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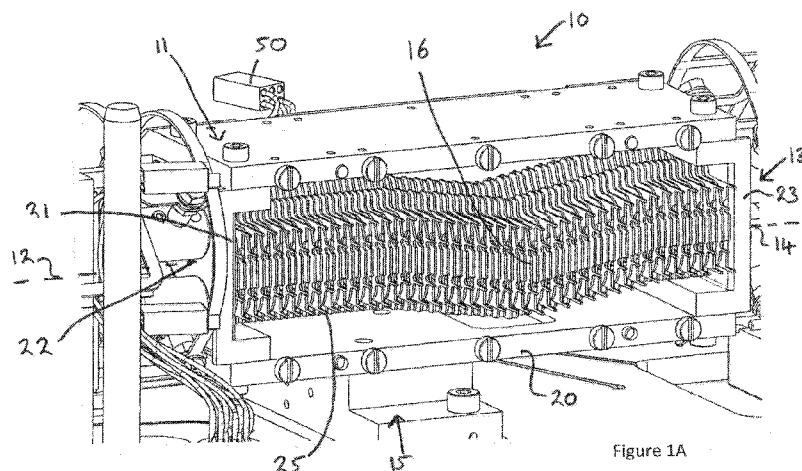
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(54) Title: ION GUIDE



(57) Abstract: An ion guide (10) comprising an inlet (11) having a first longitudinal axis (12), a middle section (15) and an outlet (13) having a second longitudinal axis (14), wherein the inlet, middle section and outlet together define an ion path, the first axis is substantially co-axial with the second axis, and the middle section is non-linear.

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Title: Ion guide

## Background to the invention

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The present invention relates generally to an ion guide. The invention also relates to a shroud for an optical detector.

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Ion guides are known, for example a collision cell, wherein ions are confined or constrained to move along the central longitudinal axis of a linear ion guide. Gas is introduced into a collision cell to interact with and fragment ions passing therethrough. The longitudinal axis of the ion guide is coincident with the centre of a radially symmetric pseudo-potential valley. The pseudo-potential valley may be formed within the ion guide as a result of applying RF voltages to the electrodes comprising the ion guide. Ions enter through an inlet and exit through an outlet of the ion guide along the central longitudinal axis of the ion guide. Additionally, a DC gradient voltage may be applied to the electrodes to fragment ions passing therethrough, plus a DC pulse to move the ions through the ion guide. Such systems are known, for example the Travelling Wave (T-Wave™) ion guide offered by Waters™. Other ion guides are known, for example the StepWave™ ion guide, offered by Waters™.

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Ion guides are adopted in mass spectrometers between an ionisation source and a detector. The ion guides serve to guide, and optionally condition ions passing from the ionisation source through to the detector, along an ion path.

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The detector measures the intensity, number and/or current of the ions passed to it by the ion guides in the source and analyser section of a mass spectrometer. Various types of detectors are known, including electron multipliers. A photomultiplier tube (PMT), also known as an ion-to-photon detector, may alternatively be adopted as part of a detection system. A benefit of a PMT over an electron multiplier is that it is more robust. In an electron multiplier the surfaces may be exposed to background contamination and further contamination each time the system is vented. Moreover, the first surface of the multiplier may become degraded over time by the ion beam. In a PMT arrangement, the initial ion strike is onto a metal dynode to create electrons. The electrons then strike a phosphor screen to create photons which then go into the sealed PMT to get converted back into electrons and multiplied. Advantageously, the multiplying sections of the PMT are never exposed to the instrument environment and the primary ion strike is made against conventional metal.

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The ionisation source of a mass spectrometer may comprise one or more filaments. When the filaments get hot in use to thermionically emit electrons, they tend to emit light, which may be broad in spectrum, including the visible light spectrum. It has been observed that light emitted from the ionisation source can travel and scatter down a mass spectrometer analyser and be incident on the detector. The light may pass linearly from the ionisation source to the detector, along the longitudinal axis of the ion guide and/or it may be scattered around the internal volume of the mass spectrometer vacuum housing. When the detector is a PMT, this unwanted spurious light creates noise in the measured signal.

Additionally, when the mass spectrometer forms part of a GCMS (Gas Chromatography Mass Spectrometry) arrangement, helium atoms in the GC carrier gas may be excited but not ionized by any collisions with electrons. These metastable helium atoms can travel down the mass spectrometer, not being susceptible to any electric fields therein, and collide with residual gas molecules at any point along their path, ionizing them and creating a further source of noise not filtered out by any analysers.

Curved ion guides are known, for example from US7923681, which may serve to reduce or eliminate visible light from the ionisation source reaching the detector. However, the physical arrangement of such curved ion guides means that they are not compatible with mass spectrometers having a substantially linear ion path.

A problem addressed by the present invention is to provide an ion guide which is compatible with existing mass spectrometers and which may replace an existing linear ion guide.

## Summary of the invention

Accordingly, one aspect of the the present invention provides an ion guide comprising:

an inlet having a first longitudinal axis;

a middle section; and

an outlet having a second longitudinal axis;

wherein the inlet, middle section and outlet together define an ion path, the first axis is substantially co-axial with the second axis, and the middle section is non-linear.

In at least one embodiment, at least a part of the middle section is offset from the first and second longitudinal axes.

In at least one embodiment, at least a part of the middle section is V-shaped.

In at least one embodiment, at least a part of the middle section is offset from the first and second longitudinal axes.

In at least one embodiment, the offset is 4mm.

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In at least one embodiment, the ion path of the inlet, middle section and outlet is of substantially the same diameter along its axial length.

10 In at least one embodiment, at least a part of the middle section is offset from the first and second longitudinal axes by a distance at least equal to said diameter.

In at least one embodiment, the ion guide comprises a plurality of electrodes.

15 In at least one embodiment, each electrode comprises an aperture.

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In at least one embodiment, each electrode is a ring electrode.

In at least one embodiment, the ion guide further comprises a power supply for selectively providing a voltage to the plurality of electrodes.

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In at least one embodiment, the power supply is configured to apply one or more transient or static DC voltages or potentials to the plurality of electrodes in order to urge ions axially or longitudinally along at least a portion of the ion path.

25 In at least one embodiment, the middle section is configured to substantially prevent a line of sight between the inlet and the outlet through the middle section.

