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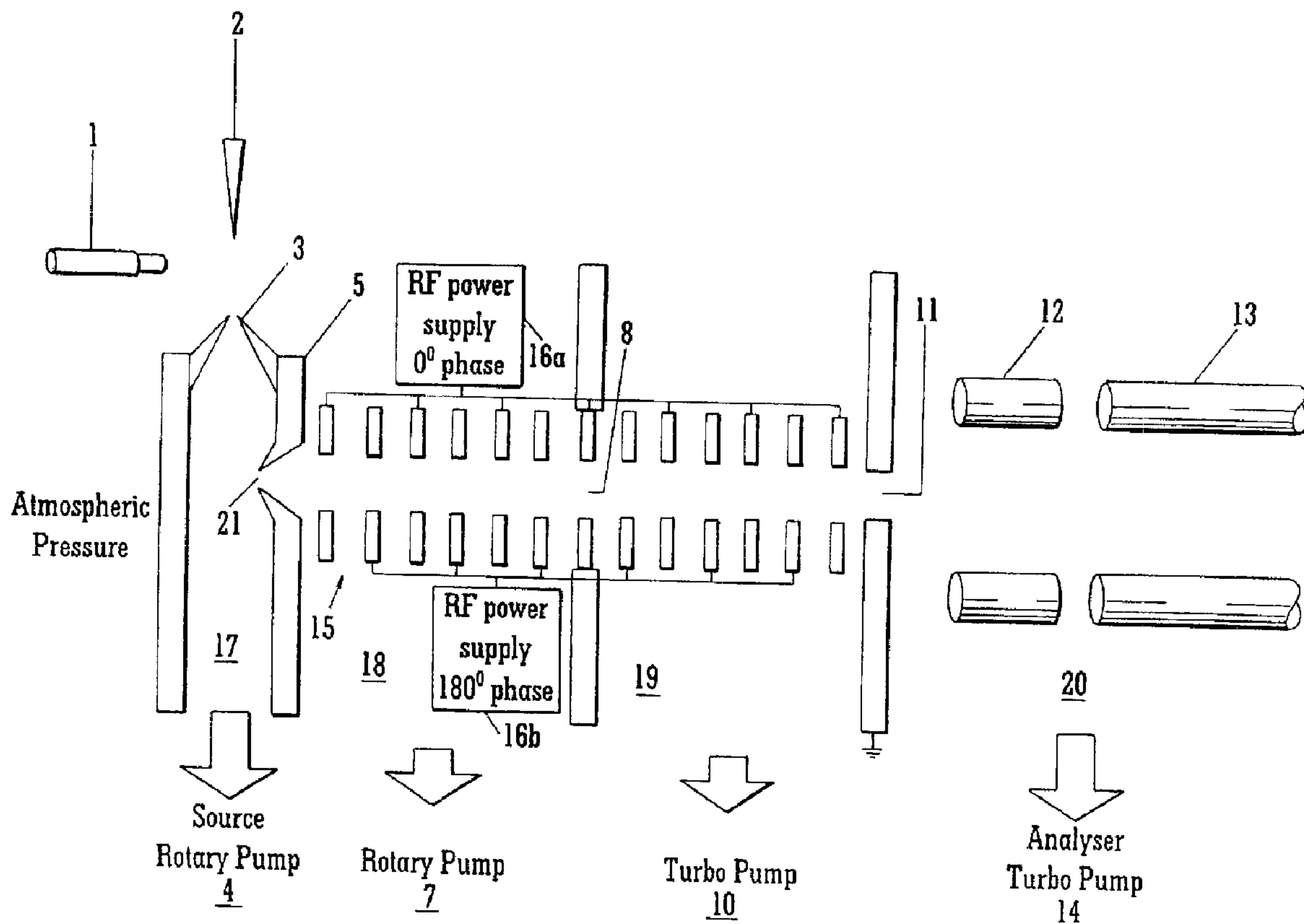
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(57) Abrégé/Abstract:

A mass spectrometer is disclosed comprising an ion guide 15 which spans two or more vacuum chambers 18,19. The ion guide 15 comprises a plurality of electrodes having apertures. Preferably, one of the electrodes 8 may also form the differential pumping aperture which separates two vacuum chambers 18,19.

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ABSTRACT

MASS SPECTROMETERS AND METHODS OF MASS SPECTROMETRY

5 A mass spectrometer is disclosed comprising an ion
guide 15 which spans two or more vacuum chambers 18,19.
The ion guide 15 comprises a plurality of electrodes
having apertures. Preferably, one of the electrodes 8
may also form the differential pumping aperture which
10 separates two vacuum chambers 18,19.

[Fig. 2]

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MASS SPECTROMETERS AND METHODS OF MASS SPECTROMETRY

5 The present invention relates to mass spectrometers and methods of mass spectrometry.

 Ion guides comprising rf-only multipole rod sets such as quadrupoles, hexapoles and octopoles are well known.

