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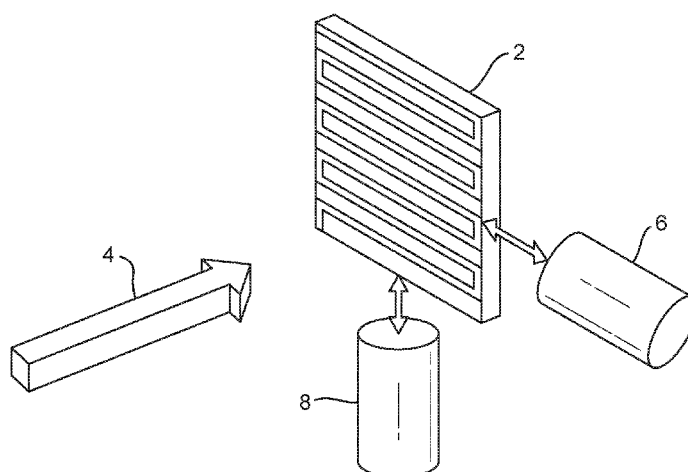
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(54) Title: ION DETECTOR ASSEMBLY

Fig. 1



(57) Abstract: A mass and/or ion mobility spectrometer is disclosed comprising: an ion detector having an ion detecting surface (2) for receiving ions; ion optics for directing an ion beam (4) onto the detecting surface (2), wherein the detecting surface (2) is larger than the cross-section of the ion beam (4) at the detecting surface (2) in at least one dimension; and one or more motor (6,8) configured for moving the detecting surface (2) in said at least one dimension so that the ion beam (4) is incident on different areas of the detecting surface (2) at different times.

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ION DETECTOR ASSEMBLY

CROSS-REFERENCE TO RELATED APPLICATION

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This application claims priority from and the benefit of United Kingdom patent application No. 1701310.3 filed on 26 January 2017. The entire content of this application is incorporated herein by reference.

10 FIELD OF THE INVENTION

The present invention relates generally to mass and/or ion mobility spectrometers and in particular to ion detector systems for such spectrometers.

15 BACKGROUND

Ion detectors may be provided in the form of non-impact ion detectors, such as inductive ion detectors, or impact ion detectors. In impact ion detectors, the impact of an ion on a surface of the detector generates a signal indicative of the detection of the ion. It is often important for impact ion detectors to provide a response for each ion impact that is within a narrow range of amplitudes. For example, this may be of assistance in measuring the ion arrival time at the detector more precisely. It may also allow better qualitative measurements of the ion signal.

However, the sensitivity or detector gain of impact ion detectors decreases during the life time of the detector due to ions striking the detector. This loss of gain and sensitivity of any given area on the detector depends on the number of ions hitting that particular area and so is not homogeneous across the detector impact surface. To the contrary, due to the uneven spatial distribution of ion intensity received at the detector impact surface, this degrades different areas of the detector at different rates and results in a strong variation of detector gain across the ion impact surface. For example, after a given time, the response of the detector for ions striking the peripheral area of the detector impact surface may be higher (e.g. an order higher) than the response of the detector for ions striking the central area of the detector impact surface. This is particularly problematic for instruments in which the ion beam has a narrow cross-sectional area since the spatial concentration of ions within the beam, and hence on the detector, is high. An example of such an instrument is a folded flight path time-of-flight mass spectrometer, which may have a very high resolving power and mass precision, and typically operates with a narrow ion beam having a cross section of the order of 10 mm^2 .

This non-homogenous wearing of the detector over time and the resulting detector response can be problematic for a number of reasons. For example, this may become

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problematic when an impact ion detector is used in spectrometers having complex ion optics to detect the efficiency with which ions are transmitted through the ion optics. The configuration and operating parameters of the ion optics may be adjusted based on the signal from the ion detector, on the understanding that this optimised detector signal
5 represents the optimal configuration and operating parameters of the ion optics for transmitting ions through the instrument (to the detector) with highest efficiency. However, as the detector response becomes inhomogeneous over time, as described above, the same flux of ions may provide different detector responses when impacting on different areas of the detector. For example, a low ion flux striking a peripheral area of the detector
10 may actually provide a higher detector response than a higher ion flux striking the central, more worn, area of the detector. In this case, the configuration and operating parameters of the ion optics will be considered optimised even though they are relatively poor.

It is known to substitute the secondary emission multipliers in detectors with photomultipliers or photo-diodes (or avalanche diodes) in order to reduce sensitivity loss
15 over time (detector aging) and to provide a relatively narrow distribution of detector response peak heights. However, these approaches do not avoid the above-mentioned spatial inhomogeneity of the detector aging.

SUMMARY

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The present invention provides a mass and/or ion mobility spectrometer comprising:
an ion detector having an ion detecting surface for receiving ions;
ion optics for directing an ion beam onto the detecting surface, wherein the
detecting surface is larger than the cross-section of the ion beam at the detecting surface
25 in at least one dimension; and

one or more motor configured for moving the detecting surface in said at least one dimension so that the ion beam is incident on different areas of the detecting surface at different times.