30 One aspect of the present invention provides a mass spectrometer comprising the ion guide, comprising at least an ionization source to supply ions to the inlet of the ion guide; and an optical detector to receive ions from the outlet of the ion guide.

In at least one embodiment, the ionization source includes at least one filament.

In at least one embodiment, the ionization source creates light in use.

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In at least one embodiment, the optical detector is a photomultiplier tube.

In at least one embodiment, the mass spectrometer further comprises a shroud surrounding the detector.

In at least one embodiment, the shroud comprises a housing having an aperture to receive ions to be detected therethrough, and the optical detector has a detector inlet, wherein the detector inlet is arranged substantially co-axially with the aperture of the housing.

In at least one embodiment, the outlet of the ion guide is arranged substantially co-axially with the aperture of the shroud.

One aspect of the present invention provides a shroud comprising a housing sized to receive an optical detector, wherein the housing comprises an aperture to receive ions to be detected therethrough.

In at least one embodiment, the shroud is comprised at least in part of PEEK.

One aspect of the present invention provides a detector assembly comprising:

a shroud; and

an optical detector arranged in the shroud, the optical detector having a detector inlet, wherein the detector inlet is arranged substantially co-axially with the aperture of the shroud.

In at least one embodiment, the mass spectrometer further comprises a detector assembly, further comprising at least:

an ion guide defining an ion path and having an outlet, wherein the outlet of the ion guide is arranged substantially co-axially with the aperture of the housing of the shroud.

### Description of the drawings

Embodiments of the present invention will now be described, by way of non-limiting example only, in which:

Figure 1A illustrates an ion guide according to one embodiment of the present invention;

Figure 1B illustrates a side view of the ion guide of Figure 1A.

Figure 2 schematically illustrates the ion path of an ion guide according to one embodiment of the present invention;

Figure 3 schematically illustrates the ion path of an ion guide according to another embodiment of the present invention;

Figure 4 illustrate a shroud according to one embodiment of the present invention; and

Figure 5 schematically illustrates a mass spectrometer in which the ion guide and/or shroud may be adopted.

#### Detailed description of the invention

Figures 1A and 1B illustrate an ion guide 10 according to one embodiment of the present invention. The ion guide 10 may be installed in a mass spectrometer 1, as schematically illustrated in Figure 5.

The mass spectrometer 1 generally comprises an ionisation source 2, which ionizes incoming molecules (e.g. from a GC source) and repels them towards a first mass filter 3 (e.g. a quadrupole mass filter). The first mass filter 3 may be calibrated only to allow ions with a particular mass-to-charge ratio ( $M/Z$ ) to pass therethrough. Selected ions pass from the first mass filter 3 into the ion guide 10. Here, the ions fragment by colliding with an inert gas. The fragmented (and any unfragmented) ions pass from the ion guide 10 into a second mass filter 4 (e.g. another quadrupole mass filter), in which further  $M/Z$  selection can take place. Selected ions are then passed to the detector 5. The ionisation source 2, first mass filter 3, ion guide 10, second mass filter 4 and optionally at least a part of the detector 5 are generally linearly aligned, such that ions pass through each stage in a substantially linear fashion.

An ion guide 10 according to one embodiment of the present invention comprises an inlet 11 having a first longitudinal axis 12, and an outlet 13 having a second longitudinal axis 14. The first axis 12 is substantially co-axial with the second axis 14. Accordingly, ions will exit the outlet 13 of the ion guide 10 in substantially the same direction as they entered the inlet 11 of the ion guide 10.

The ion guide 10 further comprises a middle section 15. The terms 'inlet', 'middle section' and 'outlet' are used herein for the purposes of describing the invention. There may be no discernible difference between the boundaries of the inlet 11, middle section 15 and outlet 13, of the ion guide 10. Each may merge into an apparently unitary ion guide 10. There may be a smooth transition between the inlet 11, middle section 15 and outlet 13.

In one embodiment, the ion guide 10 comprises a housing 20 having a first plate 21 at one (inlet) end, and a second plate 23 at an opposing (outlet) end. The first plate 21 includes an inlet aperture 22, through which ions pass into the ion guide 10. The second plate 23 includes an outlet aperture 24 (not shown) from which ions pass out of the ion guide 10. The first 21 and second 23 plates may have a DC voltage, and no RF, applied to them.

The housing 20 may fully or partially enclose the ion guide 10.

Generally, the inlet 11 may be taken to comprise at least a part of the ion guide 10 extending from the inlet aperture 22 which is generally straight (linear). Likewise, the outlet may be taken to comprise at least a part of the ion guide 10 extending towards the outlet aperture 24 which is generally straight (linear).

The middle section 15 is non-linear. It is not essential that all of the middle section 15 is non-linear; but rather that at least a portion of the middle section 15 is non-linear and thus offset from the first 12 and second 14 longitudinal axes. With reference to Figure 2, if the axial length of the middle section 15 is taken to be more than 50% of the overall axial length of the ion guide 10 (as schematically illustrated), it will be noted that at least a part of the middle section 15 is linear. Nevertheless, there is still a non-linear portion 16, described below, which renders the middle section as a whole 'non-linear'.

In the embodiment shown, the middle section 15 comprises a first offset portion 16 which is offset from the first 12 and second 14 longitudinal axes. The offset portion 16 illustrated in Figures 1A and 1B is generally V-shaped. By 'V-shaped' is meant that when viewing the ion guide 10, 100 in side profile, the shape of the offset portion(s) 16 generally resembles that of the letter V, either upright or inverted. In effect, the V-shaped offset portion 16 comprises two linear leg portions which are angled with respect to one another to create a peak at their intersection.

A benefit of a V-shaped offset portion 16 is that the ion path length is as close as reasonably possible to the path length for a completely straight section. A longer ion path length in a collision cell may otherwise adversely affect data acquisition. For example, MS1 scanning may be impacted by time of flight and synchronisation issues, which may degrade the efficacy of MS1 scanning, Parent Scanning and neutral loss scanning acquisition modes.

Alternatively, the offset portion 16 may be bell-shaped, as illustrated in Figures 2 and 3.

By 'bell-shaped' is meant that when viewing the ion guide 10, 100 in side profile, the shape of the offset portion(s) 16, 116A, 116B generally resembles that of a bell. A bell-shaped curve is likewise similar to a Gaussian distribution curve.

