

## MASS FILTER

5 CROSS-REFERENCE TO RELATED APPLICATION

This application claims priority from and the benefit of United Kingdom patent application No. 2301594.4 filed on 3 February 2023. The entire contents of this application are incorporated herein by reference.

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FIELD OF THE INVENTION

The present invention relates generally to mass and/or ion mobility spectrometers and in particular to mass filters that selectively transmit ions within a specific range of mass to charge ratios and filter out other ions. The mass filter disclosed herein enables an extended operational lifetime relative to conventional mass filters.

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BACKGROUND

It is known to use quadrupole mass filters so as to selectively transmit ions within a specific range of mass to charge ratios. A quadrupole mass filter transmits ions that satisfy conditions of stability within the quadrupole field, wherein the stability conditions are defined by the dimensionless parameters  $q$  and  $a$ :

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$$q = \frac{4eV}{r_0^2 \omega^2 m} \quad (1)$$

$$a = \frac{2eU}{r_0^2 \omega^2 m} \quad (2)$$

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where  $e$  is the charge of the ion,  $V$  is the amplitude of the RF voltage applied to the quadrupole electrodes,  $r_0$  is the inscribed radius between the rods of the quadrupole,  $\omega$  is the angular frequency of the RF voltage applied to the quadrupole (in radians/sec),  $m$  is the mass of the ion, and  $U$  is the resolving DC voltage.

Ions having values of  $a$  and  $q$  that result in unstable ion trajectories generally impact on the rods of the quadrupole and are lost. This property is exploited when the quadrupole rod set is used as a mass filter, such that the majority of the ions that are not desired to be transmitted by the mass filter impact on the inner surfaces of the rod electrodes. However, over time the inner surfaces of the rods become contaminated by the ions and electrical charge builds up on their surfaces. Eventually, local charging of the contaminated surfaces results in degradation of performance of the mass filter. This may result in loss of transmission, loss of resolution or poor mass peak shape. If this occurs the

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mass filter must be removed from the vacuum chamber of the mass spectrometer in which it is located and cleaned.

#### SUMMARY

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From a first aspect the present invention provides a mass filter comprising: a plurality of mass filtering electrodes for mass filtering ions passing therethrough, wherein at least a first of these electrodes comprises a first gap therethrough; voltage supplies arranged and configured to apply voltages to the mass filtering electrodes such that ions having mass to charge ratios within a mass transmission window are confined by the electrodes and are transmitted through the mass filter, whereas at least some ions having mass to charge ratios outside of said mass transmission window are unstable and pass through the first gap such that they are filtered out by the mass filter; and a first collector electrode arranged so as to receive the ions that are transmitted through the first gap, wherein the voltage supplies apply a DC potential difference between said first mass filtering electrode and said first collector electrode so as to urge the ions that are transmitted through the first gap onto the first collector electrode.

The provision of a gap in said first mass filtering electrode enables ions that are filtered out by the mass filter to pass through the first mass filtering electrode, rather than striking the inner surface of the electrode and causing contamination and build-up of electrical charge. However, it has been found that ions that pass into such a gap may still end up striking the mass filtering electrode and may therefore still be problematic. In order to eliminate or mitigate this, the present invention provides the collector electrode adjacent to the gap so as to urge ions onto the collector electrode. The majority of contamination and charge build up caused by the filtered ions therefore occurs at the collector electrode, which may have substantially no, or relatively little, impact on the electrical fields that cause the mass filtering within the mass filter. It may also be easier to clean or replace the collector electrode than said mass filtering electrodes, e.g. because the precision of the alignment of the collector electrode within the mass filter is less critical.

The mass filter may be configured such that the collector electrode(s) discussed herein do not have any function with respect to shaping or transport the ion beam passing through the mass filter. In other words, the collector electrode(s) preferably provide substantially no contribution to the electric field that is defined in the region between the mass filtering electrodes for mass filtering the ions.

The mass filter may be a quadrupole mass filter.

Accordingly, said plurality of mass filtering electrodes may comprise four elongated multipole electrodes.

The mass filter may be a DC resolving mass filter in which the voltage supplies apply RF and DC voltages to the mass filtering electrodes so as to define said mass transmission window.

The voltage supplies may apply a first phase of an RF voltage to a first pair of opposing mass filtering electrodes and a second, different phase of the RF voltage to

another pair of opposing mass filtering electrodes. The first and second phases may be 180 degrees out of phase with each other. The voltage supplies may also apply a first DC voltage to the first pair of opposing mass filtering electrodes and a second, different DC voltage to the other pair of opposing mass filtering electrodes.

5           The mass filtering electrodes may be elongated and substantially parallel to each other so as to define a central axis along which ions that have mass to charge ratios within the mass transmission window are transmitted. The ions that are filtered out may be radially ejected, relative to the central axis, through the first gap.

Each elongated mass filtering electrode may be a single continuous electrode.

10         Alternatively, at least one, or at least some, of the elongated electrodes may be axially segmented electrodes. In embodiments that have axially segmented electrodes, the same phase and amplitude of RF voltage may be applied to all of the axial segments within any given axially segmented electrode. However, different DC voltages may be applied to different axial segments within any given axially segmented electrode, e.g. so as to urge  
15         ions downstream through the mass filter.

A second of the mass filtering electrodes that is opposite to said first mass filtering electrode may comprise a second gap therethrough; wherein the voltage supplies are arranged and configured to apply said voltages to the mass filtering electrodes such that  
20         ions having mass to charge ratios outside of said mass transmission window are unstable and pass through the second gap; and wherein the mass filter comprises a second collector electrode arranged so as to receive the ions that are transmitted through the second gap.

The voltage supplies may apply a DC potential difference between said second mass filtering electrode and said collector electrode so as to urge the ions that are  
25         transmitted through the second gap onto the second collector electrode.

The voltage supplies may be configured to: (i) apply a first DC voltage to the first and second mass filtering electrodes; (ii) apply a second DC voltage of the opposite polarity to two other opposing mass filtering electrodes; and (iii) apply a DC voltage to the first and second collector electrodes that is the same polarity as the first DC voltage but a  
30         greater magnitude.

The voltage supplies may be configured to: (i) apply a first phase of an RF voltage to the first and second mass filtering electrodes; (ii) apply a second different phase of the RF voltage to two other opposing mass filtering electrodes; and (iii) apply the first phase of the RF voltage to the first and second collector electrodes.