10 Whitehouse and co-workers have disclosed in WO98/06481 and WO99/62101 an arrangement wherein a multipole rod set ion guide extends between two vacuum chambers. However, as will be appreciated by those skilled in the art, since each rod in a multipole rod set has a typical diameter of around 5 mm, and a space must be provided between opposed rods in order for there to be an ion guiding region, then the interchamber aperture when using such an arrangement is correspondingly very large (i.e. > 15 mm in diameter) with a corresponding cross sectional area > 150 mm². Such large interchamber apertures drastically reduce the effectiveness of the vacuum pumps which are most effective when the interchamber orifice is as small as possible (i.e. only a few millimetres in diameter).

25 It is therefore desired to provide an improved interchamber ion guide.

 According to a first aspect of the present invention, there is provided a mass spectrometer as claimed in claim 1.

30 Conventional arrangements typically provide two discrete multipole ion guides in adjacent vacuum chambers with a differential pumping aperture therebetween. Such an arrangement suffers from a disruption to the rf field near the end of a multipole rod set and other end effects. However, according to the preferred embodiment of the present invention, the ions do not leave the ion guide as they pass from one

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vacuum chamber to another. Accordingly, end effect problems are effectively eliminated thereby resulting in improved ion transmission.

5 An ion guide comprised of electrodes having apertures may take two main different forms. In a first form all the internal apertures of the electrodes are substantially the same size. Such an arrangement is known as an "ion tunnel". However, a second form referred to as an "ion funnel" is known wherein the
10 electrodes have internal apertures which become progressively smaller in size. Both forms are intended to fall within the scope of the present invention. The apertured electrodes in either case may comprise ring or annular electrodes. The inner circumference of the
15 electrodes is preferably substantially circular. However, the outer circumference of the electrodes does not need to be circular and embodiments of the present invention are contemplated wherein the outer profile of the electrodes takes on other shapes.

20 The preferred embodiment of the present invention uses an ion tunnel ion guide and it has been found that an ion tunnel ion guide exhibits an approximately 25-75% improvement in ion transmission efficiency compared with a conventional multipole, e.g. hexapole, ion guide of
25 comparable length. The reasons for this enhanced ion transmission efficiency are not fully understood, but it is thought that the ion tunnel may have a greater acceptance angle and a greater acceptance area than a comparable multipole rod set ion guide.

30 Accordingly, one advantage of the preferred embodiment is an improvement in ion transmission efficiency.

Although an ion tunnel ion guide is preferred, according to a less preferred embodiment, the inter-
35 vacuum chamber ion guide may comprise an ion funnel. In order to act as an ion guide, a dc potential gradient is applied along the length of the ion funnel in order to

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urge ions through the progressively smaller internal apertures of the electrodes. The ion funnel is believed however to suffer from a narrow mass to charge ratio bandpass transmission efficiency. Such problems are not
5 found when using an ion tunnel ion guide.

Various types of other ion optical devices are also known including multipole rod sets, Einzel lenses, segmented multipoles, short (solid) quadrupole pre/post filter lenses ("stubbies"), 3D quadrupole ion traps
10 comprising a central doughnut shaped electrode together with two concave end cap electrodes, and linear (2D) quadrupole ion traps comprising a multipole rod set with entrance and exit ring electrodes. However, such devices are not intended to fall within the scope of the
15 present invention.

According to a particularly preferred feature of the present invention, one of the electrodes forming the ion guide may form or constitute a differential pumping aperture between two vacuum chambers. Such an
20 arrangement is particularly advantageous since it allows the interchamber orifice to be much smaller than that which would be provided if a multipole rod set ion guide were used. A smaller interchamber orifice allows the vacuum pumps pumping each vacuum chamber to operate more
25 efficiently.

The electrode forming the differential pumping aperture may either have an internal aperture of different size (e.g. smaller) than the other electrodes forming the ion guide or may have the same sized
30 internal aperture. The electrode forming the differential pumping aperture and/or the other electrodes may have an internal diameter selected from the group comprising: (i) 0.5-1.5 mm; (ii) 1.5-2.5 mm; (iii) 2.5-3.5 mm; (iv) 3.5-4.5 mm; (v) 4.5-5.5 mm; (vi)
35 5.5-6.5 mm; (vii) 6.5-7.5 mm; (viii) 7.5-8.5 mm; (ix) 8.5-9.5 mm; (x) 9.5-10.5 mm; (xi) ≤ 10.0 mm; (xii) ≤ 9.0 mm; (xiii) ≤ 8.0 mm; (xiv) ≤ 7.0 mm; (xv) ≤ 6.0 mm;

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(xvi) ≤ 5.0 mm; (xvii) ≤ 4.0 mm; (xviii) ≤ 3.0 mm; (xix) ≤ 2.0 mm; (xx) ≤ 1.0 mm; (xxi) 0-2 mm; (xxii) 2-4 mm; (xxiii) 4-6 mm; (xxiv) 6-8 mm; and (xxv) 8-10 mm.