- 5 An advantage of a bell shaped curve is that the change in direction from the linear part of the ion path (either from the inlet 11 or from the first part of the middle section 15) is gradual. There may be substantially no sharp corners or changes in direction in the ion path, substantially ensuring that the ion stream passes through the ion guide 10 with minimal disturbance.
- 10 In at least one embodiment, the middle section 15 comprises a single offset portion 16 (such as in Figures 1A, 1B and 2). In other embodiments, as illustrated in Figure 3, there may be a plurality of offset portions, 116A, 116B. Some or all offset portions 116A, 116B may be bell shaped. Some or all offset portions 116A, 116B may be V-shaped. Some or all offset portions 116A, 116B may be of the same shape and/or size. In the embodiment illustrated in Figure 3,
- 15 the direction of offset of at least two of the offset portions 116A, 116B is different (e.g. opposite).

The offset portion 16, 116A, 116B does not need to be bell or V shaped. It may be shaped differently, for example a 'zig-zag', or any other non-linear feature.

- 20 In certain embodiments, the ion path 19 of the inlet 11, middle section 15 and outlet 13 is of substantially the same diameter along its length (as shown in Figures 2 and 3).

- In at least one embodiment, at least a part of the middle section 15 is offset from the first 12 and second 14 longitudinal axes by a distance at least equal to the diameter of the middle section
- 25 15. In at least one embodiment, the diameter of the ion path is 4mm. Alternatively or additionally, the offset distance of the offset portion is 4mm.

- The direction of offset of the ion guide 10 is not of importance. Figure 2 illustrates the offset portion as being offset in a 'vertical' direction. This is not essential. The offset may be in any
- 30 direction perpendicular to the longitudinal axis of the ion guide 10. Moreover, the orientation of the ion guide 10 is not of importance. It may be arranged horizontally, as shown, or vertically. In either arrangement, the rotational position of the ion guide is not of importance.

- A benefit of the middle section 15 being non-linear is that it substantially prevents a line of sight
- 35 between the inlet 11 and the outlet 13 through the middle section 15. In other words, the line of sight is occluded.

With reference to Figure 2, which schematically illustrates an ion guide 10 according to one embodiment, an ion path 19 is defined between a first 17 and second 18 surface. In one embodiment, the ion path 19 may be substantially circular in cross-section. In the orientation shown in Figures 1 and 2, the first surface 17 is effectively an upper surface, and the second surface 18 is a lower surface.

In the embodiment illustrated, the part of the lower surface 18 at the furthest extent (peak) of the offset portion 16 is at least in line with the upper surface 17 either side of the offset portion 16, as illustrated by line 30. This prevents a direct line of sight from one side of the offset portion to the other side of the offset portion. That is to say that none of the outlet 13 is visible from the inlet 11. An advantage is that the passage of any light from the ionization source to the detector will be reduced or substantially eliminated.

In other embodiments, the offset may be larger. In other embodiments, the offset may be smaller. For example, the distance of the offset may be less than the diameter of the ion path (e.g. the middle section). With reference to Figure 2, if the light emitted by the ionisation source 2 is in a substantially narrow beam and/or collimated, it may substantially only pass along the longitudinal axis 12 of the inlet 11, with minimal divergence therefrom. Consequently, the offset distance of the offset portion 16 needed to prevent a line of sight through the ion guide 10 may be less than the extent shown in Figure 2 (i.e. equal to the diameter). The offset may be 10%, 20%, 25% or 50% of the diameter of the ion path.

Figure 3 schematically illustrates an ion guide 100 according to another embodiment, in which there are two offset portions 116A, 116B. The second offset portion 116B is offset in a direction opposite to the direction of offset of the first offset portion 116A. The height of each offset 116A, 116B is substantially 50% of the height/diameter of the ion guide 100 either side of the offset portions 116A, 116B. Since the first 116A and second 116B offset portions are offset in opposing directions, the distance between the lower surface 18 of the first offset portion 116A at its peak and the upper surface 17 of the second offset portion 116B at its lowest point is at least equal to the height/diameter of the ion guide 100 either side of the offset. This is demonstrated by line 130. As with the ion guide 10 of Figures 1 and 2, the ion guide 100 of Figure 3 prevents a direct line of sign from one side of the offset portions (e.g. the inlet 11) to the other side of the offset portions (e.g. the outlet 13).

In the embodiment illustrated in Figure 3, the second offset portion 116B is arranged immediately after the first offset portion 116A. This is not essential. They may be spaced apart from another, with a substantially linear portion therebetween. The order of the first 116A and

second 116B offset portions may be reversed from that shown in Figure 3. There may be 3, 4, 5, 6 or more offset portions 116.

In the embodiment illustrated in Figures 1A and 1B, the ion guide 10 comprises a plurality of electrodes 25. They may be 10, 20, 30, 40, 50, 60 or more electrodes 25. The electrodes 25 may each comprise a central aperture (not shown). In some embodiments, the electrodes 25 are planar having a central aperture. The electrodes 25 may be ring electrodes. The electrodes 25 are arranged in series and parallel to one another. The electrodes 25 may be connected to one another, and/or may be connected to the housing 20 or other support structure. The electrodes 25 may be electrically insulated from one another. In an embodiment comprising a plurality of electrodes 25, the offset may be at least equal central aperture of the ring electrodes.

An ion guide 10, 100 embodying the present invention may comprise at least one power supply 50 (illustrated schematically in Figure 1), for providing a voltage to the at least one electrode 25. In some embodiments, the power supply 50 may selectively provide a voltage to each of a plurality of electrodes 25. In at least one embodiment, the power supply 50 is configured to apply one or more transient or static DC voltages or potentials to the plurality of electrodes 25 in order to urge ions axially or longitudinally along at least a portion of the ion path of the ion guide 10, 100.

A benefit of the inlet 11 and outlet 13 being co-axial with one another is that an ion guide 10, 100 embodying the present invention can be retrofitted to an existing mass spectrometer in which at least the components either side of the ion guide 10, 100 (e.g. the first 3 and second 4 mass filters) are arranged linearly. Consequently, little or no adjustment or calibration is needed to the existing components and an ion guide 10, 100 embodying the present invention may be substantially 'plug and play'.

The non-linear portion 15 may have substantially no effect on the passage of the ions through the ion guide 10, 100. The non-linear portion 15 may help to eliminate or reduce the effect of metastable helium atoms (helium neutrals).