35         A RF voltage may be applied to the first and/or second collector electrode.

Each of the first and/or second collector electrodes may comprise multiple electrically conductive regions and the voltage supplies may be configured to apply different voltages to the different electrically conductive regions so as to urge the filtered ions onto at least one of said electrically conductive regions.

40         The voltage supplies maybe configured to simultaneously apply the different voltages to the different electrically conductive regions.

The voltage supplies may be configured to: (i) operate in a first mode in which a first voltage is applied to a first of the electrically conductive regions and one or more different voltage is applied to one or more other electrically conductive region such that substantially all, or a majority, of the ions that strike the collector electrode strike the first electrically  
5 conductive region; and (ii) operate in a second mode in which a voltage is applied to a second of the electrically conductive regions and one or more different voltage is applied to one or more other electrically conductive region such that substantially all, or a majority, of the ions that strike the collector electrode strike the second electrically conductive region.

The voltages that are applied to the electrically conductive regions are preferably  
10 DC voltages.

The mass filter may comprise charge detection circuitry configured to detect the electric charge on the first electrically conductive region during the first mode and to switch the mass filter to the second mode when the detected charge reaches a threshold level.

The mass filter may be configured to switch from the first mode to the second mode  
15 after a maximum pre-selected amount of time of operating in the first mode.

The mass filter may comprise charge or current detection circuitry configured to detect the electric charge or current on the second electrically conductive region during the second mode; wherein the mass filter is configured, in the second mode, to determine the remaining operational lifetime of the collector electrode based on the charge or ion current  
20 detected at the second electrically conductive region, and then switch to the first mode.

The mass filter may compare the ion current or charge that is detected with calibration data that relates values of ion current or charge to remaining operational lifetimes for the collector electrode. The mass and/or mobility spectrometer that comprises the mass filter may display the remaining operational lifetime and/or be configured to  
25 provide an alert indicating that the operational lifetime has ended and, for example, that the collector electrode should be replaced or cleaned.

The first electrically conductive region may not comprise ion detection circuitry.

The mass filter may be operated primarily in the first mode and may switch to the second mode for a smaller proportion of time during an experimental run.

The surface of the first collector electrode that faces the first gap may comprise a  
30 ridge pointing towards the first gap; and/or the surface of the second collector electrode that faces the second gap may comprise a ridge pointing towards the second gap.

Such a ridged profile of the collector electrode may enhance the ion focusing and attractive properties of the collector electrode.

The ridge may extend along the length of the collector electrode, e.g. substantially  
35 parallel to the gap.

The peak of the ridge may be aligned with the centre of the gap, in the width direction of the gap (i.e. orthogonal to the length of the gap).

The ridge may have a constant height along the length of the collector electrode, or  
40 its height may vary as a function of length along the collector electrode, e.g. so that the electric field between the collector electrode and first mass filtering electrode varies as a function of the length.

At least part of the surface of the first and/or second collector electrode that faces the first and/or second gap, respectively, may have a modified surface such that it is easier for an operator to see contamination on that surface due to it being hit by the ions than it would be without the modified surface.

5       The at least part of the surface that is modified may be a discrete portion of the surface arranged adjacent to the gap.

Said at least part of the surface may have been modified relative to other parts of the collector electrode so as to have a different topology and/or be less reflective to visible light, such as by being etched or coated.

10       The first and/or second collector electrode may be, or may comprise, an electrically conductive plate arranged to face the first and/or second gap, respectively.

The plate may be removed from the mass filter so as to analyse the contamination thereon due to the mass filtered ions striking the plate.

15       Each of the first and/or second collector electrodes may comprise a stack of electrically conductive peel strips arranged so as to receive the ions that pass through the first and/or second gap respectively.

This enables the outermost peel strip in the stack to be removed when contamination has built up on it, so as to reveal a clean, uncontaminated peel strip.

20       The peel strip that has been removed may be analysed in the same manner described herein in relation to the plates.

The stack may be arranged on a main body of the collector electrode and may be configured such that applying a voltage to the main body of the collector electrode transmits that voltage to all of the peel strips.

25       The peel strips in each stack may be adhered to each other, and optionally to a main body of the collector electrode, using an electrically conductive adhesive.

The mass filter may comprise one or more structural support configured to mount the first and/or second collector electrode to the mass filtering electrodes so that the first and/or second collector electrode is located adjacent to the first and/or second gap, respectively.

30       The one or more structural support may be an electrically insulating material, such as PEEK for example.

The collector electrodes are electrically conductive, such as being made from steel.

35       Each of the collector electrodes may be releasably mounted to the one or more structural support so that it may be removed and replaced. For example, each collector electrode may be releasably mounted to the one or more structural support with screws.

40       The first and/or second collector electrode may be located relatively close to the first and/or second mass filtering electrode, respectively. For example, the distance between the first and/or second collector electrode and the first and/or second mass filtering electrode, respectively, at their closest points may be less than 10 mm or less than 5 mm.

The one or more structural support may be configured to releasably mount the first and/or second collector electrode in a plurality or different orientations or locations relative

to the mass filtering electrodes such that each collector electrode is: (i) rotatable so that different surfaces of the collector electrode receive the ions from the gap at different respective times; and/or (ii) movable so that different portions of the same surface on the collector electrode receives the ions from the gap at different respective times.

5           The first gap may be a slot through the first mass filtering electrode and/or the second gap may be a slot through the second mass filtering electrode.

The circumference of each slot may therefore be entirely encircled by electrode material.

10           Alternatively, the first electrode may have two separate spaced apart electrode portions that define the first gap therebetween. Similarly, the second electrode may have two separate spaced apart electrode portions that define the second gap therebetween.

The mass filter is preferably configured so as not to trap ions in three-dimensions whilst the mass filtering is occurring. As such, the mass filter and the voltages applied to it allow ions to enter the mass filter at an entrance end and for ions within the mass  
15           transmission window to continue through the mass filter and exit at a downstream end, without being axially trapped.

The mass filter or mass spectrometer disclosed herein preferably does not have circuitry that determines the mass to charge ratios of the ions that strike the first and/or second collector electrode.

20           It is contemplated that the mass filter need not necessarily apply a DC potential difference between said first mass filtering electrode and said first collector electrode so as to urge the ions that are transmitted through the first gap onto the first collector electrode. Similarly, the mass filter need not necessarily apply a DC potential difference between said second mass filtering electrode and said second collector electrode so as to urge the ions  
25           that are transmitted through the second gap onto the second collector electrode.