5 The differential pumping aperture may have an area selected from the group comprising: (i) ≤ 40 mm²; (ii) ≤ 35 mm²; (iii) ≤ 30 mm²; (iv) ≤ 25 mm²; (v) ≤ 20 mm²; (vi) ≤ 15 mm²; (vii) ≤ 10 mm²; and (viii) ≤ 5 mm². The area of the differential pumping aperture may therefore be more than an order of magnitude smaller than the area of
10 the differential pumping aperture inherent with using a multipole ion guide to extend between two vacuum regions.

The ion guide may comprise at least 4, 5, 6, 7, 8, 9, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120,
15 130, 140, 150, 160, 170, 180, 190 or 200 electrodes. At least 90%, preferably 100% of the electrodes may be arranged and adapted to be maintained at substantially the same dc reference potential upon which an AC voltage is superimposed.

20 According to the preferred embodiment, when the ion guide extends between two vacuum chambers, the pressure in the upstream vacuum chamber may, preferably, be: (i) ≥ 0.5 mbar; (ii) ≥ 0.7 mbar; (iii) ≥ 1.0 mbar; (iv) ≥ 1.3 mbar; (v) ≥ 1.5 mbar; (vi) ≥ 2.0 mbar; (vii) ≥ 5.0 mbar; (viii) ≥ 10.0 mbar; (ix) 1-5 mbar; (x) 1-2 mbar;
25 or (xi) 0.5-1.5 mbar. Preferably, the pressure is less than 30 mbar and further preferably less than 20 mbar. The pressure in the downstream vacuum chamber may, preferably, be: (i) 10^{-3} - 10^{-2} mbar; (ii) $\geq 2 \times 10^{-3}$ mbar;
30 (iii) $\geq 5 \times 10^{-3}$ mbar; (iv) $\leq 10^{-2}$ mbar; (v) 10^{-3} - 5×10^{-3} mbar; or (vi) 5×10^{-3} - 10^{-2} mbar.

At least a majority, preferably all, of the electrodes forming the ion guide may have apertures having internal diameters or dimensions: (i) ≤ 5.0 mm;
35 (ii) ≤ 4.5 mm; (iii) ≤ 4.0 mm; (iv) ≤ 3.5 mm; (v) ≤ 3.0 mm; (vi) ≤ 2.5 mm; (vii) 3.0 ± 0.5 mm; (viii) ≤ 10.0 mm; (ix) ≤ 9.0 mm; (x) ≤ 8.0 mm; (xi) ≤ 7.0 mm; (xii) ≤ 6.0

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mm; (xiii) 5.0 ± 0.5 mm; or (xiv) 4-6 mm.

The length of the ion guide may be: (i) ≥ 100 mm; (ii) ≥ 120 mm; (iii) ≥ 150 mm; (iv) 130 ± 10 mm; (v) 100-150 mm; (vi) ≤ 160 mm; (vii) ≤ 180 mm; (viii) ≤ 200 mm; (ix) 130-150 mm; (x) 120-180 mm; (xi) 120-140 mm; (xii) $130 \text{ mm} \pm 5, 10, 15, 20, 25 \text{ or } 30$ mm; (xiii) 50-300 mm; (xiv) 150-300 mm; (xv) ≥ 50 mm; (xvi) 50-100 mm; (xvii) 60-90 mm; (xviii) ≥ 75 mm; (xix) 50-75 mm; (xx) 75-100 mm; (xxi) approx. 26 cm; (xxii) 24-28 cm; (xxiii) 20-30 cm; or (xxiv) > 30 cm.

According to a preferred embodiment, the ion source is an atmospheric pressure ion source such as an Electrospray ("ES") ion source or an Atmospheric Pressure Chemical Ionisation ("APCI") ion source.

According to an alternative embodiment, the ion source may be a Matrix Assisted Laser Desorption Ionisation ("MALDI") ion source or an Inductively Coupled Plasma ("ICP") ion source. The MALDI ion source may be either an atmospheric source or a low vacuum source.

According to a preferred embodiment, the ion source is a continuous ion source.

The mass spectrometer preferably comprises either a time-of-flight mass analyser, preferably an orthogonal time of flight mass analyser, a quadrupole mass analyser or a quadrupole ion trap.

According to a second aspect of the present invention, there is provided a mass spectrometer as claimed in claim 21.

Preferably, an electrode of the ion guide forms a differential pumping aperture between the input and intermediate vacuum chambers.

Preferably, the mass spectrometer comprises means for supplying an AC-voltage to the electrodes. Preferably, an AC generator is provided which is connected to the electrodes in such a way that at any instant during an AC cycle of the output of the AC generator, adjacent ones of the electrodes forming the

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AC-only ion guide are supplied respectively with approximately equal positive and negative potentials relative to a reference potential.