As the detecting surface is moved so that ions are received on different areas of the
30 detecting surface at different times, the rate of wear (i.e. loss of ion detection efficiency) for any given area of the detecting surface may be reduced. For example, the detecting surface may be moved so that the rate of wear (and sensitivity loss) is substantially homogenous across the detecting surface and so may increase the life-span of the detector (e.g. proportionally to the ratio of the detecting surface area that is irradiated over
35 time to the area irradiated at any one time). This may also lead to an improvement in the precision of single ion detection since the detecting surface provides a narrower distribution of signal amplitudes across the detecting surface.

In embodiments where the detector is used to detect the efficiency with which the ion optics transmit ions to the detector, the relatively uniform rate of wear across the
40 detector ensures that high detector signals represent high ion transmission efficiencies and

lower detector signals represent lower ion transmission efficiencies. The detector signal may then be used to accurately adjust and/or optimise the ion optics such that the ion trajectories and ion transmission efficiency are adjusted and/or optimised. This is in contrast to conventional instruments in which the detecting surface is worn at significantly different rates in different areas, such that a given ion flux results in lower ion signals at more worn areas, erroneously implying differences in ion transmission efficiencies when the ions are incident on the different areas.

For the avoidance of doubt, the ion detecting surface according to the embodiments of the present invention is the surface of the detector on which incident ions cause a detector response to be generated, i.e. cause an electrical signal to be generated by the detector.

The spectrometer may comprise a controller set up and configured to control the one or more motor to move the detecting surface in said at least one dimension whilst ions arrive at the detecting surface or between ions arriving at the detecting surface.

The spectrometer may comprise an ion source and a controller set up and configured to control the one or more motor to move the detecting surface in said at least one dimension whilst ions are being generated by the ion source. The detector may be moved during a single experimental run, or between consecutive experimental runs.

The detecting surface may be a single detector, rather than being formed from multiple separate detectors.

The ion optics may be arranged and configured to direct substantially the entire ion beam cross-section onto the detecting surface.

The at least one dimension of the detecting surface may be larger than the maximum dimension of the cross section of the ion beam at any point throughout the spectrometer.

The ion entrance to the detector may be larger than the cross section of the ion beam received at the detector in said at least one dimension.

The spectrometer or the detector may not comprise a slit or aperture for blocking ions so as to reduce the cross-sectional area of the ion beam received on the detecting surface.

The ion optics may be set up and configured such that ions having the same mass to charge ratio, or same range of mass to charge ratios, are received at the detecting surface when the detecting surface is in different locations.

The detecting surface may be a substantially planar surface.

The whole of the detecting surface may be substantially planar.

The one or more motors may move the detecting surface in the plane of the planar detecting surface.

The spectrometer may comprise a controller set up and configured to control the ion optics such that the position of the mean flight path of the ions and/or the length of the mean flight path of the ions remains static and does not move with time.

The spectrometer may comprise a controller set up and configured to control the ion optics such that the position of the axis of the ion beam at the point of incidence on the detecting surface remains static and does not move with time.

5 The ion optics and detector may be configured such that the angle between the detecting surface and the axis of the ion beam at the point of incidence on the detecting surface remains constant whilst the detecting surface is moved.

The at least one dimension may be substantially orthogonal to the axis of the ion beam at the point of incidence on the detecting surface.

10 The position of the detecting surface may be moved linearly in only one dimension, or in two dimensions.

Accordingly, the detecting surface may be larger than the cross-section of the ion beam at the detecting surface in two dimensions, wherein the one or more motor is configured for moving the detecting surface in said two dimensions so that the ion beam is incident on different areas of the detecting surface at different times.

15 The one or more motor may be configured to move the detector only in one dimension at a time. For example, the one or more motor may be configured to move the detector in a first of the dimensions and then in a second of the dimensions. The one or more motor may be configured to alternate between moving the detector in a first of the dimensions and a second of the dimensions.

20 The position of the detecting surface may be moved such that the ion beam traces the path of a square, rectangle, zig-zag, square-wave, triangular-wave, circle, oval, spiral or other non-linear path along the detecting surface.

Said one or more motor may be configured to move the detecting surface so that the ion beam is moved across the detecting surface in a raster mode.

25 Any one, or all, of the one or more motors may be configured to move the detecting surface smoothly and progressively.

Any one, or all, of the one or more motors may be configured to move the detecting surface in a stepped manner.

30 Each step may be smaller than the size of the ion beam cross-section as determined in the direction of stepping

The detector may be configured to detect the intensity and/or cross sectional size of the ion beam at the detecting surface, wherein the spectrometer comprises a controller for controlling the rate or speed at which the detecting surface is moved by the one or more motor based on the intensity and/or cross-sectional size of the ion beam detected.