Accordingly, from a second aspect the present invention provides a mass filter comprising: a plurality of mass filtering electrodes for mass filtering ions passing therethrough, wherein at least a first of these electrodes comprises a first gap  
30           therethrough; voltage supplies arranged and configured to apply voltages to the mass filtering electrodes such that ions having mass to charge ratios within a mass transmission window are confined by the electrodes and are transmitted through the mass filter, whereas at least some of the ions having mass to charge ratios outside of said mass transmission window are unstable and pass through the first gap such that they are filtered  
35           out by the mass filter; and a first collector electrode arranged so as to receive the ions that are transmitted through the first gap.

The second aspect of the present invention may have any of the optional features described in relation to the first aspect of the present invention, except that a DC potential difference need not necessarily be arranged between said first and/or second mass filtering electrode and said first and/or second collector electrode, respectively, for urging the ions  
40           onto the collector electrodes.

The present invention also provides a mass and/or ion mobility spectrometer comprising a mass filter as described herein, further comprising a detector or analyser for

detecting or analysing ions within the mass transmission window that are transmitted by the mass filter, or ions derived therefrom.

The mass filter may be a bandpass mass filter that filters out ions that would otherwise strike a component of the spectrometer downstream of the mass filter; and/or  
5 the mass filter may be maintained at a pressure of  $\geq 10^{-4}$  mbar.

The downstream component may be an apertured wall or electrode through which ions pass, or an ion-optical component such as an ion lens, a further mass filter or an ion guide. For example, the bandpass mass filter may transmit ions having mass to charge ratios within a first mass transmission window and filter out ions having mass to charge  
10 ratios outside this window, and the transmitted ions may then pass into a further mass filter that has a second mass transmission window that is smaller than and within the first mass transmission window. For example, the width of the second mass transmission window may be such that it is capable of only transmitting a single ion species. The bandpass mass filter protects the further mass filter by filtering out some of the ions that would  
15 otherwise strike the electrodes of the further mass filter. Ions passing through the bandpass mass filter that are within the second mass transmission window will also pass through the further mass filter.

The bandpass mass filter may have a mass transmission window that is capable of simultaneously transmitting multiple species of ions. For example, the mass transmission  
20 window may have a width of  $\geq 50$  Da,  $\geq 100$  Da,  $\geq 150$  Da, or  $\geq 200$  Da, although other widths of mass transmission window are also contemplated.

The mass filter described herein may be provided in a relatively high pressure region of the spectrometer, e.g. at a relatively upstream region such that it can perform prefiltering of the ions so as to protect downstream components. For example, the mass  
25 filter may be at a pressure between  $10^{-2}$  mbar and  $10^{-3}$  mbar. However, it is contemplated that the mass filter may be used at lower pressures.

The present invention also provides a method of mass filtering ions comprising: providing a mass filter as described herein; applying said voltages to the mass filter so that the mass filter transmits only ions having mass to charge ratios within the mass  
30 transmission window and filters out ions having mass to charge ratios outside the mass transmission window, wherein at least some of the ions that are filtered out pass through the first and/or second gap and onto the first and/or second collection electrode respectively.

The present invention also provides a method of mass and/or ion mobility spectrometry comprising a method of mass filtering ions as described herein, comprising  
35 detecting and/or mass analysing and/or ion mobility analysing ions transmitted by the mass filter, or ions derived therefrom.

#### BRIEF DESCRIPTION OF THE DRAWINGS

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

Fig. 1 shows a mass spectrometer according to an embodiment of the present invention;

Fig. 2 shows a conventional quadrupole mass filter;

Fig. 3 shows a quadrupole mass filter having slotted electrodes;

5 Figs. 4A-4D show different views of a mass filter according to an embodiment of the present invention;

Figs. 5A-5B show simulations of trajectories of ions in the mass filter of Figs. 4A-4D;

10 Fig. 6 shows a collector electrode according to an embodiment that has multiple discrete electrically conductive regions;

Fig. 7 shows a collector electrode according to an embodiment that has a ridged surface;

Fig. 8 shows a collector electrode according to an embodiment that has a modified region so as to aid visualisation of contamination thereon;

15 Fig. 9 shows a collector electrode according to an embodiment that has a stack of conductive peel strips; and

Fig. 10 shows a portion of a mass filter according to an embodiment in which the collector electrode can be rotated.

## 20 DETAILED DESCRIPTION

Fig. 1 shows a block diagram of a mass spectrometer according to an embodiment of the present invention that comprises an ion source 2, a quadrupole mass filter 4, a fragmentation or reaction cell 6 and an orthogonal acceleration time of flight mass analyser 8.

25 In operation, ions are generated by ion source 2 and pass to the quadrupole mass filter 4. Voltages are applied to the quadrupole mass filter 4 so that it is only capable of transmitting ions within a certain range of mass to charge ratios, known as the mass transmission window. Ions having mass to charge ratios outside of this window are filtered out and not transmitted by the mass filter 4. The ions that are transmitted by the mass filter 30 pass into the fragmentation or reaction cell 6, which may fragment or react the ions with other ions or molecules so as to produce fragment or other product ions. These fragment or product ions are onwardly transmitted to the time of flight mass analyser 8, in which they are mass analysed, along with any unfragmented precursor ions. The mass to charge ratio 35 transmission window of the mass filter 4 may be scanned with time during the analytical run such that different ranges of mass to charge ratios are transmitted by the mass filter 4 at different times, as is known in the art. The different precursor ions transmitted at different times may then be associated with their respective product ions in the known manner.

40 Although a particular instrument has been described, it will be appreciated that the present invention is not limited to a mass spectrometer having the above features. For

example, the fragmentation or reaction device may be switched on and off in different modes, or may not even be present. Additionally, or alternatively, the time of flight mass analyser may be substituted for a different type of mass analyser. Additionally, or alternatively, additional ion-optical devices may be provided between the ion source and the mass filter and/or between the mass filter and the mass analyser.

As described above, the mass filter 14 only transmits ions within a certain mass transmission window at any given instant, and may be required to filter out a relatively large proportion of the ions that it receives. Conventionally, this has led to the electrodes of the mass filter becoming contaminated relatively quickly, as will now be described with reference to Fig. 2.

