sensitivity at the expense of mass resolving power but not for both simultaneously and in all cases, the scan rate is relatively slow. The present invention, however, provides for a system and method of operation that simultaneously provides for both a high mass resolving power and an increased sensitivity at higher scan rates, which exceeds current capabilities of quadrupole mass analyzers.

[0011] Accordingly, there is a need in the field of mass spectrometry to improve the mass resolving power of such systems without the loss in signal-to-noise ratio (i.e., sensitivity). The present invention addresses this need, as disclosed herein, by measuring the ion current as a function of both time and spatial displacement in the beam cross-section and then deconvolving the contributions of the signals from the individual ion species.

SUMMARY OF THE INVENTION

[0011a] According to a first aspect, there is provided a high mass resolving power high sensitivity mass spectrometer, comprising: a multipole configured to pass an abundance of one or more ion species within stability boundaries defined by (a, q) values; a detector configured to record the spatial and temporal properties of said abundance of ions at a cross-sectional area of said multipole; and a processing means configured to subject said recorded spatial and temporal properties of said abundance of one or more species of ions as a function of the applied RF and/or DC fields to deconvolution so as to provide mass discrimination of said one or more ion species.

[0011b] According to a second aspect, there is provided a high mass resolving power high sensitivity multipole mass spectrometer method, comprising: providing a reference signal; acquiring spatial and temporal raw data of an abundance of one or more ion species from an exit channel of said multipole; breaking the acquired data into one or more chunks; computing the dot product of one of more chunks of data with each of said reference signals; reconstructing a mass spectrum by providing estimates of ion abundance at regular intervals of mass-to-charge ratio using said observed raw data and said reference signals; and reconstructing a list of distinct m/z values and estimated intensities using said observed raw data and said reference signals.

[0012] Embodiments of t~~T~~he present invention are~~is~~ directed to a novel quadrupole mass filter method and system that discriminates among ion species, even when both are simultaneously stable, by recording where the ions strike a position-sensitive detector as a function of the applied RF and DC fields. When the arrival times and positions are binned, the data can be thought of as a series of ion images. Each observed ion image is essentially the superposition of component images, one for each distinct m/z value exiting the quadrupole at a given time instant. Because embodiments of the present invention provide~~s~~ for the prediction of an arbitrary ion image as a function of m/z and the applied field, each individual component can be extracted from a sequence of observed ion images by the mathematical deconvolution processes discussed herein. The mass-to-charge ratio and abundance of each species necessarily follow directly from the deconvolution.

[0013] An embodiment ~~first aspect~~ of the present invention is directed to a high mass resolving power high sensitivity mass spectrometer instrument that includes a multipole configured to pass an abundance of one or more ion species within stability boundaries defined by the applied RF and DC fields, which are characterized by the unitless Mathieu parameters (a,q); a detector configured to record the spatial and temporal properties of the abundance of ions at a cross-sectional area of the multipole; and a processing means configured to subject said recorded spatial and temporal properties of said abundance of one or more species of ions as a function of the applied RF and/or DC fields to deconvolution so as to provide mass discrimination of said one or more ion species.

[0014] Another embodimentaspect of the present invention provides for a deconvolution process of acquired images from a mass analyzer and detector by first acquiring or synthetically generating a reference signal. The reference signal is a series of images, where each image represents the spatial distribution of exiting ions of a single (canonical) species produced by a particular state of the fields applied to the quadrupole. Thereafter the process is designed to acquire spatial and temporal raw data of an abundance of one or more ion species from an exit channel of said multipole. It then generates a shifted autocorrelation vector from the reference signals and breaks the acquired data into suitable chunks and pads such data with zeros. The dot product of one of more chunks of data with each of the reference signals is then generated. The deconvolution problem is then put into a matrix form, often in Toeplitz form, so as to solve and thus provide mass discrimination of said abundance of one or more ion species to include: the number of distinct ion species and, for each species, accurate estimates of its relative abundance and mass-to-charge ratio.

[0015] Accordingly, embodiments of the present invention provides for an apparatus and method of operation that enables a user to acquire comprehensive mass data with a time resolution on the order of about an RF cycle by computing the distribution of the ion density not only as a function of the applied fields but also as a function of position in the spatial cross section at a quadrupole exit. Applications include, but are not strictly limited to: petroleum analysis, drug analysis, phosphopeptide analysis, DNA and protein sequencing, etc. that hereinbefore were not capable of being interrogated with quadrupole systems. As side benefits, such configurations and methods disclosed herein enable relaxed requirements on the manufacturing tolerances, which reduces overall cost while improving robustness.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] **FIG 1A** shows example quadrupole mass data from a beneficial commercial TSQ.

[0017] **FIG 1B** shows additional Q3 data from a TSQ quadrupole operated with an AMU stability transmission window of 0.7 FWHM in comparison with an AMU stability transmission window of 10.0 FWHM.

[0018] **FIG. 2A** shows the Mathieu stability diagram with a scan line representing narrower mass stability limits and a "reduced" scan line, in which the DC/RF ratio has been reduced to provide wider mass stability limits.