35 The spectrometer may comprise a device for pulsing ions towards the detecting surface and wherein the spectrometer is configured to separate the ions spatially or temporally between said device and the detecting surface.

For example, the ions may be separated according to mass to charge ratio or ion mobility.

40 The spectrometer may comprise a device for pulsing ions towards the detecting surface, wherein the ion optics and detector are arranged and configured such that ions

having the same mass to charge ratio or ion mobility arrive at the detecting surface at substantially the same time, even whilst the detecting surface is moved.

The spectrometer may be a time of flight spectrometer.

The spectrometer may be a folded flight path time of flight mass spectrometer.

5 In embodiments in which the spectrometer is a folded flight path time of flight mass spectrometer, the ion optics may be configured to reflect or deflect the ions one or more times between said device for pulsing ions and the detecting surface.

Although, embodiments of the invention have been described in terms of a time of flight mass spectrometer, it is contemplated that it may be used in other types of
10 spectrometer. For example, the detector may be used to detect ions in a magnetic sector mass spectrometer, a quadrupole mass spectrometer, an ion mobility spectrometer or another type of instrument.

The detector assembly itself is considered to be novel and inventive in its own right.

Accordingly, the present invention also provides an ion detector assembly
15 comprising:

an ion detector having a substantially planar ion detecting surface for receiving ions; and

one or more motor configured for moving the detecting surface in two different dimensions within the plane of the detecting surface.

20 The ion detector assembly may have any of the features described elsewhere herein.

For example, the ion detector assembly may comprise a controller configured to control the one or more motor to move the detecting surface in a raster mode.

The detector assembly may be configured to detect the intensity and/or cross
25 sectional size of an ion beam at the detecting surface, and may comprise a controller for controlling the rate or speed at which the detecting surface is moved by the one or more motor based on the intensity and/or cross-sectional size of the ion beam detected.

The present invention also provides a method of detecting ions comprising:

30 providing a spectrometer or ion detector as described herein; and
guiding ions onto the detecting surface whilst moving said detecting surface with said one or more motor so that an ion beam is incident on different areas of the detecting surface at different times.

The method may comprise adjusting and/or optimising the ion optics based on the ion signal detected at the detecting surface so as to increase the ion transmission
35 efficiency through the ion optics.

The present invention also provides a method of mass or ion mobility spectrometry comprising a method as described herein and comprising determining the mass or ion mobility of the ions based on the signal from ions detected at the detecting surface.

The spectrometer herein may comprise an ion source selected from the group
40 consisting of: (i) an Electrospray ionisation ("ESI") ion source; (ii) an Atmospheric Pressure Photo Ionisation ("APPI") ion source; (iii) an Atmospheric Pressure Chemical Ionisation ("APCI") ion source; (iv) a Matrix Assisted Laser Desorption Ionisation ("MALDI") ion

source; (v) a Laser Desorption Ionisation ("LDI") ion source; (vi) an Atmospheric Pressure Ionisation ("API") ion source; (vii) a Desorption Ionisation on Silicon ("DIOS") ion source; (viii) an Electron Impact ("EI") ion source; (ix) a Chemical Ionisation ("CI") ion source; (x) a Field Ionisation ("FI") ion source; (xi) a Field Desorption ("FD") ion source; (xii) an Inductively Coupled Plasma ("ICP") ion source; (xiii) a Fast Atom Bombardment ("FAB") ion source; (xiv) a Liquid Secondary Ion Mass Spectrometry ("LSIMS") ion source; (xv) a Desorption Electrospray Ionisation ("DESI") ion source; (xvi) a Nickel-63 radioactive ion source; (xvii) an Atmospheric Pressure Matrix Assisted Laser Desorption Ionisation ion source; (xviii) a Thermospray ion source; (xix) an Atmospheric Sampling Glow Discharge Ionisation ("ASGDI") ion source; (xx) a Glow Discharge ("GD") ion source; (xxi) an Impactor ion source; (xxii) a Direct Analysis in Real Time ("DART") ion source; (xxiii) a Laserspray Ionisation ("LSI") ion source; (xxiv) a Sonicspray Ionisation ("SSI") ion source; (xxv) a Matrix Assisted Inlet Ionisation ("MAII") ion source; (xxvi) a Solvent Assisted Inlet Ionisation ("SAII") ion source; (xxvii) a Desorption Electrospray Ionisation ("DESI") ion source; (xxviii) a Laser Ablation Electrospray Ionisation ("LAESI") ion source; and (xxix) Surface Assisted Laser Desorption Ionisation ("SALDI").

The spectrometer may comprise one or more continuous or pulsed ion sources.

The spectrometer may comprise one or more ion guides.

The spectrometer may comprise one or more ion mobility separation devices and/or one or more Field Asymmetric Ion Mobility Spectrometer devices.