Fig. 2 shows a schematic of a conventional quadrupole mass filter 10. The mass filter comprises four parallel rod electrodes 12a, 12b. An RF voltage supply 14 is connected to these electrodes so as to supply a first phase of an RF voltage to a first pair of opposing electrodes 12a and a second phase of the RF voltage to the other pair of electrodes 12b, where the first and second phases are 180 degrees out of phase with each other. In other words, circumferentially adjacent rods have opposite phases of an RF voltage applied to them. A DC voltage supply 16 is also connected to these electrodes so as to supply a first DC voltage to the first pair of opposing electrodes 12a and a second different DC voltage to the other pair of electrodes 12b. In other words, the mass filter is a DC resolving mass filter.

As is well known in the art, only ions having mass to charge ratios which fall within a certain mass transmission window will have stable trajectories through the mass filter. Accordingly, only these ions will be onwardly transmitted by the mass filter and all other ions will be filtered out by the mass filter. The ions that are filtered out typically strike the rod electrodes 12a, 12b, resulting in contamination building up on the inner surfaces of the electrodes. The contamination acts as an electrical insulator and so when further ions that are filtered out strike the contaminated surface this can cause electrical charge to build up on the contaminated surface, which perturbs the electric field of the mass filter, thus altering the performance of the mass filter.

It is known to mitigate the above-described problems by providing slots through the electrodes of the mass filter such that fewer ions strike the inner surfaces of the electrodes 12a, 12b, e.g. as described below in relation to Fig. 3.

Fig. 3 shows a cross-sectional view (in the x-y plane) of a known mass filter that is the same as that described in relation to Fig. 2, except that each of the rod electrodes 12a, 12b comprises a slotted aperture 18 that extends all of the way through the electrode, from an ion entrance opening facing the ion optical axis through the mass filter to an ion exit opening facing radially outward from the mass filter. A grid or mesh electrode 20 may be provided over the ion entrance opening of each slot 18 for substantially maintaining the electric field profile.

Fig. 3 shows the trajectories 22, 24 of analyte ions having mass to charge ratios that are outside of the mass transmission window. Positive ions having mass to charge ratios that are outside of the mass transmission window that the mass filter is set to transmit are

unstable and exit the mass filter in the y-direction through the slots 18, as shown by trajectories 22. Negative ions having mass to charge ratios that are outside of the mass transmission window that the mass filter is set to transmit are also unstable and exit the mass filter in the x-direction through the slots 18, as shown by trajectories 24. It will  
5 therefore be appreciated that the mass filter is able to filter out ions without a substantial proportion of these filtered ions impacting on the radially inner surfaces of the electrodes 12a,12b and hence without the filtered ions causing significant contamination and charging of the radially inner surfaces of the electrodes.

Figs. 4A-4D show different views of a mass filter according to an embodiment of the present invention. The mass filter comprises four elongated mass filtering electrodes 26a,26b that act to mass filter ions, although one of the electrodes 26b has been omitted in Figs. 4B-4C for illustrative purposes only. As best shown in Fig. 4D, an RF voltage supply 28 is connected to these electrodes so as to supply a first phase of an RF voltage to a first pair of opposing electrodes 26a and a second phase of the RF voltage to a second pair of  
15 electrodes 26b. In other words, different RF phases may be applied to mass filtering electrodes 26a,26b that are adjacent each other in a circumferential direction around the central axis through the mass filter. The first and second phases are preferably 180 degrees out of phase with each other. Preferably the same amplitude RF voltage is applied to all of the electrodes 26a,26b. A DC voltage supply 30 is also connected to these  
20 electrodes 26a,26b so as to supply a first DC voltage to the first pair of opposing electrodes 26a and a second different DC voltage to the other pair of electrodes 26b, such that the mass filter acts as a DC resolving mass filter.

RF and DC voltages are applied to the mass filtering electrodes 26a,26b so that ions having mass to charge ratios within a mass transmission window are transmitted by  
25 the mass filter, whereas other ions are filtered out by the mass filter in the same manner as described above in relation to Figs. 2-3. As shown in Fig. 4A, an apertured plate or wall 32 may be arranged at the downstream end of the mass filter that has an aperture through which ions that are transmitted by the mass filter pass.

Each electrode in the first pair of electrodes 26a has a gap 34 in the form of a  
30 slotted aperture extending radially therethrough for allowing ions that are filtered out by the mass filter to pass through the electrode 26a. Each slot 34 may have a length that extends along the majority of the length of the electrode that it is within. Alternatively, the slot may have a relatively short length and may be located at an axial position where most of the ion ejection is expected to occur, e.g. at the entrance end of the mass filter. Each slot 34 may  
35 have a width of less than 2 mm, such as around 1 mm. It has been found that such widths enable the filtered ions to be ejected without significantly perturbing the electric field inside the mass filter. However, other widths are also contemplated.

A collector electrode 36 is placed behind each slot 34 so that ions that are filtered out, and pass through the slots, strike the collector electrodes 36. In Fig. 4A, one of the  
40 collector electrodes 36 is illustrated as being transparent purely for the purpose of being able to see the slot 34 that is behind it.

The electrodes 26,36 described above may be held in a fixed position relative to each other by one or more structural support, e.g. as shown in Fig. 4D. For example, a first structural support 38 may be secured to one of the collector electrodes 36, one of the first pair of electrodes 26a, and one of the second pair of electrodes 26b. The first  
5 structural support may be secured to these electrodes using securing members that, for example, engage holes 40 in the electrodes (which are best seen in Fig. 4B). For instance, the securing members may screw into the holes in the electrodes. A second structural support may be provided that is secured to the other one of the collector electrodes 26, the other one of the first pair of electrodes 26a, and the other one of the second pair of  
10 electrodes 26b. Again, securing members may be provided that secure these electrodes to the second structural support in a corresponding manner to that described above in relation to the first structural support. The first and second structural supports may then be secured to each other so that none of the electrodes 26,36 can move relative to each other. The securing members may releasably secure the electrodes to the structural  
15 supports so that at least the collector electrodes may be removed, e.g. for being cleaned.

Although certain electrodes have been described as being secured to each structural support, it is contemplated that a different combination of the electrodes may be secured to each structural support. It is also contemplated that more than two structural supports may be used to fix the positions of the electrodes relative to each other.

20 The DC voltages that are applied to the mass filtering electrodes 26a,26b are selected such that the analyte ions that are unstable in the mass filter are urged towards and through the slots 34. For example, if positive ions are being mass filtered then the DC voltage that is applied to the first electrodes 26a may be more negative than the DC voltage that is applied to the second electrodes 26b. Alternatively, if negative ions are  
25 being mass filtered then the DC voltage that is applied to the first electrodes 26a may be more positive than the DC voltage that is applied to the second electrodes 26b.