### Shroud

According to another aspect of the present invention, as illustrated in Figure 4, there is provided a shroud 60 comprising a housing 61. The housing 61 may comprise a top wall 62, opposing side walls 63 (one shown), front wall 64 and back wall 65. The housing 61 is sized to receive a detector 5 therein. The detector 5 is mounted on or partially received within a mounting plate 67

of a mass spectrometer 1. Effectively, the mounting plate 67 closes the bottom surface of the housing 61 to form a shroud 60 over and around the detector 5.

The front plate 64 of the housing 61 comprises an aperture 66 to allow an ion stream to pass into the housing 61. The aperture is sized as small as possible, such that it is only just bigger than the diameter of the ion stream. The aperture 66 may be the only opening to the housing 61. A benefit of the shroud 60 is that it may serve to eliminate or reduce the passage of unwanted ions and/or unwanted light onto the detector. An advantage of the shroud is that it may serve to eliminate or reduce any unwanted scattered visible light from reaching the detector.

The housing 61 may be comprised at least in part of PEEK.

The optical detector 5, for example including a PMT, has a detector inlet, and the detector inlet is arranged substantially co-axially with the aperture of the shroud. The PMT detector unit may be arranged perpendicularly to the detector inlet. For example, to further reduce noise in the system, the ions entering into the detector inlet may first be redirected to a path perpendicular to the longitudinal axis, before impacting a dynode of the PMT.

Any of the features of the ion guide described and/or illustrated herein may be used in combination with any of the features of the shroud described and/or illustrated herein.

When used in this specification and claims, the terms "comprises" and "comprising" and variations thereof mean that the specified features, steps or integers are included. The terms are not to be interpreted to exclude the presence of other features, steps or components.

The features disclosed in the foregoing description, or the following claims, or the accompanying drawings, expressed in their specific forms or in terms of a means for performing the disclosed function, or a method or process for attaining the disclosed result, as appropriate, may, separately, or in any combination of such features, be utilised for realising the invention in diverse forms thereof.

## REPRESENTATIVE FEATURES

### Ion guide

A1 An ion guide comprising:  
an inlet having a first longitudinal axis;  
5 a middle section; and  
an outlet having a second longitudinal axis;  
wherein the inlet, middle section and outlet together define an ion path, the first axis is substantially co-axial with the second axis, and the middle section is non-linear.

10 A2. An ion guide according to clause A1, wherein at least a part of the middle section is offset from the first and second longitudinal axes.

A3 An ion guide according to any of clauses A1 and A2, wherein at least a part of the middle section is bell shaped or V-shaped.

15 A4. An ion guide according to any of clauses A1 to A3, wherein at least a part of the middle section is offset from the first and second longitudinal axes.

A5. An ion guide according to clause A4, wherein the offset is 4mm.

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A6. An ion guide according to any of clauses A1 to A4, wherein the ion path of the inlet, middle section and outlet is of substantially the same diameter along its axial length.

A7. An ion guide according to clause A6, wherein at least a part of the middle section is  
25 offset from the first and second longitudinal axes by a distance at least equal to said diameter.

A8. An ion guide according to any of clauses A1 to A7 comprising a plurality of electrodes.

A9. An ion guide according to clause A8, wherein each electrode comprises an aperture.

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A10 An ion guide according to any of clauses A8 to A9, wherein each electrode is a ring electrode.

A11. An ion guide according to any of clauses A8 to A10, further comprising a power supply  
35 for selectively providing a voltage to the plurality of electrodes.

**REPRESENTATIVE FEATURES**

A12. An ion guide according to clause A11, wherein the power supply is configured to apply one or more transient or static DC voltages or potentials to the plurality of electrodes in order to urge ions axially or longitudinally along at least a portion of the ion path.

- 5 A13. An ion guide according to any of clauses A1 to A12, wherein the middle section is configured to substantially prevent a line of sight between the inlet and the outlet through the middle section.

- 10 A14. A mass spectrometer comprising the ion guide of any of clauses A1 to A13 comprising at least an ionization source to supply ions to the inlet of the ion guide; and an optical detector to receive ions from the outlet of the ion guide.

- 15 A15. A mass spectrometer according to clause A14, wherein the ionization source includes at least one filament.

A16. A mass spectrometer according to any of clauses A14 and A15, wherein the ionization source creates light in use.

- 20 A17. A mass spectrometer according to any of clauses A14 to A16, wherein the optical detector is a photomultiplier tube.

A18. A mass spectrometer according to any of clauses A14 to A17, further comprising a shroud surrounding the detector.

- 25 A19. A mass spectrometer according to clause A18, wherein the shroud comprises a housing having an aperture to receive ions to be detected therethrough, and the optical detector has a detector inlet, wherein the detector inlet is arranged substantially co-axially with the aperture of the housing.

- 30 A20. A mass spectrometer according to clause A19, wherein the outlet of the ion guide is arranged substantially co-axially with the aperture of the shroud.

**Shroud**

- 35 B1 A shroud comprising a housing sized to receive an optical detector, wherein the housing comprises an aperture to receive ions to be detected therethrough.

**REPRESENTATIVE FEATURES**

B2. A shroud according to clause B1, comprised at least in part of PEEK.

B3. A detector assembly comprising:

- 5           a shroud according to any of clauses B1 and B2  
          an optical detector arranged in the shroud, the optical detector having a detector inlet,  
wherein the detector inlet is arranged substantially co-axially with the aperture of the shroud.

B4. A mass spectrometer comprising a detector assembly according to clause B3, further  
10 comprising at least:

          an ion guide defining an ion path and having an outlet, wherein the outlet of the ion  
guide is arranged substantially co-axially with the aperture of the housing of the shroud.