The spectrometer may comprise one or more ion traps or one or more ion trapping regions.

The spectrometer may comprise one or more collision, fragmentation or reaction cells selected from the group consisting of: (i) a Collisional Induced Dissociation ("CID") fragmentation device; (ii) a Surface Induced Dissociation ("SID") fragmentation device; (iii) an Electron Transfer Dissociation ("ETD") fragmentation device; (iv) an Electron Capture Dissociation ("ECD") fragmentation device; (v) an Electron Collision or Impact Dissociation fragmentation device; (vi) a Photo Induced Dissociation ("PID") fragmentation device; (vii) a Laser Induced Dissociation fragmentation device; (viii) an infrared radiation induced dissociation device; (ix) an ultraviolet radiation induced dissociation device; (x) a nozzle-skimmer interface fragmentation device; (xi) an in-source fragmentation device; (xii) an in-source Collision Induced Dissociation fragmentation device; (xiii) a thermal or temperature source fragmentation device; (xiv) an electric field induced fragmentation device; (xv) a magnetic field induced fragmentation device; (xvi) an enzyme digestion or enzyme degradation fragmentation device; (xvii) an ion-ion reaction fragmentation device; (xviii) an ion-molecule reaction fragmentation device; (xix) an ion-atom reaction fragmentation device; (xx) an ion-metastable ion reaction fragmentation device; (xxi) an ion-metastable molecule reaction fragmentation device; (xxii) an ion-metastable atom reaction fragmentation device; (xxiii) an ion-ion reaction device for reacting ions to form adduct or product ions; (xxiv) an ion-molecule reaction device for reacting ions to form adduct or product ions; (xxv) an ion-atom reaction device for reacting ions to form adduct or product ions; (xxvi) an ion-metastable ion reaction device for reacting ions to form adduct or

product ions; (xxvii) an ion-metastable molecule reaction device for reacting ions to form adduct or product ions; (xxviii) an ion-metastable atom reaction device for reacting ions to form adduct or product ions; and (xxix) an Electron Ionisation Dissociation ("EID") fragmentation device.

5 The spectrometer may comprise a mass analyser selected from the group consisting of: (i) a quadrupole mass analyser; (ii) a 2D or linear quadrupole mass analyser; (iii) a Paul or 3D quadrupole mass analyser; (iv) a Penning trap mass analyser; (v) an ion trap mass analyser; (vi) a magnetic sector mass analyser; (vii) Ion Cyclotron Resonance ("ICR") mass analyser; (viii) a Fourier Transform Ion Cyclotron Resonance ("FTICR") mass
10 analyser; (ix) an electrostatic mass analyser arranged to generate an electrostatic field having a quadro-logarithmic potential distribution; (x) a Fourier Transform electrostatic mass analyser; (xi) a Fourier Transform mass analyser; (xii) a Time of Flight mass analyser; (xiii) an orthogonal acceleration Time of Flight mass analyser; and (xiv) a linear acceleration Time of Flight mass analyser.

15 The spectrometer may comprise one or more energy analysers or electrostatic energy analysers.

 The spectrometer may comprise one or more mass filters selected from the group consisting of: (i) a quadrupole mass filter; (ii) a 2D or linear quadrupole ion trap; (iii) a Paul or 3D quadrupole ion trap; (iv) a Penning ion trap; (v) an ion trap; (vi) a magnetic sector
20 mass filter; (vii) a Time of Flight mass filter; and (viii) a Wien filter.

 The spectrometer may comprise a device or ion gate for pulsing ions; and/or a device for converting a substantially continuous ion beam into a pulsed ion beam.

 The spectrometer may comprise a C-trap and a mass analyser comprising an outer barrel-like electrode and a coaxial inner spindle-like electrode that form an electrostatic
25 field with a quadro-logarithmic potential distribution, wherein in a first mode of operation ions are transmitted to the C-trap and are then injected into the mass analyser and wherein in a second mode of operation ions are transmitted to the C-trap and then to a collision cell or Electron Transfer Dissociation device wherein at least some ions are fragmented into fragment ions, and wherein the fragment ions are then transmitted to the C-trap before
30 being injected into the mass analyser.

 The spectrometer may comprise a stacked ring ion guide comprising a plurality of electrodes each having an aperture through which ions are transmitted in use and wherein the spacing of the electrodes increases along the length of the ion path, and wherein the apertures in the electrodes in an upstream section of the ion guide have a first diameter
35 and wherein the apertures in the electrodes in a downstream section of the ion guide have a second diameter which is smaller than the first diameter, and wherein opposite phases of an AC or RF voltage are applied, in use, to successive electrodes.