As shown in Fig. 4D, a DC voltage supply 42 may supply a DC voltage to the collector electrodes 36. This DC voltage is preferably different to the DC voltage that is applied to the first pair of electrodes 26a such that a DC potential difference is maintained  
30 between each electrode in the first pair of electrodes 26a and the collector electrode 36 that is adjacent to it. The voltages may be selected so as to urge the ions that exit the slots 34 onto the collector electrodes 36. For example, if positive ions are being mass filtered then the collector electrodes 36 may be maintained at a DC voltage that is more negative than the first pair of electrodes 26a. Conversely, if negative ions are being mass filtered  
35 then the collector electrodes 36 may be maintained at a DC voltage that is more positive than the first pair of electrodes 26a. This DC potential difference helps prevent ions that have been ejected through the slots 34 from turning around and landing on the first and second pairs of electrodes 26a,26b. Additionally, or alternatively to applying DC voltages to the collector electrodes, an RF voltage supply 28 may apply an RF voltage to the  
40 collector electrodes 36. This RF voltage may have the same phase and/or amplitude as the RF voltage that is applied to the first electrodes 26a.

Figs. 5A-5B show simulations of trajectories of ions within the mass filter. Fig. 5A shows the trajectories 44 of ions having mass to charge ratios that are within the mass transmission window. These ions are radially confined by the mass filtering electrodes 26a,26b and have a stable trajectory such that they pass along the central axis of the mass filter from the upstream end to the downstream end. Fig. 5B shows the trajectories 46 of ions having mass to charge ratios that are outside of the mass transmission window. These ions are not radially confined by the mass filtering electrodes 26a,26b, but are instead unstable such that they pass radially through the slots 34 in the first pair of electrodes 26a and strike the collector electrodes 36.

As described above, the slots 34 may have relatively small widths, which helps prevent field penetration into the region between the first and second pairs of electrodes 26a,26b, e.g. due to the voltages applied to the collector electrodes 36. As such, any voltages that are applied to the collector electrodes 36 may not interfere with the ions that are confined within the mass filter. The voltages applied to the collector electrodes 36 can therefore be set to any amplitude, although they should not be set so high that an electrical discharge occurs. It has also been found that contamination that builds up on the collector electrodes 36 does not interfere with the ions that are radially confined within the mass filter. For example, if charge builds up on contaminated portions of the collector electrodes, due to being struck by ions that have been mass filtered, this does not affect the voltage switching speed or any other aspect of performance of the mass filter. Also, the collector electrodes are easy to replace if that becomes necessary.

For illustrative purposes only, an example of the voltages that may be applied to the mass filter will now be described. An RF voltage having a frequency of 1.6 MHz and an amplitude of 700 V (peak-to-peak) may be applied to the first and second pairs of electrodes 26a,26b and also to the collector electrodes 36. The same phase of the RF voltage may be applied to the first pair of electrodes 26a and the collector electrodes 36, but the RF voltage applied to the second pair of electrodes 26b may be 180 degrees out of phase. The DC voltage applied to the first pair of electrodes 26a may be -15V. The DC voltage applied to the second pair of electrodes 26b may be +15V. The DC voltage applied to the collector electrodes 36 may be -25V. However, as mentioned above, these are only exemplary voltages and voltages having alternative frequencies and amplitudes may be applied instead.

Fig. 6 shows a portion of one of the collector electrodes 36 according to an embodiment that is configured to cause the ions that are filtered out by the mass filter to strike different discrete regions of the collector electrode at different times. The surface of the collector electrode that faces the slot 34 comprises multiple discrete electrically conductive regions 60,62,64 that are able to be electrically biased independently from each other so that the ions that are filtered out can be caused to strike a selected one of the regions at any given time. For example, during a first duration, a first of the regions 60 may be electrically biased with a DC voltage so as to form a DC potential difference between the first region 60 and the adjacent electrode 26a with the slot 34 in it so that the ions are focused onto that first region 60. Different DC voltages may be applied to the

other discrete regions 62,64 such that fewer ions, or substantially no ions, strike those other discrete regions during the first duration.

After a certain duration, it may be desired to cause the filtered ions to strike a second of the discrete regions 62 and not to strike the first discrete region 60. For example, if ions are filtered out by the mass filter at a high rate, then the filtered ions can strike the first discrete region 60 and cause charge to build up to a level that ions which are subsequently filtered out may be repelled away from the collector electrode and back onto the slotted electrode 26a. When it is desired to cause the filtered ions to strike the second discrete region 62, during a second duration, the second region 62 may be electrically biased with a DC voltage so as to form a DC potential difference between the second region 62 and the slotted electrode 26a so that the ions are focused onto that second region. Different DC voltages may be applied to the other discrete regions 60,64 such that fewer ions, or substantially no ions, strike those other discrete regions during the second duration.

Similarly, after some time, it may be desired to cause the filtered ions to strike a third of the discrete regions 64 and not to strike the first and second discrete regions 60,62. At this time, the third region 64 may be electrically biased with a DC voltage so as to form a DC potential difference between the third region and the slotted electrode 26a so that the ions are focused onto that third region. Different DC voltages may be applied to the other discrete regions 60,62 such that fewer ions, or substantially no ions, strike those other discrete regions.

The provision of such discrete impact regions 60-64 may be useful for a number of reasons. For example, as described above, it may be desired to direct the filtered ions to different regions of the collector electrode 36 at different times so as to prevent excessive charge building up in any particular region.

The collector electrode 36 may be connected to charge detection circuitry 66 that is configured to determine the electric charge on the discrete region 60-64 to which the filtered ions are being directed to, and if the determined charge reaches a threshold level then the mass filter may switch the voltages that are applied to the discrete regions 60-64 such that the filtered ions are directed to a different one of the discrete regions 60-64. The electric charge on that different discrete region may also be monitored and if it reaches a threshold level then the mass filter may switch the voltages that are applied to the discrete regions 60-64 again such that the filtered ions are directed to another one of the discrete regions 60-64.

Alternatively, or additionally, to the charge detection techniques, the spectrometer may be configured to switch the voltages that are applied to the discrete regions 60-64 such that the filtered ions are directed to each of the discrete regions for a maximum pre-selected amount of time.