**CLAIMS**

- 1        An ion guide comprising:  
5        an inlet having a first longitudinal axis;  
         a middle section; and  
         an outlet having a second longitudinal axis;  
         wherein the inlet, middle section and outlet together define an ion path, the first axis is  
         substantially co-axial with the second axis, and the middle section is non-linear.
- 10       2.        An ion guide according to claim 1, wherein at least a part of the middle section is offset  
         from the first and second longitudinal axes.
3.        An ion guide according to claim 2, wherein the offset is 4mm.
- 15       4        An ion guide according to any preceding claim, wherein at least a part of the middle  
         section is V-shaped.
5.        An ion guide according to any preceding claim, wherein the ion path of the inlet, middle  
20       section and outlet is of substantially the same diameter along its axial length.
6.        An ion guide according to claim 5, wherein at least a part of the middle section is offset  
         from the first and second longitudinal axes by a distance at least equal to said diameter.
- 25       7.        An ion guide according to any preceding claim, comprising a plurality of electrodes.
8.        An ion guide according to claim 7, wherein each electrode comprises an aperture.
9.        An ion guide according to any of claims 7 to 8, further comprising a power supply for  
30       selectively providing a voltage to the plurality of electrodes.
10.       An ion guide according to claim 9, wherein the power supply is configured to apply one  
         or more transient or static DC voltages or potentials to the plurality of electrodes in order to urge  
         ions axially or longitudinally along at least a portion of the ion path.

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11. An ion guide according to any preceding claim, wherein the middle section is configured to substantially prevent a line of sight between the inlet and the outlet through the middle section.

5 12. A mass spectrometer comprising an ion guide according to any preceding claim, comprising at least an ionization source to supply ions to the inlet of the ion guide; and an optical detector to receive ions from the outlet of the ion guide.

10 13. A mass spectrometer according to claim 12, wherein the ionization source includes at least one filament and/or creates light in use.

14. A mass spectrometer according to any of claims 12 to 13, wherein the optical detector is a photomultiplier tube.

15 15. A mass spectrometer according to any of claims 12 to 14, further comprising a shroud surrounding the detector.

20 16. A mass spectrometer according to claim 15, wherein the shroud comprises a housing having an aperture to receive ions to be detected therethrough, and the optical detector has a detector inlet, wherein the detector inlet is arranged substantially co-axially with the aperture of the housing.

25 17. A shroud comprising a housing sized to receive an optical detector, wherein the housing comprises an aperture to receive ions to be detected therethrough.

18. A shroud according to claim 17, comprised at least in part of PEEK.

19 A detector assembly comprising:

a shroud according to any of claims 17 and 18;

30 an optical detector arranged in the shroud, the optical detector having a detector inlet, wherein the detector inlet is arranged substantially co-axially with the aperture of the shroud.

20. A mass spectrometer comprising a detector assembly according to claim 19, further comprising at least:

5 an ion guide defining an ion path and having an outlet, wherein the outlet of the ion guide is arranged substantially co-axially with the aperture of the housing of the shroud.

21 A shroud comprising a housing sized to receive an optical detector, wherein the housing comprises an aperture to receive ions to be detected therethrough.

10 22. A shroud according to claim 21, comprised at least in part of PEEK.

23. A detector assembly comprising:

a shroud according to any of claims 21 and 22

15 an optical detector arranged in the shroud, the optical detector having a detector inlet, wherein the detector inlet is arranged substantially co-axially with the aperture of the shroud.

24. A mass spectrometer comprising a detector assembly according to claim 23, further comprising at least:

20 an ion guide defining an ion path and having an outlet, wherein the outlet of the ion guide is arranged substantially co-axially with the aperture of the housing of the shroud.