 The spectrometer may comprise a device arranged and adapted to supply an AC or RF voltage to the electrodes. The AC or RF voltage optionally has an amplitude selected
40 from the group consisting of: (i) about < 50 V peak to peak; (ii) about 50-100 V peak to peak; (iii) about 100-150 V peak to peak; (iv) about 150-200 V peak to peak; (v) about 200-250 V peak to peak; (vi) about 250-300 V peak to peak; (vii) about 300-350 V peak to peak;

(viii) about 350-400 V peak to peak; (ix) about 400-450 V peak to peak; (x) about 450-500 V peak to peak; and (xi) > about 500 V peak to peak.

The AC or RF voltage may have a frequency selected from the group consisting of: (i) < about 100 kHz; (ii) about 100-200 kHz; (iii) about 200-300 kHz; (iv) about 300-400 kHz; (v) about 400-500 kHz; (vi) about 0.5-1.0 MHz; (vii) about 1.0-1.5 MHz; (viii) about 1.5-2.0 MHz; (ix) about 2.0-2.5 MHz; (x) about 2.5-3.0 MHz; (xi) about 3.0-3.5 MHz; (xii) about 3.5-4.0 MHz; (xiii) about 4.0-4.5 MHz; (xiv) about 4.5-5.0 MHz; (xv) about 5.0-5.5 MHz; (xvi) about 5.5-6.0 MHz; (xvii) about 6.0-6.5 MHz; (xviii) about 6.5-7.0 MHz; (xix) about 7.0-7.5 MHz; (xx) about 7.5-8.0 MHz; (xxi) about 8.0-8.5 MHz; (xxii) about 8.5-9.0 MHz; (xxiii) about 9.0-9.5 MHz; (xxiv) about 9.5-10.0 MHz; and (xxv) > about 10.0 MHz.

The spectrometer may comprise a chromatography or other separation device upstream of an ion source. The chromatography separation device may comprise a liquid chromatography or gas chromatography device. Alternatively, the separation device may comprise: (i) a Capillary Electrophoresis ("CE") separation device; (ii) a Capillary Electrochromatography ("CEC") separation device; (iii) a substantially rigid ceramic-based multilayer microfluidic substrate ("ceramic tile") separation device; or (iv) a supercritical fluid chromatography separation device.

The ion guide may be maintained at a pressure selected from the group consisting of: (i) < about 0.0001 mbar; (ii) about 0.0001-0.001 mbar; (iii) about 0.001-0.01 mbar; (iv) about 0.01-0.1 mbar; (v) about 0.1-1 mbar; (vi) about 1-10 mbar; (vii) about 10-100 mbar; (viii) about 100-1000 mbar; and (ix) > about 1000 mbar.

Analyte ions may be subjected to Electron Transfer Dissociation ("ETD") fragmentation in an Electron Transfer Dissociation fragmentation device. Analyte ions may be caused to interact with ETD reagent ions within an ion guide or fragmentation device.

The spectrometer may be operated in various modes of operation including a mass spectrometry ("MS") mode of operation; a tandem mass spectrometry ("MS/MS") mode of operation; a mode of operation in which parent or precursor ions are alternatively fragmented or reacted so as to produce fragment or product ions, and not fragmented or reacted or fragmented or reacted to a lesser degree; a Multiple Reaction Monitoring ("MRM") mode of operation; a Data Dependent Analysis ("DDA") mode of operation; a Data Independent Analysis ("DIA") mode of operation a Quantification mode of operation or an Ion Mobility Spectrometry ("IMS") mode of operation.

BRIEF DESCRIPTION OF THE DRAWINGS

Various embodiments will now be described, by way of example only, and with reference to the accompanying drawings in which:

Fig. 1 shows a detector assembly according to an embodiment of the present invention.

DETAILED DESCRIPTION

Embodiments described herein cause ions to impact on different areas of an ion detector at different times, e.g. so that the detector wears more uniformly over its impact surface and therefore maintains a more uniform detector response when ions impact different areas of the detector.

Although it is possible to achieve the above by moving the ion beam across the impact surface of the ion detector or by defocussing the ion beam over the detector, the inventor has recognised that this may not be desirable as it may be difficult or undesirable to alter the path of the ion beam. For example, in time-of-flight mass spectrometers it is important that the ions have the same effective path length from the ion accelerator to the detector. It may therefore be undesirable to scan the ion beam over the detector with time or to defocus the ion beam over the detector, as this may cause different ions to have different effective flight path lengths and so may degrade the precision of the instrument.

The inventor has recognised that the detector surface may be moved instead of the ion beam, thus distributing the ions more uniformly over the detector with time and without necessarily altering the path length of the ion beam and/or the angle at which the ions strike the detector.

Fig. 1 shows a schematic of an ion detector assembly according to an embodiment of the present invention. The ion detector assembly comprises an ion impact detecting surface 2 on which the ions impact in use. The detecting surface 2 is larger than the cross-sectional area of the ion beam 4 transmitted to it, and may be larger in one or both dimensions orthogonal to the ion beam axis. The detector assembly also comprises a first motor 6 for moving the detecting surface 2 in a first dimension (X-dimension) and a second motor 8 for moving the detecting surface 2 in a second dimension (Y-dimension).

