the system's new StepWave ion-transfer technology. This off-axis design dramatically increases the efficiency of ion transfer from the ion source to the quadrupole MS analyzer while at the same time actively eliminating undesirable neutral contaminants".

**MICROCONSTANTS, INC., press release, 2 March 2011**

## Extending robust use of the enhanced performance

Historically, one of the limiting factors of efforts to increase signal transmission was the impact on instrument robustness. The transfer of excessive solvent, matrix, and ion beam into the ion optics can quickly and dramatically reduce sensitivity over time. Any gains made in sensitivity are essentially made redundant if that performance cannot be repeated day after day.

Figure 4 illustrates the design robustness with no significant change in performance after 6000 repeat injections of verapamil in protein-precipitated plasma.

Other designs that offset the flight path of ions from the source to the analyzer can still lead to contamination of the surrounding optics, degrading sensitivity over time. However, the StepWave design protects the critical upper ion guide and the subsequent aperture from the direct line of sight of the high gas flow and contaminants. Key tuning parameters therefore remain unaffected, and sensitive methods are maintained over time.

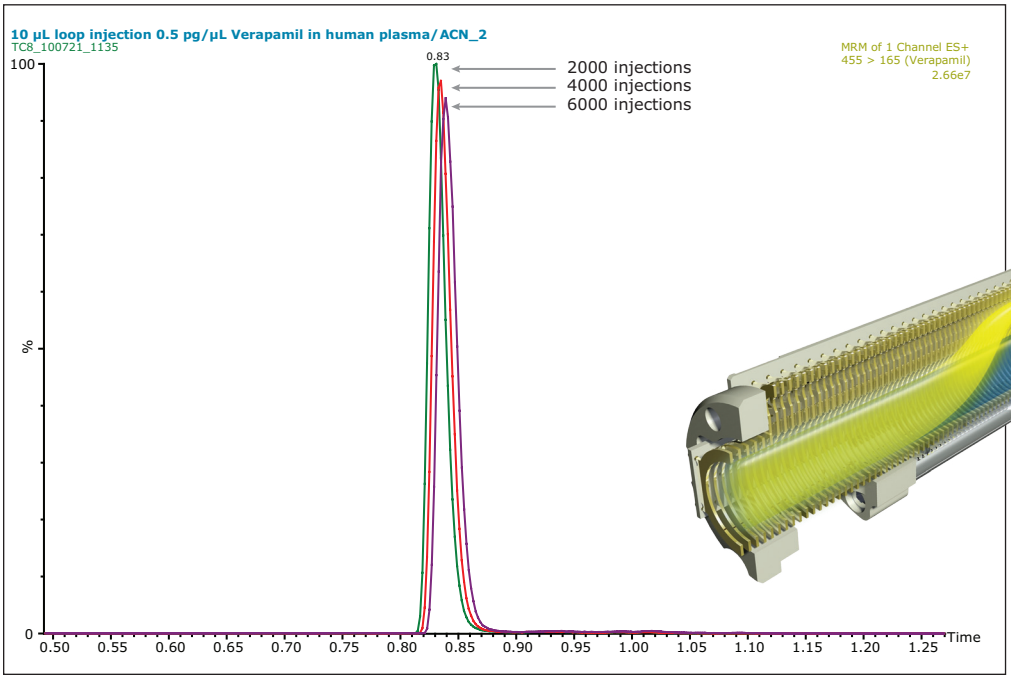
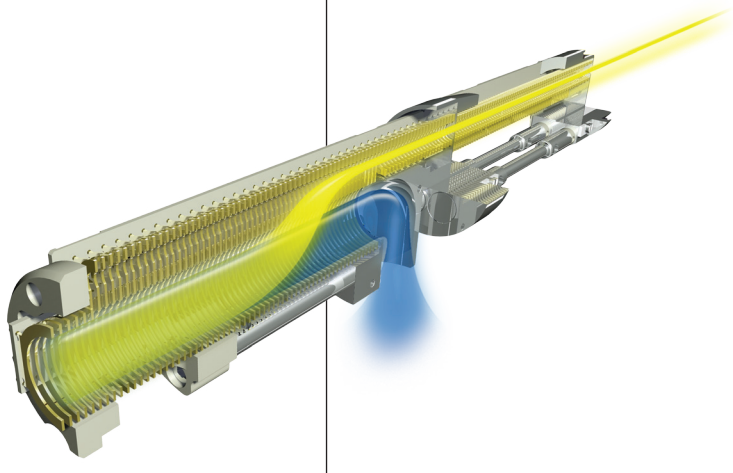



*Figure 4. Robustness with no significant change in performance after 6000 repeat injections of verapamil in protein-precipitated plasma.*



"The Waters Xevo® TQ-S [featuring StepWave] has allowed us to greatly improve achievable sensitivity on a number of challenging assays, ranging from the analysis of very high potency small molecules to the quantification of therapeutic peptides."

**MOHAMMED ABRAR, Method Development Manager, Unilabs York Bioanalytical Solutions, York, UK**

### Remaining compatible with UPLC® speed and multi-function acquisitions

Manipulating ions in such a high flow environment introduces a significant challenge. The use of travelling waves in the conjoined guide allows the speed of ions to be finely controlled. By propelling ions through the device, the T-Wave™ aids the speed of transfer into the mass analyzer, thus maintaining the critical acquisition parameters required to carry out multimode tandem MS experiments over the narrow peak widths from UltraPerformance LC.®

## SUMMARY

StepWave is a unique ion transfer device designed to maximize transmission from the ion source to the mass analyzer. Typical gains observed are 25 X increase in peak area and 10 X in signal-to-noise. Critically, the device also maintains instrument robustness and delivers significant improvements over alternative commercialized methods.

## Further Reading

1. Applications of a travelling wave-based radio-frequency only stacked ring ion guide, *Rapid Commun. Mass Spectrom.*, 2004; 18: 2401-2414.
2. A new conjoined RF ion guide for enhanced ion transmission, K. Giles and D. Gordon, Application Note 720003606EN.
3. Dramatically Enhanced Analytical Sensitivity with the Use of Novel StepWave Ion Transfer Technology in the SYNAPT G2-S System. Waters Application Note, Literature No. 720003964EN.
4. Increasing Bioanalytical Assay Sensitivity For Low Exposure Compounds with Xevo TQ-S. Waters Application Note, Literature No. 720003419EN.
5. An Introduction to Waters T-Wave Devices, Unique Technology for Advanced MS Capabilities. Waters Literature No. 720004177EN.

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