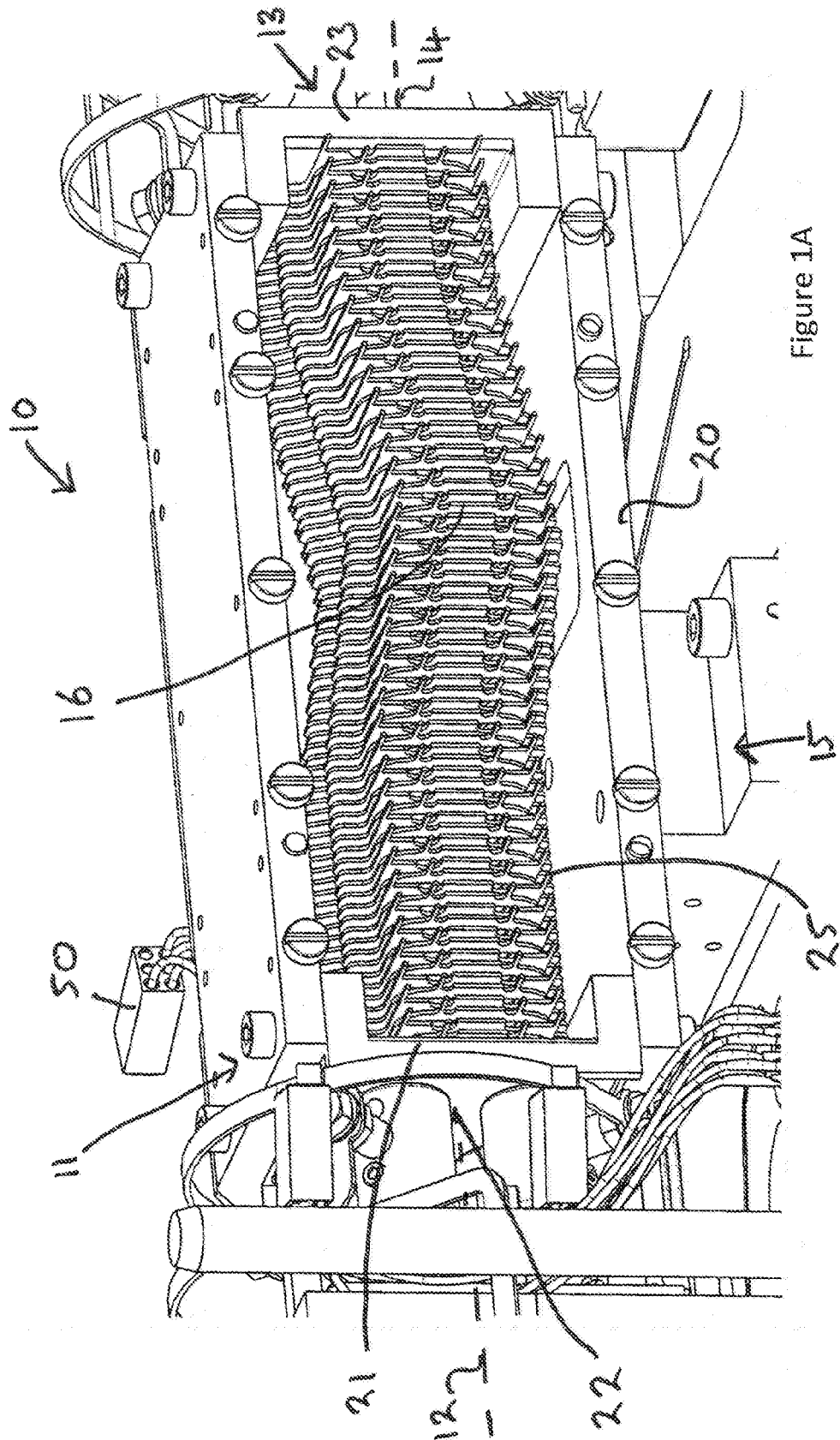


Figure 1A

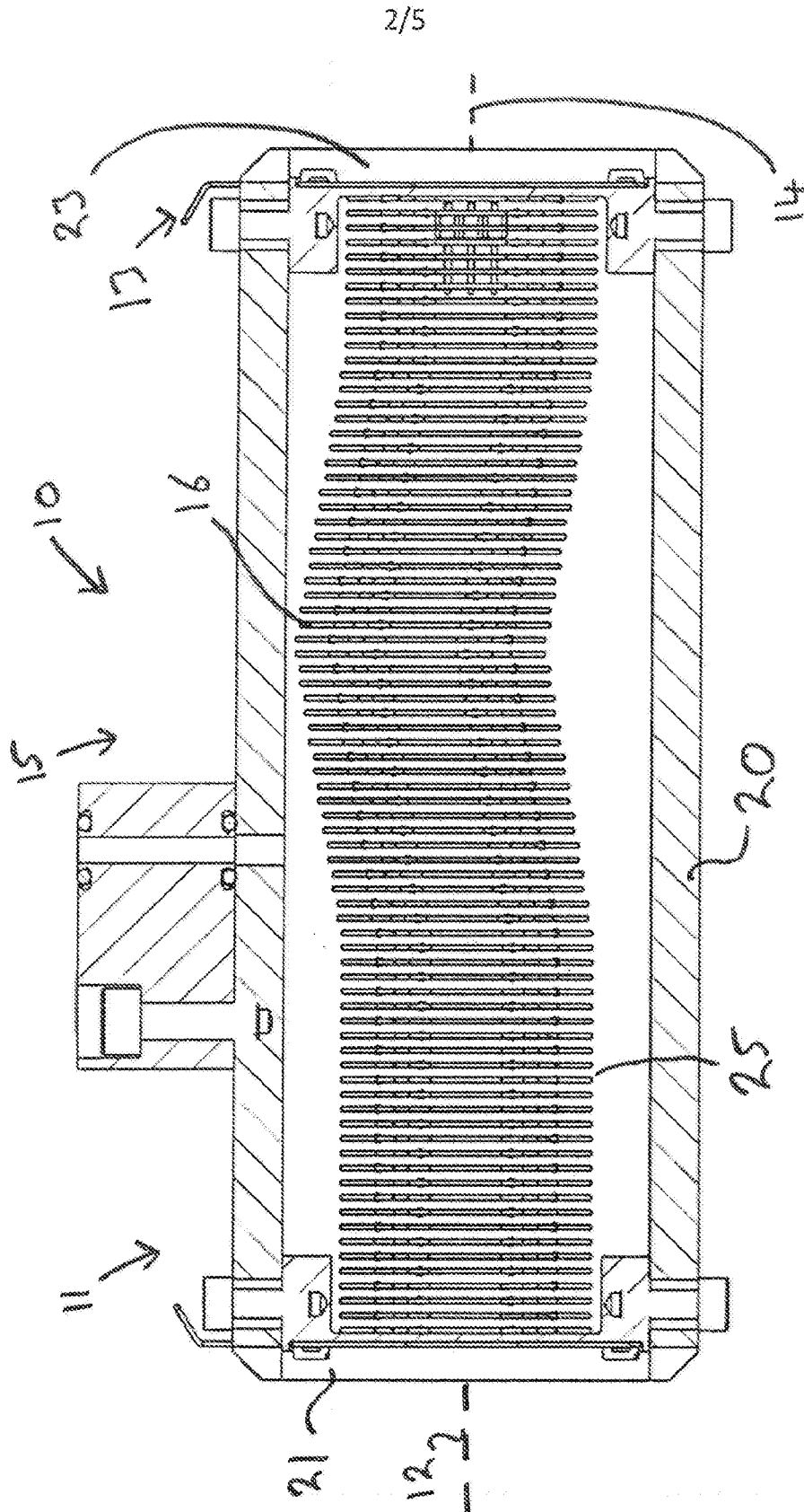


Figure 1B

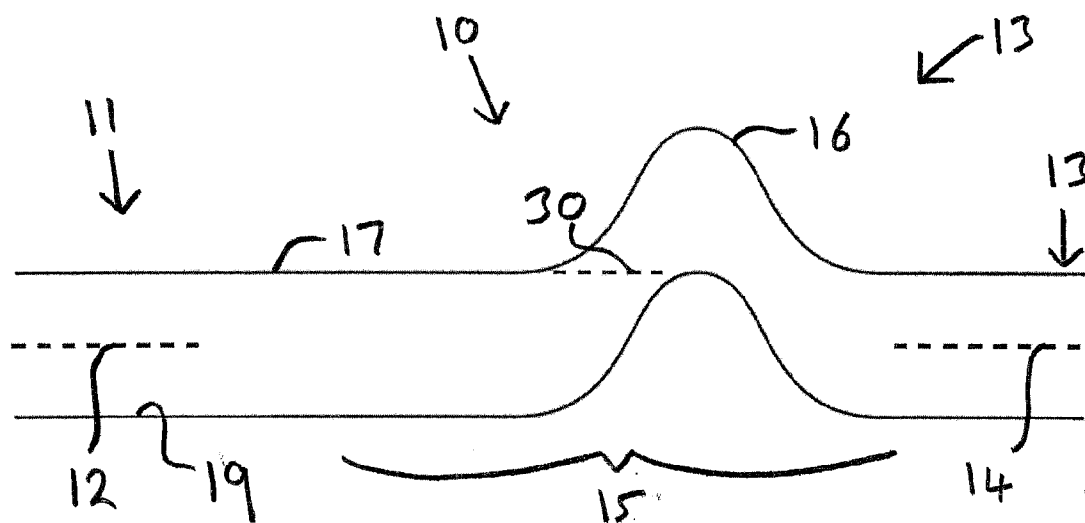


Figure 2

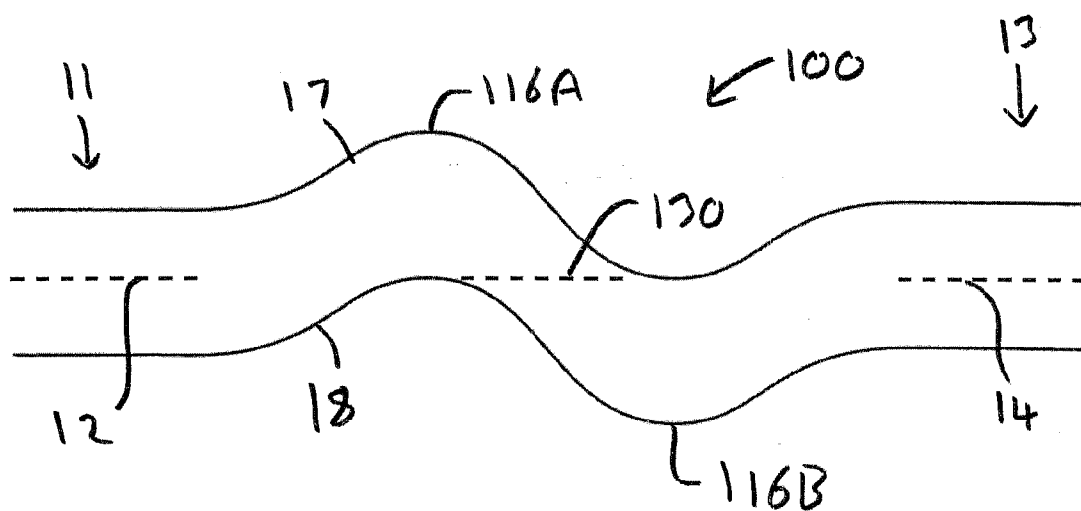


Figure 3

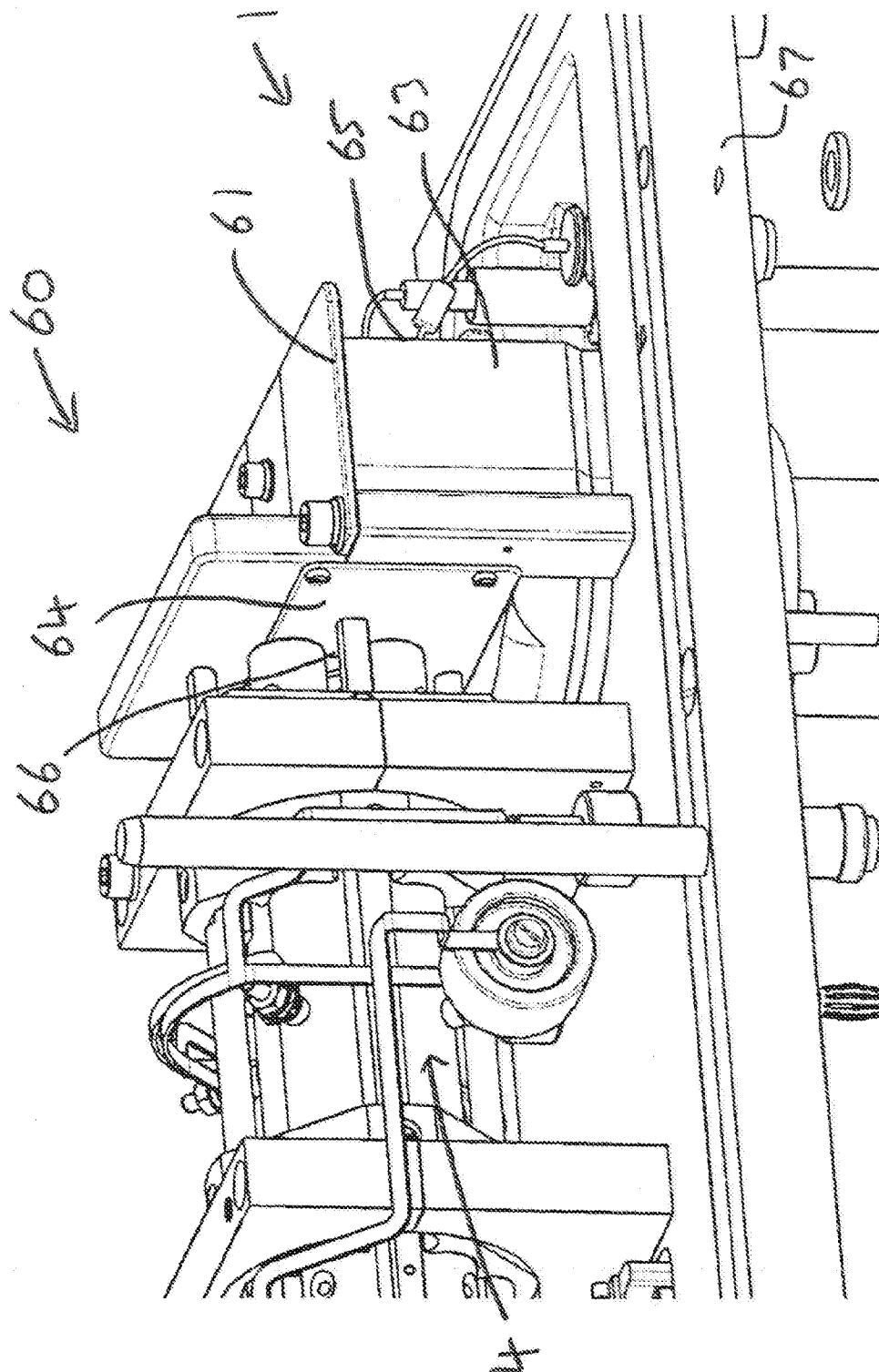


Figure 4

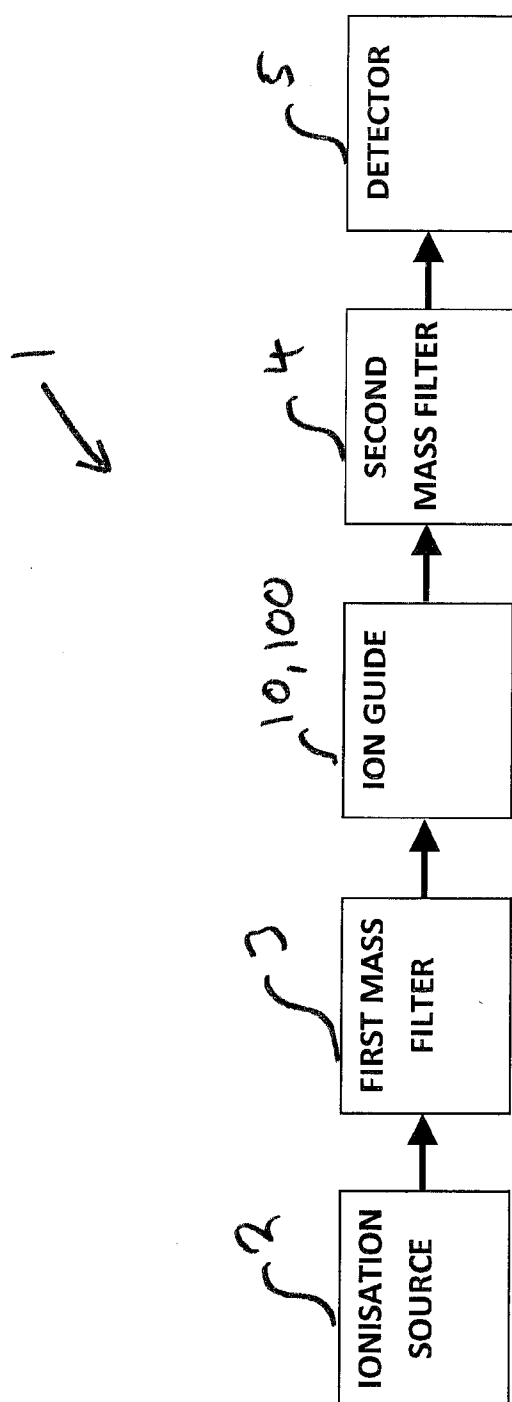


Figure 5

# INTERNATIONAL SEARCH REPORT

International application No  
PCT/GB2019/051489

A. CLASSIFICATION OF SUBJECT MATTER  
INV. H01J49/06  
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

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. |
|-----------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| X         | US 2008/308721 A1 (SENKO MICHAEL W [US] ET AL) 18 December 2008 (2008-12-18)<br>abstract<br>figures 1, 6<br>paragraphs [0005] - [0007], [0015] - [0017], [0022], [0025]<br>claims 1, 7-9<br>-----                                                                             | 1-16                  |
| X         | US 8 796 620 B2 (SHAW PHILIP NEIL [GB]; BATEY JONATHAN HUGH [GB]; MKS INSTR INC [US]) 5 August 2014 (2014-08-05)<br>abstract<br>figures 1, 5A-E<br>column 1, lines 11-17<br>column 2, line 46 - column 3, line 10<br>column 14, line 28 - column 17, line 12<br>-----<br>-/-- | 1-16                  |



Further documents are listed in the continuation of Box C.



See patent family annex.

\* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

9 August 2019

Date of mailing of the international search report

15/10/2019

Name and mailing address of the ISA/

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Dietsche, Rainer

# INTERNATIONAL SEARCH REPORT

International application No

PCT/GB2019/051489

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

| Category | Citation of document, with indication, where appropriate, of the relevant passages                                                                                                                                                                                                                    | Relevant to claim No. |