In operation, the ion beam 4 impacts on the detecting surface 2 at a first position at a first time. As time progresses, the axis of the ion beam 4 remains static and the motors 6,8 move the detecting surface 2 such that the ion beam 4 impacts on different regions of the detecting surface 2 at different times.

In the embodiment shown, the first motor 6 moves the detecting surface 2 in a first direction in the first dimension (X-dimension) such that the ion beam 4 impacts on different areas of the detecting surface 2 along the first dimension. When the ion beam 4 reaches the peripheral edge of the detecting surface 2 (in the first dimension), the first motor 6 halts the movement of the detecting surface 2 in the first dimension (X-dimension) and the second motor 8 begins to move the detecting surface 2 in a first direction in the second dimension (Y-dimension) such that the ion beam 4 impacts on different areas of the detecting surface 2 along the second dimension. The second motor 8 then halts the movement of the detecting surface 2 in the second dimension (Y-dimension) and the first motor 6 begins to move the detecting surface 2 in a second direction in the first dimension (X-dimension) such that the ion beam 4 impacts on different areas of the detecting surface 2 along the first dimension. When the ion beam 4 reaches the peripheral edge of the detecting surface 2, in the first dimension (X-dimension), the first motor 6 again halts the

movement of the detecting surface 2 in the first dimension (X-dimension) and the second motor 8 again begins to move the detecting surface 2 in the first direction of the second dimension (Y-dimension) such that the ion beam 4 impacts on different areas of the detecting surface 2 along the second dimension. This cycle may be repeated cyclically
5 such that the an ion impact path is traced over the detector surface, e.g. in a zig-zag pattern. The detecting surface 2 may be moved such that the trace pattern is repeated or reversed.

Although the detecting surface 2 may be moved such that its position is scanned in a raster scan, it is also contemplated that the position of the detecting surface 2 may be
10 moved in other manners. For example, the position of the detecting surface 2 may be moved linearly in only one dimension, or such that the ion beam 4 traces the path of a square, rectangle, zig-zag, square-wave, triangular-wave, circle, spiral or other non-linear path along the detecting surface 2. A motor control system may be programmed to control one or more motors to move the detecting surface 2 in any of these manners. Raster
15 scanning is currently preferred for maintaining the homogeneous spatial distribution of detector gain.

Any one, or each, of the one or more motors described herein may move the detecting surface 2 smoothly and progressively (i.e. as a continuous motion). Alternatively, any one, or each, of the one or more motors may step the movement of the detector
20 surface with time, e.g. periodically step the movement with time. When the movement is stepped, the distance the detecting surface 2 is moved in each step may be smaller than the features of the ion beam 4 cross-section (e.g. smaller than the FWHM).

Any one, or each, of the one or more motors may be a linear motor form moving the detecting surface 2 in a linear direction. A plurality of these motors may be used in
25 combination to move the detecting surface 2 with non-linear movements.

Any one, or each, of the one or more motors may be a piezo-motor. However, other motors may be used. Desirably, the detecting surface 2 may be arranged in a sub-atmospheric pressure vacuum chamber and the motors are capable of operating in such a chamber. The one of more motors may be used along with micro-mini X-Y stages.

30 The rate or speed at which the detecting surface 2 is moved may be selected based on the intensity and/or cross-sectional size of the ion beam 4. Alternatively, or additionally, the pattern of movement of the detector surface may be selected based on the cross-sectional size of the ion beam 4. Each or all of these parameters may be selected and/or optimised so that the ion beam 4 wears the detector surface substantially homogenously.

35 It is contemplated that the ion beam 4 may be continuous during movement of the detector surface, or may be a pulsed ion beam 4. When the ion beam 4 is pulsed, the detecting surface 2 is moved such that at least some of the pulses of ions are received at different regions of the detecting surface 2 at different times.

The detector may comprise one or more large stage secondary emission multiplier,
40 photomultipliers, photo-diode or avalanche diode.

The detector may be a time of flight mass spectrometer detector. In such instruments, it is desired that the axis along which the ions strike the detecting surface 2

remains static during movement of the detecting surface 2. It is also desired that the angle between this axis and the detector surface remains constant during movement of the detecting surface 2.

5 It is contemplated that the detector may be used in instruments other than time of flight mass spectrometers. For example, the detector may be used to detect ions in a magnetic sector mass spectrometer, a quadrupole mass spectrometer or another type of instrument. It is less important in instruments other than time of flight mass spectrometers for the position of the ion beam axis to remain static and/or for the angle between the ion beam axis and the detecting surface 2 to remain static during movement of the detecting
10 surface 2.