Another benefit of using multiple discrete electrically conductive regions is that one region 60-64 may be used to detect and analyse the ion signal for the filtered ions and another of the regions may simply be a non-detecting region that receives the filtered ions. This allows, for example, the filtered ions to be generally directed onto the non-detecting

region, but from time to time for ions to be instead directed onto the detecting region for analysis of the ion signal for the filtered ions. The ions may be directed onto the detecting region for a smaller proportion of time than they are directed onto the non-detecting region, enabling the detecting region to remain relatively clean and therefore accurate at detecting the ion signal.

For example, the detecting region may be connected to ion current or electric charge detection circuitry 66 that detects an ion current or electric charge at that detecting region due to the filtered ions striking the detecting region. The detected current or charge may be used to determine the ion strike rate at the collection electrode, e.g. in order to determine the rate of contamination and hence the remaining operational lifetime before the non-detecting region of the collector electrode should be cleaned or replaced. For example, the mass spectrometer may compare the ion current or charge that is detected with calibration data that relates values of ion current or charge to remaining operational lifetimes for the non-detecting region. The spectrometer may display the remaining operational lifetime and/or be configured to provide an alert indicating that the operational lifetime has ended and the collector electrode should be replaced or cleaned.

Alternatively, or additionally, the ion current or charge that is detected may be used to determine the operational lifetime of one or more component of the spectrometer that is downstream (or even upstream) of the mass filter, since the detected current or charge is related to the ion flux passing through the spectrometer and hence the rate of contamination of components downstream (or upstream) of the mass filter. The ion current or charge that is detected may be compared with calibration data that relates values of ion current or charge to remaining operational lifetimes of a component downstream (or upstream) of the mass filter, such as an apertured component through which the ions pass or an ion-optical component such as an ion lens, a further mass filter or an ion guide. The spectrometer may display the remaining operational lifetime of the component and/or be configured to provide an alert indicating that the operational lifetime has ended and the component should be replaced or cleaned.

Although three regions 60-64 have been described, it will be appreciated that only two, or more than three, regions may be provided instead. It will also be appreciated that the operational lifetime monitoring system described herein may be used in embodiments in which the collector electrode has only a single detection region.

Fig. 7 shows a portion of one of the collector electrodes 36 according to an embodiment in which the surface of the collector electrode that the filtered ions strike has a three-dimensional profile, rather than being flat. In the depicted embodiment, the surface of the collector electrode that faces the slotted electrode has a ridge 70 pointing towards the slotted electrode 26a. The ridge preferably extends longitudinally along the collector electrode, parallel to the slot 34 in the slotted electrode. The peak of the ridge is preferably located so as to be aligned with the centre of the slot (in the width direction of the slot, i.e. orthogonal to the length of the slot). The surface of the collector electrode may therefore be tapered such that its distance from the slotted electrode 26a increases as a function of distance away from the ridge 70 in the width dimension of the slot 34. Such a ridged profile

of the collector electrode may enhance the ion focusing and attractive properties of the collector electrode.

Although the ridge 70 is shown as having the same height and shape along the length of the collector electrode 36, it is contemplated that the height of the ridge may vary  
5 as a function of length along the collector electrode, e.g. so that the electric field between the collector electrode and slotted electrode varies as a function of the length.

The surface of the collector electrode facing the slotted electrode 26a is shown as gradually and continuously tapering from the ridge. However, it is contemplated that the surface may vary in other manners.

10 Fig. 8 shows a portion of one of the collector electrodes 36 according to an embodiment in which at least part of the surface of the collector electrode that faces the slotted electrode has a modified surface 80 such that it is easier for an operator to see contamination on that surface due to being hit by the filtered ions than it would be without the modified surface. This may help the operator determine that the filtered ions are  
15 striking the collector electrode and also when the collector electrode needs to be cleaned or replaced. The at least part of the surface that is modified 80 may be a discrete portion of the surface that faces the slotted electrode 26a that is arranged adjacent to the slot 34. For example, the topography of part of the surface 80 facing the slotted electrode may be modified, e.g. so as to have a different texture, profile, or adhesion characteristics to the  
20 other parts of the surface facing the slotted electrode. It is contemplated that said at least part of the surface may be modified so as to be less reflective to visible light. For instance, the at least part of the surface may be etched or coated so as to reduce its reflectivity of visible light.

Embodiments are contemplated in which a collector electrode is a plate that is  
25 removably mounted to a supporting member, or the collector electrode comprises an electrically conductive plate arranged to face the slot and that is removably mounted on the remainder of the collector electrode. In such an embodiment, the plate may be removed from the mass filter so as to analyse the contamination thereon due to the filtered ions striking the plate. For example, the contamination may be analysed using a surface  
30 analysis technique such as scanning electron microscopy (SEM) or a mass spectrometry technique such as matrix assisted laser desorption ionisation (MALDI). It will be appreciated that the provision of such a plate enables such analysis to be performed easily. The plate may be rigid or flexible.

Fig. 9 shows a portion of one of the collector electrodes 36 according to an  
35 embodiment in which the collector electrode comprises a stack of conductive peel strips 90 arranged on the collector electrode so as to receive the filtered ions from the slotted electrode 26a. The stack 90 may be arranged on a main body 92 of the collector electrode and may be configured such that applying a voltage to the main body of the collector electrode transmits that voltage to all of the peel strips. For example, the plurality of peel  
40 strips in the stack may be adhered to each other, and optionally to the main body of the collector electrode, using an electrically conductive adhesive. During use of the mass filter filtered ions will strike the outermost peel strip 94 in the stack of peel strips and so

contamination will build up thereon. The outermost peel strip 94 may be subsequently removed from the stack so as to reveal a clean, uncontaminated peel strip 96. For example, if a conductive adhesive is used to adhere the peel strips together in the stack then the adhesive is provided with a level of adhesion such that the outermost peel strip  
5 may be removed manually from the remainder of the stack. This process may be repeated each time that it is desired to remove the contaminated surface of the collector electrode. It is contemplated that the peel strips may be flexible, such as a conductive tape, or they may be rigid plates.