5 In one embodiment the AC power supply may be an RF power supply. However, the present invention is not intended to be limited to RF frequencies. Furthermore, "AC" is intended to mean simply that the waveform alternates and hence embodiments of the present invention are also contemplated wherein non-sinusoidal
10 waveforms including square waves are supplied to the ion guide.

According to a third aspect of the present invention, there is provided a mass spectrometer as claimed in claim 24.

15 Preferably, at least 5, 10, 15, 20, 25, 30, 35, 40, 45, 50 or 100 of the electrodes are disposed in one or both vacuum chambers.

According to a fourth aspect of the present invention, there is provided a mass spectrometer as
20 claimed in claim 29.

According to a fifth aspect of the present invention, there is provided a mass spectrometer as claimed in claim 30.

25 Preferably, a differential pumping aperture between the vacuum chambers is formed by an electrode of the ion guide, the differential pumping aperture having an area $\leq 20 \text{ mm}^2$, preferably $\leq 15 \text{ mm}^2$, further preferably $\leq 10 \text{ mm}^2$.

30 According to a sixth aspect of the present invention, there is provided a mass spectrometer as claimed in claim 32.

According to a seventh aspect of the present invention, there is provided a mass spectrometer as claimed in claim 33.

35 According to a eighth aspect of the present invention, there is provided a mass spectrometer as claimed in claim 34.

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According to this embodiment a substantially continuous ion tunnel ion guide may be provided which extends through two, three, four or more vacuum chambers. Also, instead of each vacuum chamber being
5 separately pumped, a single split flow vacuum pump may preferably be used to pump each chamber.

According to a ninth aspect of the present invention, there is provided a method of mass spectrometry as claimed in claim 35.

10 According to a tenth aspect of the present invention, there is provided a method of mass spectrometry as claimed in claim 36.

According to an eleventh aspect of the present invention, there is provided a mass spectrometer as
15 claimed in claim 37.

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 an ion tunnel ion guide; and
20 Fig. 2 shows a preferred arrangement.

As shown in Fig. 1, an ion tunnel 15 comprises a plurality of electrodes 15a,15b having apertures. Adjacent electrodes 15a,15b are connected to different phases of an AC power supply which may in one embodiment
25 be an RF power supply. For example, the first, third, fifth etc. electrodes 15a may be connected to the 0° phase supply 16a, and the second, fourth, sixth etc. electrodes 15b may be connected to the 180° phase supply 16b. Ions from an ion source pass through the ion
30 tunnel 15 and are efficiently transmitted by it. In contrast to an ion funnel arrangement, preferably all of the electrodes 15a,15b are maintained at substantially the same dc reference potential about which an AC voltage is superimposed. Unlike ion traps, blocking dc
35 potentials are not applied to either the entrance or exit of the ion tunnel 15.

Fig. 2 shows a preferred embodiment of the present

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invention. An Electrospray ("ES") ion source 1 or an Atmospheric Pressure Chemical Ionisation ("APCI") ion source 1 (which requires a corona pin 2) emits ions which enter a vacuum chamber 17 via a sample cone 3.

5 Vacuum chamber 17 is pumped by a rotary or mechanical pump 4. A portion of the gas and ions pass through a differential pumping aperture 21 with the plate surrounding the aperture being preferably maintained at 50-120V into a vacuum chamber 18 housing an ion tunnel

10 ion guide 15 which extends into another vacuum chamber 19. Vacuum chamber 18 is pumped by a rotary or mechanical pump 7. Ions are transmitted by the ion guide 15 through the vacuum chamber 18 and pass, without exiting the ion guide 15, through another differential

15 pumping aperture 8 formed by an electrode of the ion tunnel ion guide 15 into vacuum chamber 19 which is pumped by a turbo-molecular pump 10. Ions continue to be transmitted by the ion tunnel ion guide 15 through the vacuum chamber 19. The ions then leave the ion

20 guide 15 and pass through differential pumping aperture 11 into an analyser vacuum chamber 20 which is pumped by a turbo-molecular pump 14. Analyser vacuum chamber 20 houses a prefilter rod set 12, a quadrupole mass filter/analyser 13 and may include other elements such

25 as a collision cell (not shown), another quadrupole mass filter/analyser together with an ion detector (not shown) or a time of flight analyser (not shown).

An AC-voltage is applied to the electrodes and the ion tunnel 15 is preferably maintained at 0-2 V dc above

30 the dc potential of the plate forming the differential pumping aperture 11 which is preferably at ground (0 V dc). According to other embodiments, the plate forming the differential pumping aperture 11 may be maintained at other dc potentials.

35 The ion tunnel 15 is preferably about 26 cm long and in one embodiment comprises approximately 170 ring electrodes. Upstream vacuum chamber 18 is preferably

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maintained at a pressure ≥ 1 mbar, and downstream vacuum chamber 19 is preferably maintained at a pressure of 10^{-3} - 10^{-2} mbar. The ion guide 15 is preferably supplied with an AC-voltage at a frequency of between 1-2 MHz.

