An ion funnel interface has been designed and implemented on a linear ion trap mass spectrometer. The ion funnel replaced the skimmer and greatly decreased ion accumulation times. Increasing the rate of ion accumulation greatly reduced the linear ion trap "fill" times. Faster trap "fit" times increased the duty cycle and provided higher quality data in MS/MS spectra. Increased scan speed by shorter ion trap "fill" times improved the use of high resolution MS with fast separation techniques. An LTQ FT with ion funnel interface was coupled to fast HPLC separations (~5 min) which produced several hundred protein identifications from a 1 μg global digest from S. oneidensis. Reference ion funnel parameters:

- 100 electrodes with 0.5 mm thickness and 0.5 mm spacing
- RF = 615 kHz with 60 VP-P
- Pressure of 1.5 Torr

Infusion experiments:

- A range of reserpine solutions (0.001 – 10 μg/mL) were made in 50:50 MeOH and H2O with 1% acetic acid. Solutions were infused from lowest to highest concentration at 300 nL/min using the same ESI emitter, syringe, voltage, etc. for both the standard and ion funnel interfaces.

LC MS and LC MS/MS:

- Automated HPLC system based on Isco 1000M syringe pumps using a 200 μL i.d. x 60 cm capillary column packed with 5 μm Jupiter C18 stationary phase.
- Samples made from whole cell lysates of the bacterium, Shewanella oneidensis were digested by trypsin and cleaned using a C18 SPE column.

Compared to the standard interface, the ion funnel interface increased the number of identifications, especially for the lower concentration samples. Largest factor for the increased identifications is higher quality MS/MS spectra. The ion funnel increased the number of ions in the ion trap for MS/MS analyses.

Proteomics analyses using fast HPLC separations on LTQ FT MS with ion funnel interface:

- ~10-fold increase in peak numbers of ions in the ion trap
- Target ion population of 1e6 for the ICR mass analyzer
- Electrospray ionization directly from the pulled exit of the LC column

Comparison of standard and ion funnel interfaces in LC-MS/MS analyses of S. oneidensis samples:

- Ion funnel interfaceConventional interface
- Mass range of m/z 400-1800
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LC-MS analysis of 10 μg of Shewanella oneidensis digest on LTQ standard with the ion funnel interface.

- Peak intensities increased and ion accumulation times decreased when the ion funnel interface was used.
- Similar peak profiles indicate similar ion transmission profiles in this mass range for both interfaces.

Overview

An ion funnel interface for a LTQ mass spectrometer has been designed which mimics the original LTQ traps. The ion funnel replaced the skimmer and reduced ion loss in the ion trap by ~90%.

The greater ion flux afforded by the ion funnel greatly decreased ion accumulation times. Increasing the rate of ion accumulation produced higher quality MS/MS spectra.

Faster high resolution scans enabled better coupling to fast separation techniques for high sample throughput.

Introduction

The linear ion trap mass spectrometer has an increased ion capacity, improved ion trapping efficiency, and faster cycle times compared to the three-dimensional (3D) Paul trap mass spectrometer. However, even with the increased performance, its atmospheric pressure ionization interface still incurs significant ion loss. We have previously developed and reported on an electrospray ion funnel that replaces the skimmer interface and greatly improves the ion transmission efficiency.

Here, we evaluate an ion funnel interface on a linear ion trap instrument (Thermo Electron, LTQ) and on a hybrid linear ion trap/Fourier transform ion cyclotron resonance instrument (LTQ FT). We show that a large reduction in ion accumulation times enables higher quality tandem mass spectrometry (MS/MS) analyses and fast liquid chromatography (LC) FT-ICR MS analyses resulting in increased sample throughput.

Results

Limit of detection experiment using reserpine solutions to test ion funnel performance with an LTQ ion trap MS

- ~0.5-fold increase in peak intensities (corresponding to 90% reduction in ion trap "fit" times) was observed.
- Experiment was repeated on two different LTQs with similar results.
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