Optimizing Toroidal Ion Traps for Miniature, Field Portable GC/MS Systems

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Ion traps in general have unique advantages over other types of mass analyzers when employed in miniaturized, field-portable versions of GC/MS systems. Furthermore, as the mass analyzer dimensions are miniaturized, toroidal ion traps have additional, unique advantages over other ion trap geometries when scalability and the geometry of supporting MS components are considered. These devices don't neatly fit into the family of general quadrupole devices (e.g. 3D/Paul and linear/rectilinear ion traps), and since the mathematical foundation and learned geometry optimization techniques do not directly apply, they need to be developed from scratch. This foundation is important to improving the performance of these devices since the original toroidal ion trap, first published in 2001, still has only rudimentary, first-order corrections applied to the trapping field electrodes which were based, erroneously on the rotation of a 3D ion trap cross section. The result is a mass analyzer that, while it provides good sensitivity as well as better-than-unit mass resolution out to m/z 500, is not fully optimized to provide complete ejection efficiency.

We are taking a broad approach to understanding the behavior of ions in toroidal trapping fields. Previously, this has included the study of solutions to the Laplace equation in toroidal coordinates and how they relate to our current design. More recently, we have developed new tools within SIMION® to mathematically construct new trapping field candidates, as well as deconstruct toroidal trapping fields in order to understand the effects of slits, asymptotes, curve shapes and asymmetry both on ion motion during ejection and on the frequency content of ions during storage and ejection. Our goal is to improve not only the ejection efficiency, but simplify the ion motion in order to better accommodate the resonance techniques that are used in MS/MS.