5 However, according to other embodiments, frequencies of 800kHz-3MHz may be used. The electrodes forming the ion tunnel 15 preferably have circular apertures which preferably have a diameter in the range of 3-5 mm.

Embodiments of the present invention are also
10 contemplated wherein electrodes of the ion tunnel in one vacuum chamber have a different peak AC voltage amplitude compared with electrodes of the same ion tunnel which are disposed in another vacuum chamber. For example, with reference to Fig. 2 the electrodes
15 disposed in chamber 18 may be coupled to the AC power supply 16a,16b via a capacitor but the electrodes disposed in chamber 19 may be directly coupled to the AC power supply 16a,16b. Accordingly, the electrodes disposed in chamber 19 may see a peak AC voltage of
20 500V, but the electrodes disposed in chamber 18 may see a peak AC voltage of 300V. The electrode which forms the differential pumping aperture 8 may be maintained at the AC voltage of either the electrodes in chamber 18 or the electrodes in chamber 19, or alternatively the
25 electrode may be maintained at a voltage which is different from the other electrodes.

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Claims

- 5 1. A mass spectrometer, comprising:
 an ion source;
 an input vacuum chamber;
 an analyser vacuum chamber comprising an ion mass
 analyser;
10 an intermediate vacuum chamber, said intermediate
 vacuum chamber being disposed between said input vacuum
 chamber and said analyser vacuum chamber; and
 an AC-only ion guide extending between said input
 vacuum chamber and said intermediate vacuum chamber;
15 wherein said AC-only ion guide comprises a
 plurality of electrodes having internal apertures.
2. A mass spectrometer as claimed in claim 1, wherein
 at least a majority of said electrodes have similar
20 sized internal apertures.
3. A mass spectrometer as claimed in claim 1, wherein
 at least a majority of said electrodes have internal
 apertures which become progressively smaller.
25
4. A mass spectrometer as claimed in claim 1, 2 or 3,
 wherein an electrode of said ion guide forms a
 differential pumping aperture between said input and
 said intermediate vacuum chambers.
30
5. A mass spectrometer as claimed in claim 4, wherein
 the electrode forming said differential pumping aperture
 has an internal diameter selected from the group
 comprising: (i) 0.5-1.5 mm; (ii) 1.5-2.5 mm; (iii) 2.5-
35 3.5 mm; (iv) 3.5-4.5 mm; (v) 4.5-5.5 mm; (vi) 5.5-6.5
 mm; (vii) 6.5-7.5 mm; (viii) 7.5-8.5 mm; (ix) 8.5-9.5
 mm; (x) 9.5-10.5 mm; (xi) $\leq$ 10.0 mm; (xii) $\leq$ 9.0 mm;
 (xiii) $\leq$ 8.0 mm; (xiv) $\leq$ 7.0 mm; (xv) $\leq$ 6.0 mm; (xvi) $\leq$

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5.0 mm; (xvii) $\leq$ 4.0 mm; (xviii) $\leq$ 3.0 mm; (xix) $\leq$ 2.0 mm; (xx) $\leq$ 1.0 mm; (xxi) 0-2 mm; (xxii) 2-4 mm; (xxiii) 4-6 mm; (xxiv) 6-8 mm; and (xxv) 8-10 mm.

5 6. A mass spectrometer as claimed in claim 4 or 5,
 wherein at least a majority of the electrodes apart from
 the electrode forming said differential pumping aperture
 have internal diameters selected from the group
 comprising: (i) 0.5-1.5 mm; (ii) 1.5-2.5 mm; (iii) 2.5-
10 3.5 mm; (iv) 3.5-4.5 mm; (v) 4.5-5.5 mm; (vi) 5.5-6.5
 mm; (vii) 6.5-7.5 mm; (viii) 7.5-8.5 mm; (ix) 8.5-9.5
 mm; (x) 9.5-10.5 mm; (xi) $\leq$ 10.0 mm; (xii) $\leq$ 9.0 mm;
 (xiii) $\leq$ 8.0 mm; (xiv) $\leq$ 7.0 mm; (xv) $\leq$ 6.0 mm; (xvi) $\leq$
 5.0 mm; (xvii) $\leq$ 4.0 mm; (xviii) $\leq$ 3.0 mm; (xix) $\leq$ 2.0
15 mm; (xx) $\leq$ 1.0 mm; (xxi) 0-2 mm; (xxii) 2-4 mm; (xxiii)
 4-6 mm; (xxiv) 6-8 mm; and (xxv) 8-10 mm.

 7. A mass spectrometer as claimed in claim 4, wherein
 the electrode forming said differential pumping aperture
20 has an internal aperture of different size to the other
 electrodes forming said ion guide.