Fig. 10 shows a portion of the mass filter in an embodiment in which each collector  
10 electrode 36 can be rotated such that different surfaces of the collector electrode can be arranged to face the slotted electrode 26a at different respective times. Only some of the electrodes 26a, 26b, 36 of the mass filter are shown, although it will be appreciated that the mass filter of this embodiment also comprises the other electrodes described in relation to Figs. 4A-4D. The collector electrode 36 may be configured so that it can be removed from  
15 the structural support 38 (e.g. as described in relation to Fig. 4D) and replaced in the structural support with a different surface of the collector electrode facing the slotted electrode 26a. For example, if the collector electrode has a rectangular cross-sectional profile, as shown in Fig. 10, then it may be rotated one or more times such that up to four  
20 different surfaces of the collector electrode are able to be arranged to face the slotted electrode. However, it is contemplated that the collector electrode may have other cross-sectional shapes so as to provide fewer or a greater number of surfaces that can be arranged to face the slotted electrode. For example, the collector electrode may have at least three, at least five, or at least six surfaces that may be arranged to face the slotted electrode.

It is contemplated that the collector electrode may be mounted within the mass filter  
25 by one or more structural support 38 that is configured such that the collector electrode may be rotated so that different faces of the collector electrode face the slotted electrode, without having to deconstruct the mass filter and remove the collector electrode. For example, the collector electrode may be mounted on a pivoting member of the structural  
30 support such that it may be rotated. The pivoting member may be slidably mounted within the structural support so that the collector electrode may be moved away from the slotted electrode in order to provide space to rotate the collector electrode. The structural support may also comprise a locking mechanism 100 for releasably locking the collector electrode in a plurality of positions in which the different surfaces face the slotted electrode.

35 Although the collector electrode has been described as being rotated in order to expose different ones of its surfaces to the slotted electrode, it is alternatively contemplated that the collector electrode may be slid vertically and/or horizontally relative to the slotted electrode such that different portions of the same surface of the collector electrode are arranged adjacent the slot at different respective times.

40 Additionally, or alternatively, to the collector electrode being rotatable and/or slidable in the manners described above, it is contemplated that the structural support 38 may enable the collector electrode to be moved towards and away from the slotted

electrode 26a, and optionally fixed at a plurality of different distances from the slotted electrode.

It is contemplated that the mass filter described herein may be used to filter out ions that would otherwise strike and contaminate components of the mass spectrometer that are downstream of the mass filter. For example, the mass filter described herein may be a sacrificial mass filter that is arranged to protect a downstream component, such as an apertured component through which the ions pass or an ion-optical component such as an ion lens, a further mass filter or an ion guide. As such, the mass filter described herein may be a bandpass mass filter having a mass transmission window, at any given time, that is capable of simultaneously transmitting multiple species of ions. For example, the mass transmission window may have a width of  $\geq 50$  Da,  $\geq 100$  Da,  $\geq 150$  Da, or  $\geq 200$  Da, although other widths of mass transmission window are also contemplated.

The mass filter described herein may be provided in a relatively high pressure region of the spectrometer, e.g. at a relatively upstream region such that it can perform prefiltering of the ions so as to protect downstream components. For example, the mass filter may be at a pressure of  $\geq 10^{-4}$  mbar, such as between  $10^{-2}$  mbar and  $10^{-3}$  mbar. However, it is contemplated that the mass filter may be used at lower pressures.

Although the present invention has been described with reference to 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.

For example, embodiments have been described herein in relation to different Figures, but it is contemplated that the features from the various embodiments may be combined.

Although embodiments have been described in which each of the first pair of electrodes 26a has a gap/slot 34 through it, it is contemplated that only one of these electrodes may have a slot. Alternatively, or additionally, one or more of the second pair of electrodes 26b may have a gap/slot through which ions may be ejected, and a collector electrode may be provided behind such a slot. This allows, for example, the DC voltages applied to the first and second pairs of electrodes to be switched such that the ions that are filtered out pass through one or more slots in the second pair of electrodes, rather than passing through slots in the first pair of electrodes.

The embodiments described thus far have a slot formed as a slotted aperture within an electrode, i.e. the slot is entirely encircled by the electrode that it is located within. However, it is contemplated that each slot may not be entirely encircled by electrode material. For example, the slot may extend to the perimeter of the electrode that it is within. For instance, the slot may extend parallel to the central axis of the mass filter and a first end of the slot may extend to the upstream end of the electrode.

It is alternatively contemplated that each slot may be formed between two or more separate electrode portions, rather than being defined within an electrode. For example, two electrodes portions may be spaced apart so as to form the slot therebetween. The

electrodes portions may be connected to the same voltage supplies, and optionally to each other, such that they act as a single electrode.

Although mass filters have been described in which the electrodes extend substantially the whole length of the mass filter, it is contemplated that at least some of the electrodes may be axially segmented. For example, the first pair of electrodes 26a and and/or second pair of electrodes 26b may be axially segmented and different DC and/or RF voltages may be applied to different axial segments, e.g. such that ions are urged axially through the mass filter. This allows the mass transmission window to be switched or scanned through different mass ranges more quickly, for example. Additionally, or alternatively, the collector electrodes may be axially segmented and different DC and/or RF voltages may be applied to the different axial segments.

Embodiments have been described in which the mass filtering electrodes 26a,26b are rectilinear. For example, at least the radially inner surface of each of the first and second pairs of electrodes may be a substantially flat, planar surface. The surfaces of the collector electrodes that receive the filtered ions may also be substantially flat, planar surfaces. However, the present invention is not limited to such electrodes. For instance, the electrodes of the first and/or second pairs of electrodes 26a,26b may have a cross-sectional shape, in the plane orthogonal to the central axis, that is circular, hyperbolic, c-shaped, plate-like or any other shape.

Although embodiments have been described in which the mass filter is a quadrupole mass filter, the invention may extend to other types of mass filter.