Although the present invention has been described with reference to preferred embodiments, it will be understood by those skilled in the art that various changes in form and detail may be made without departing from the scope of the invention as set forth in the accompanying claims.
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Claims

- 5 1. A mass and/or ion mobility spectrometer comprising:
 an ion detector having an ion detecting surface for receiving ions;
 ion optics for directing an ion beam onto the detecting surface, wherein the
 detecting surface is larger than the cross-section of the ion beam at the detecting surface
 in at least one dimension; and
10 one or more motor configured for moving the detecting surface in said at least one
 dimension so that the ion beam is incident on different areas of the detecting surface at
 different times.
- 15 2. The spectrometer of claim 1, wherein the ion optics are arranged and configured to
 direct substantially the entire ion beam cross-section onto the detecting surface.
- 20 3. The spectrometer of any preceding claim, wherein said at least one dimension of
 the detecting surface is larger than the maximum dimension of the cross section of the ion
 beam at any point throughout the spectrometer.
- 25 4. The spectrometer of any preceding claim, wherein the detecting surface is a
 substantially planar surface.
- 30 5. The spectrometer of any preceding claim, comprising a controller set up and
 configured to control the ion optics such that the position of the mean flight path of the ions
 and/or the length of the mean flight path of the ions remains static and does not move with
 time.
- 35 6. The spectrometer of any preceding claim, comprising a controller set up and
 configured to control the ion optics such that the position of the axis of the ion beam at the
 point of incidence on the detecting surface remains static and does not move with time.
- 40 7. The spectrometer of any preceding claim, wherein the ion optics and detector are
 configured such that the angle between the detecting surface and the axis of the ion beam
 at the point of incidence on the detecting surface remains constant whilst the detecting
 surface is moved.
8. The spectrometer of any preceding claim, wherein said at least one dimension is
 substantially orthogonal to the axis of the ion beam at the point of incidence on the
 detecting surface.

9. The spectrometer of any preceding claim, wherein the detecting surface is larger than the cross-section of the ion beam at the detecting surface in two dimensions, and wherein the one or more motor is configured for moving the detecting surface in said two dimensions so that the ion beam is incident on different areas of the detecting surface at different times.
10. The spectrometer of any preceding claim, wherein said one or more motor is configured to move the detecting surface so that the ion beam is moved across the detecting surface in a raster mode.
11. The spectrometer of any preceding claim, wherein any one, or all, of the one or more motors is configured to either:
- (i) move the detecting surface smoothly and progressively; or
 - (ii) move the detecting surface in a stepped manner; optionally wherein each step is smaller than the size of the ion beam cross-section as determined in the direction of stepping.
12. The spectrometer of any preceding claim, wherein the detector is configured to detect the intensity and/or cross sectional size of the ion beam at the detecting surface, and wherein the spectrometer comprises a controller for controlling the rate or speed at which the detecting surface is moved by the one or more motor based on the intensity and/or cross-sectional size of the ion beam detected.
13. The spectrometer of any preceding claim, comprising a device for pulsing ions towards the detecting surface and wherein the spectrometer is configured to separate the ions spatially or temporally between said device and the detecting surface.
14. The spectrometer of any preceding claim, comprising a device for pulsing ions towards the detecting surface, and wherein the ion optics and detector are arranged and configured such that ions having the same mass to charge ratio or ion mobility arrive at the detecting surface at substantially the same time, even whilst the detecting surface is moved.
15. The spectrometer of any preceding claim, wherein the spectrometer is a time of flight spectrometer. such as a folded flight path time of flight mass spectrometer.
16. An ion detector assembly comprising:
- an ion detector having a substantially planar ion detecting surface for receiving ions; and
 - one or more motor configured for moving the detecting surface in two different dimensions within the plane of the detecting surface.

17. The detector assembly of claim 16, comprising a controller configured to control the one or more motor to move the detecting surface in a raster mode.