 8. A mass spectrometer as claimed in claim 7, wherein
 the electrode forming said differential pumping aperture
25 has a smaller internal aperture than the other
 electrodes forming said ion guide.

 9. A mass spectrometer as claimed in claim 4, wherein
 the electrode forming said differential pumping aperture
30 has an internal aperture substantially the same size as
 the other electrodes forming said ion guide.

 10. A mass spectrometer as claimed in claim 4, wherein
 said differential pumping aperture has an area selected
35 from the group comprising: (i) $\leq$ 40 mm²; (ii) $\leq$ 35 mm²;
 (iii) $\leq$ 30 mm²; (iv) $\leq$ 25 mm²; (v) $\leq$ 20 mm²; (vi) $\leq$ 15
 mm²; (vii) $\leq$ 10 mm²; and (viii) $\leq$ 5 mm².

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11. A mass spectrometer as claimed in any of claims 1 to 10, wherein said ion guide comprises at least 4, 5, 6, 7, 8, 9, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120, 130, 140, 150, 160, 170, 180, 190 or 200 electrodes.

12. A mass spectrometer as claimed in any of claims 1 to 11, wherein the pressure in said input vacuum chamber is selected from the group comprising: (i) ≥ 0.5 mbar; (ii) ≥ 0.7 mbar; (iii) ≥ 1.0 mbar; (iv) ≥ 1.3 mbar; (v) ≥ 1.5 mbar; (vi) ≥ 2.0 mbar; (vii) ≥ 5.0 mbar; (viii) ≥ 10.0 mbar; (ix) 1-5 mbar; (x) 1-2 mbar; and (xi) 0.5-1.5 mbar.

13. A mass spectrometer as claimed in any of claims 1 to 12, wherein the pressure in said intermediate vacuum chamber is selected from the group comprising: (i) 10^{-3} - 10^{-2} mbar; (ii) $\geq 2 \times 10^{-3}$ mbar; (iii) $\geq 5 \times 10^{-3}$ mbar; (iv) $\leq 10^{-2}$ mbar; (v) 10^{-3} - 5×10^{-3} mbar; and (vi) 5×10^{-3} - 10^{-2} mbar.

14. A mass spectrometer as claimed in any of claims 1 to 13, wherein the length of said ion guide is selected from the group comprising: (i) ≥ 100 mm; (ii) ≥ 120 mm; (iii) ≥ 150 mm; (iv) 130 ± 10 mm; (v) 100-150 mm; (vi) ≤ 160 mm; (vii) ≤ 180 mm; (viii) ≤ 200 mm; (ix) 130-150 mm; (x) 120-180 mm; (xi) 120-140 mm; (xii) $130 \text{ mm} \pm 5, 10, 15, 20, 25 \text{ or } 30$ mm; (xiii) 50-300 mm; (xiv) 150-300 mm; (xv) ≥ 50 mm; (xvi) 50-100 mm; (xvii) 60-90 mm; (xviii) ≥ 75 mm; (xix) 50-75 mm; (xx) 75-100 mm; (xxi) approx. 26 cm; (xxii) 24-28 cm; (xxiii) 20-30 cm; and (xxiv) > 30 cm.

15. A mass spectrometer as claimed in any of claims 1 to 14, wherein said ion source is an atmospheric pressure ion source.

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16. A mass spectrometer as claimed in claim 15, wherein said ion source is an Electrospray ("ES") ion source or an Atmospheric Pressure Chemical Ionisation ("APCI") ion source.
- 5 17. A mass spectrometer as claimed in any of claims 1-14, wherein said ion source is a Matrix Assisted Laser Desorption Ionisation ("MALDI") ion source.
- 10 18. A mass spectrometer as claimed in claim 15, wherein said ion source is an Inductively Coupled Plasma ("ICP") ion source.
- 15 19. A mass spectrometer as claimed in any of claims 1 to 18, wherein said mass analyser is selected from the group comprising: (i) a time-of-flight mass analyser, preferably an orthogonal time of flight mass analyser; (ii) a quadrupole mass analyser; and (iii) a quadrupole ion trap.
- 20 20. A mass spectrometer as claimed in any of claims 1 to 19, wherein at least 90% of said plurality of electrodes are arranged to be maintained at substantially the same dc reference potential about which an AC voltage supplied to said electrodes is superimposed.
- 25 21. A mass spectrometer, comprising:
an input vacuum chamber;
30 an analyser vacuum chamber comprising a mass analyser; and
an intermediate vacuum chamber, said intermediate vacuum chamber being arranged between said input vacuum chamber and said analyser vacuum chamber;
- 35 wherein said mass spectrometer further comprises an AC-only ion guide comprising at least five electrodes having apertures, said ion guide extending from said input vacuum chamber through to said intermediate vacuum

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chamber.