Claims

- 5     1.     A mass filter comprising:  
         a plurality of mass filtering electrodes for mass filtering ions passing therethrough,  
         wherein at least a first of these electrodes comprises a first gap therethrough;  
         voltage supplies arranged and configured to apply voltages to the mass filtering  
         electrodes such that ions having mass to charge ratios within a mass transmission window  
10     are confined by the electrodes and are transmitted through the mass filter, whereas at least  
         some ions having mass to charge ratios outside of said mass transmission window are  
         unstable and pass through the first gap such that they are filtered out by the mass filter;  
         and  
         a first collector electrode arranged so as to receive the ions that are transmitted  
15     through the first gap, wherein the voltage supplies apply a DC potential difference between  
         said first mass filtering electrode and said first collector electrode so as to urge the ions  
         that are transmitted through the first gap onto the first collector electrode.
- 20     2.     The mass filter of claim 1, wherein the mass filter is a quadrupole mass filter.
3.     The mass filter of claim 1 or 2, wherein a second of the mass filtering electrodes  
         that is arranged opposite to said first mass filtering electrode comprises a second gap  
         therethrough; wherein the voltage supplies are arranged and configured to apply said  
         voltages to the mass filtering electrodes such that ions having mass to charge ratios  
25     outside of said mass transmission window are unstable and pass through the second gap;  
         and wherein the mass filter comprises a second collector electrode arranged so as to  
         receive the ions that are transmitted through the second gap.
- 30     4.     The mass filter of claim 3, wherein the voltage supplies are configured to: (i) apply a  
         first DC voltage to the first and second mass filtering electrodes; (ii) apply a second DC  
         voltage of the opposite polarity to two other opposing mass filtering electrodes; and (iii)  
         apply a DC voltage to the first and second collector electrodes that is the same polarity as  
         the first DC voltage but a greater magnitude.
- 35     5.     The mass filter of claim 3 or 4, wherein the voltage supplies are configured to: (i)  
         apply a first phase of an RF voltage to the first and second mass filtering electrodes; (ii)  
         apply a second different phase of the RF voltage to two other opposing mass filtering  
         electrodes; and (iii) apply the first phase of the RF voltage to the first and second collector  
         electrodes.
- 40     6.     The mass filter of any preceding claim, wherein a RF voltage is applied to the first  
         and/or second collector electrode.

7. The mass filter of any preceding claim, wherein each of the first and/or second collector electrodes comprises multiple electrically conductive regions and the voltage supplies are configured to apply different voltages to the different electrically conductive regions so as to urge the filtered ions onto at least one of said electrically conductive regions.
8. The mass filter of claim 7, wherein the voltage supplies are configured to: (i) operate in a first mode in which a first voltage is applied to a first of the electrically conductive regions and one or more different voltage is applied to one or more other electrically conductive region such that substantially all, or a majority, of the ions that strike the collector electrode strike the first electrically conductive region; and (ii) operate in a second mode in which a voltage is applied to a second of the electrically conductive regions and one or more different voltage is applied to one or more other electrically conductive region such that substantially all, or a majority, of the ions that strike the collector electrode strike the second electrically conductive region.
9. The mass filter of claim 8, comprising charge detection circuitry configured to detect the electric charge on the first electrically conductive region during the first mode and to switch the mass filter to the second mode when the detected charge reaches a threshold level.
10. The mass filter of claim 8 or 9, wherein the mass filter is configured to switch from the first mode to the second mode after a maximum pre-selected amount of time of operating in the first mode.
11. The mass filter of claim 8, comprising charge or current detection circuitry configured to detect the electric charge or current on the second electrically conductive region during the second mode; wherein the mass filter is configured, in the second mode, to determine the remaining operational lifetime of the collector electrode based on the charge or ion current detected at the second electrically conductive region, and then switch to the first mode.
12. The mass filter of any preceding claim, wherein the surface of the first collector electrode that faces the first gap comprises a ridge pointing towards the first gap; and/or the surface of the second collector electrode that faces the second gap comprises a ridge pointing towards the second gap.
13. The mass filter of any preceding claim, wherein at least part of the surface of the first and/or second collector electrode that faces the first and/or second gap, respectively, has a modified surface such that it is easier for an operator to see contamination on that surface due to it being hit by the ions than it would be without the modified surface.

14. The mass filter of claim 13, wherein said at least part of the surface has been modified relative to other parts of the collector electrode so as to have a different topology and/or be less reflective to visible light, such as by being etched or coated.
- 5 15. The mass filter of any preceding claim, wherein the first and/or second collector electrode is, or comprises, an electrically conductive plate arranged to face the first and/or second gap, respectively.
- 10 16. The mass filter of any preceding claim, wherein each of the first and/or second collector electrodes comprises a stack of electrically conductive peel strips arranged so as to receive the ions that pass through the first and/or second gap respectively.
- 15 17. The mass filter of claim 16, wherein the peel strips in each stack are adhered to each other, and optionally to a main body of the collector electrode, using an electrically conductive adhesive.
- 20 18. The mass filter of any preceding claim, comprising one or more structural support configured to mount the first and/or second collector electrode to the mass filtering electrodes so that the first and/or second collector electrode is located adjacent to the first and/or second gap, respectively.
- 25 19. The mass filter of claim 18, wherein the one or more structural support is configured to releasably mount the first and/or second collector electrode in a plurality or different orientations or locations relative to the mass filtering electrodes such that each collector electrode is: (i) rotatable so that different surfaces of the collector electrode receive the ions from the gap at different respective times; and/or (ii) movable so that different portions of the same surface on the collector electrode receives the ions from the gap at different respective times.
- 30 20. The mass filter of any preceding claim, wherein the first gap is a slot through the first mass filtering electrode and/or the second gap is a slot through the second mass filtering electrode.
- 35 21. A mass filter comprising:  
a plurality of mass filtering electrodes for mass filtering ions passing therethrough, wherein at least a first of these electrodes comprises a first gap therethrough;  
voltage supplies arranged and configured to apply voltages to the mass filtering electrodes such that ions having mass to charge ratios within a mass transmission window  
40 are confined by the electrodes and are transmitted through the mass filter, whereas at least some of the ions having mass to charge ratios outside of said mass transmission window

are unstable and pass through the first gap such that they are filtered out by the mass filter;  
and

a first collector electrode arranged so as to receive the ions that are transmitted  
through the first gap.

5

22. A mass and/or ion mobility spectrometer comprising a mass filter as claimed in any  
preceding claim, further comprising a detector or analyser for detecting or analysing ions  
within the mass transmission window that are transmitted by the mass filter, or ions derived  
therefrom.

10

23. The spectrometer of claim 22, wherein the mass filter is a bandpass mass filter that  
filters out ions that would otherwise strike a component of the spectrometer downstream of  
the mass filter; and/or

wherein the mass filter is maintained at a pressure of  $\geq 10^{-4}$  mbar.

15

24. A method of mass filtering ions comprising:

providing a mass filter as claimed in any one of claims 1-21;

applying said voltages to the mass filter so that the mass filter transmits only ions  
having mass to charge ratios within the mass transmission window and filters out ions

20 having mass to charge ratios outside the mass transmission window, wherein at least  
some of the ions that are filtered out pass through the first and/or second gap and onto the  
first and/or second collection electrode respectively.

25. A method of mass and/or ion mobility spectrometry comprising a method as

25 claimed in claim 24, further comprising detecting and/or mass analysing and/or ion mobility  
analysing ions transmitted by the mass filter, or ions derived therefrom.