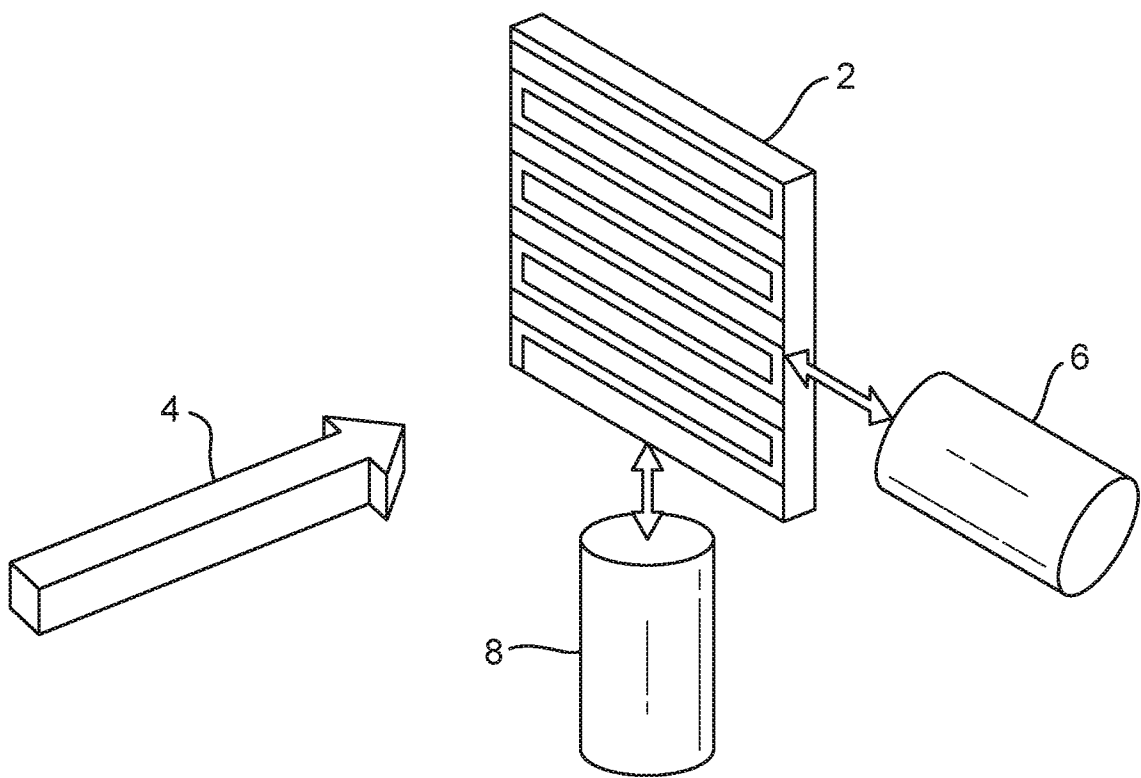
5 18. The detector assembly of claim 16 or 17, wherein the detector assembly is configured to detect the intensity and/or cross sectional size of an ion beam at the detecting surface, and comprising a controller for controlling the rate or speed at which the detecting surface is moved by the one or more motor based on the intensity and/or cross-sectional size of the ion beam detected.

10 19. A method of detecting ions comprising:
providing a spectrometer or ion detector as claimed in any preceding claim; and
guiding ions onto the detecting surface whilst moving said detecting surface with
said one or more motor so that an ion beam is incident on different areas of the detecting
surface at different times.

15 20. The method of claim 19, comprising adjusting and/or optimising the ion optics based on the ion signal detected at the detecting surface so as to increase the ion transmission efficiency through the ion optics.

20

Fig. 1



INTERNATIONAL SEARCH REPORT

International application No

PCT/GB2018/050188

A. CLASSIFICATION OF SUBJECT MATTER

INV. H01J49/00 H01J49/02 G01N27/62
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H01J G01N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2004/206911 A1 (LAPRADE BRUCE [US]) 21 October 2004 (2004-10-21) paragraph [0023] paragraph [0069] - paragraph [0077] figures 11,12 -----	1-20
Y	EP 0 193 311 A2 (FINNIGAN CORP [US]) 3 September 1986 (1986-09-03) page 7, line 17 - line 20 -----	1-20
A	US 2003/154773 A1 (NISHIKAWA OSAMU [JP]) 21 August 2003 (2003-08-21) paragraph [0037] - paragraph [0038] figures 1,2 -----	1-20
A	US 5 198 666 A (BATEMAN ROBERT H [GB]) 30 March 1993 (1993-03-30) column 6, line 19 - column 8, line 10 figures 5,6 -----	1-20



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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"&" document member of the same patent family

Date of the actual completion of the international search

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/GB2018/050188

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2004206911 A1	21-10-2004	US 6828729 B1	07-12-2004
		US 2004206911 A1	21-10-2004
EP 0193311 A2	03-09-1986	EP 0193311 A2	03-09-1986
		JP S61233958 A	18-10-1986
US 2003154773 A1	21-08-2003	EP 1376650 A1	02-01-2004
		JP 4111501 B2	02-07-2008
		JP WO2002093615 A1	02-09-2004
		US 2003154773 A1	21-08-2003
		WO 02093615 A1	21-11-2002
US 5198666 A	30-03-1993	AT 149741 T	15-03-1997
		AT 186612 T	15-11-1999
		CA 2055609 A1	02-12-1990
		CA 2056424 A1	02-12-1990
		DE 69030085 D1	10-04-1997
		DE 69030085 T2	12-06-1997
		DE 69033353 D1	16-12-1999
		DE 69033353 T2	24-02-2000
		EP 0474723 A1	18-03-1992
		EP 0570361 A1	24-11-1993
		JP 2857685 B2	17-02-1999
		JP 2857686 B2	17-02-1999
		JP H05505900 A	26-08-1993
		JP H05505901 A	26-08-1993
		US 5194732 A	16-03-1993
		US 5198666 A	30-03-1993
		WO 9015433 A1	13-12-1990
		WO 9015434 A1	13-12-1990