22. A mass spectrometer as claimed in claim 21, wherein
an electrode of said ion guide forms a differential
5 pumping aperture between said input vacuum chamber and
said intermediate vacuum chamber.

23. A mass spectrometer as claimed in claim 21 or 22,
further comprising means for supplying an AC-voltage to
10 said electrodes.

24. A mass spectrometer, comprising:
an inter-vacuum chamber AC-only ion guide, said
inter-vacuum chamber ion guide being > 5 cm in length;
15 wherein said ion guide comprises a plurality of
electrodes having apertures.

25. A mass spectrometer as claimed in claim 24, wherein
said ion guide comprises at least 10, 20, 30, 40, 50,
20 60, 70, 80, 90, 100, 110, 120, 130, 140, 150, 160, 170,
180, 190 or 200 electrodes.

26. A mass spectrometer as claimed in claim 25, wherein
at least 5, 10, 15, 20, 25, 30, 35, 40, 45, 50 or 100 of
25 said electrodes are disposed in an input vacuum chamber.

27. A mass spectrometer as claimed in claim 26, wherein
at least 5, 10, 15, 20, 25, 30, 35, 40, 45 or 50 or 100
of said electrodes are disposed in an intermediate
30 vacuum chamber, said intermediate vacuum chamber being
arranged between said input vacuum chamber and an
analyser vacuum chamber comprising a mass analyser, said
input and intermediate vacuum chambers being separated
by an inter-chamber differential pumping aperture or
35 orifice.

28. A mass spectrometer as claimed in claim 27, wherein
an electrode of said ion guide forms said inter-chamber

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aperture or orifice.

29. A mass spectrometer comprising:

an ion source selected from the group comprising:

- 5 (i) an Electrospray ("ES") ion source; (ii) an Atmospheric Pressure Chemical Ionisation ("APCI") ion source; (iii) a Matrix Assisted Laser Desorption Ionisation ("MALDI") ion source; and (iv) an Inductively Coupled Plasma ("ICP") ion source;

10 an input vacuum chamber;

an intermediate vacuum chamber separated from the input vacuum chamber by a differential pumping aperture;

15 a mass analyser, preferably a time of flight or a quadrupole mass analyser disposed in an analyser vacuum chamber; and

an AC-only ion guide spanning said input and intermediate vacuum chambers;

20 wherein said ion guide comprises ≥ 10 electrodes having apertures, and wherein one of said electrodes forms said differential pumping aperture.

30. A mass spectrometer comprising:

25 an AC-only ion guide comprising a plurality of electrodes having apertures spanning two vacuum chambers, each said vacuum chamber comprising a vacuum pump for pumping gas from said vacuum chamber so as to produce a partial vacuum in said vacuum chamber.

30 31. A mass spectrometer as claimed in claim 30, wherein a differential pumping aperture between said vacuum chambers is formed by an electrode of said ion guide, said differential pumping aperture having an area $\leq 20 \text{ mm}^2$, preferably $\leq 15 \text{ mm}^2$, further preferably $\leq 10 \text{ mm}^2$.

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32. A mass spectrometer comprising:

an input vacuum chamber, said input vacuum chamber including a port connected to a vacuum pump;

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an intermediate vacuum chamber, said intermediate vacuum chamber including a port connected to another vacuum pump; and

an interchamber orifice or aperture separating said vacuum chambers;

wherein said interchamber orifice is formed by an electrode of an AC-only ion guide comprised of a plurality of electrodes having apertures.

33. A mass spectrometer, comprising:

an ion source;

an input vacuum chamber;

an intermediate vacuum chamber; and

an AC-only ion guide disposed in said input vacuum chamber and extending beyond said input vacuum chamber into said intermediate vacuum chamber;

wherein said ion guide comprises a plurality of electrodes each having similar internal apertures and wherein at least one electrode of said ion guide forms a differential pumping aperture between said vacuum chambers.

34. A mass spectrometer comprising:

at least two vacuum chambers connected to a split flow turbo vacuum pump; and

a continuous AC-only ion guide extending between said vacuum chambers, said ion guide comprising a plurality of electrodes having apertures.

35. A method of mass spectrometry, comprising:

guiding ions from a vacuum chamber to another vacuum chamber by passing said ions through an AC-only ion guide extending between the two vacuum chambers, said ion guide comprising a plurality of electrodes having apertures.

35

36. A method of mass spectrometry, comprising:

generating a beam of ions from an ion source;

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passing said ions into an AC-only ion guide
comprised of a plurality of electrodes having apertures,
said ion guide extending between two vacuum chambers;

5 guiding the ions along the ion guide so that they
pass from a vacuum chamber into another vacuum chamber
without leaving said ion guide; and then
mass analysing at least some of said ions.

10 37. A mass spectrometer comprising a continuous AC-only
ion guide comprising a plurality of electrodes having
apertures extending through three or more vacuum
chambers.

15 38. A mass spectrometer as claimed in any of claims 1-
20, further comprising an AC power supply for supplying
an AC voltage to said electrodes.