|----------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| X        | US 2004/056189 A1 (TANNER SCOTT D [CA] ET AL) 25 March 2004 (2004-03-25)<br>abstract<br>figures 1, 3<br>paragraphs [0001], [0043]<br>-----                                                                                                                                                            | 1-16                  |
| X        | US 5 811 820 A (KIRCHNER NICHOLAS J [US] ET AL) 22 September 1998 (1998-09-22)<br>abstract<br>figure 6<br>column 9, line 65 - column 10, line 38<br>column 11, lines 51-55<br>-----                                                                                                                   | 1-11                  |
| T        | Anonymous: "Daly detector",<br>Wikipedia,<br>22 May 2018 (2018-05-22), XP055611947,<br>Retrieved from the Internet:<br>URL:https://en.wikipedia.org/w/index.php?title=Daly_detector&oldid=842400584<br>[retrieved on 2019-08-09]<br>abstract<br>figure 1<br>Section "Principle of operation"<br>----- |                       |
| T        | Anonymous: "Electron ionization",<br>Wikipedia,<br>11 May 2018 (2018-05-11), XP055611948,<br>Retrieved from the Internet:<br>URL:https://en.wikipedia.org/w/index.php?title=Electron_ionization&oldid=840645317<br>[retrieved on 2019-08-09]<br>abstract<br>Section "Instrumentation"<br>-----        |                       |

## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/GB2019/051489

### Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:  
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:  
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

### Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-16

#### Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

**FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210**

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-16

ion guide with non-linear middle section

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2. claims: 17-24

shroud for detector

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# INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/GB2019/051489

| Patent document<br>cited in search report | Publication<br>date | Patent family<br>member(s) | Publication<br>date                                                                                                                                                                                |
|-------------------------------------------|---------------------|----------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| US 2008308721                             | A1                  | 18-12-2008                 | NONE                                                                                                                                                                                               |
| US 8796620                                | B2                  | 05-08-2014                 | TW 201306088 A 01-02-2013<br>US 2012312984 A1 13-12-2012<br>WO 2012170168 A2 13-12-2012                                                                                                            |
| US 2004056189                             | A1                  | 25-03-2004                 | CA 2317085 A1 28-02-2002<br>EP 1314187 A2 28-05-2003<br>JP 5281223 B2 04-09-2013<br>JP 2004507875 A 11-03-2004<br>US 2004056189 A1 25-03-2004<br>WO 0219382 A2 07-03-2002                          |
| US 5811820                                | A                   | 22-09-1998                 | AU 6477496 A 09-01-1997<br>EP 0846190 A1 10-06-1998<br>JP 4097695 B2 11-06-2008<br>JP H11507702 A 06-07-1999<br>KR 19990022867 A 25-03-1999<br>US 5811820 A 22-09-1998<br>WO 9641900 A1 27-12-1996 |