20 39. A mass spectrometer as claimed in claim 38, wherein
electrodes in said input vacuum chamber are arranged to
be supplied with an AC voltage having an amplitude and
electrodes in said intermediate vacuum chamber are
arranged to be supplied with an AC voltage having another
different amplitude.

25 40. A mass spectrometer as claimed in claim 39, wherein
the amplitude of the AC voltage supplied to the
electrodes in said input vacuum chamber is smaller than
the amplitude of the AC voltage supplied to the
electrodes in the intermediate vacuum chamber, preferably
30 at least 100 V smaller.

35 41. A mass spectrometer as claimed in claim 39 or 40,
wherein the amplitude of the AC voltage supplied to the
electrodes in said input vacuum chamber is in the range
200-400 V and/or the amplitude of the AC voltage supplied
to the electrodes in said intermediate vacuum chamber is
in the range 400-600 V.

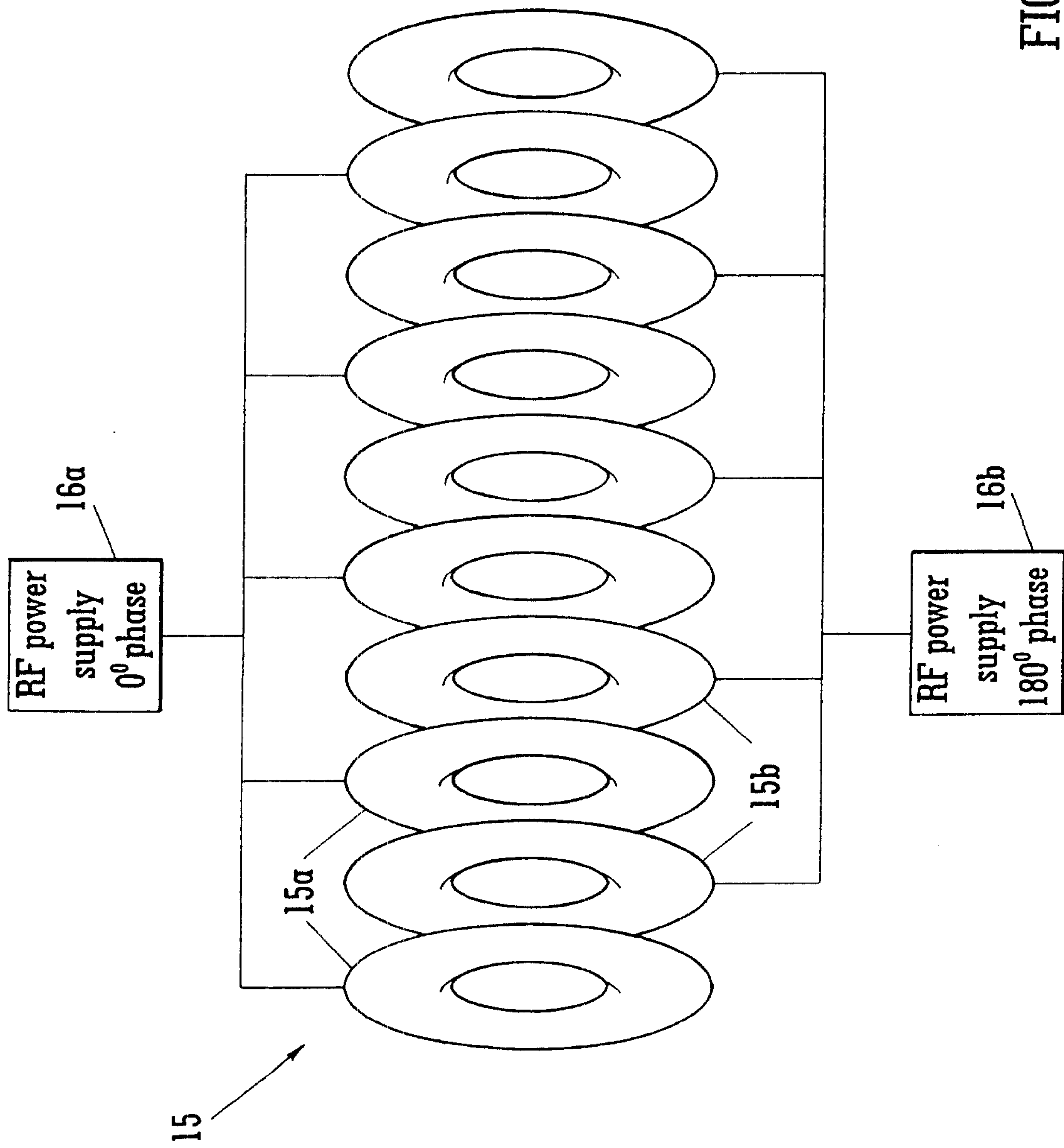


FIG. 1

